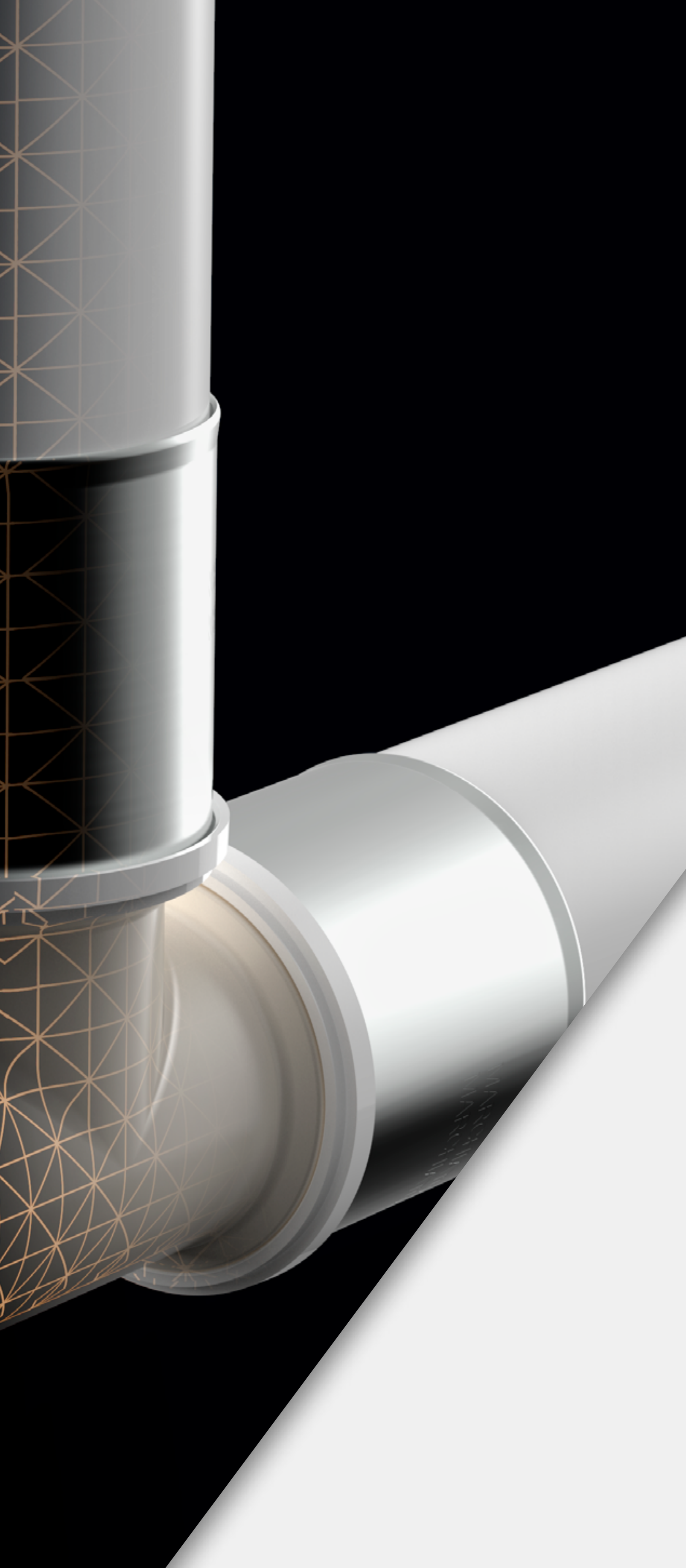


8

TECHNICAL MANUAL

SUPPLY SYSTEMS

Installation

MADE IN ITALY

valsir®

QUALITY FOR PLUMBING

8

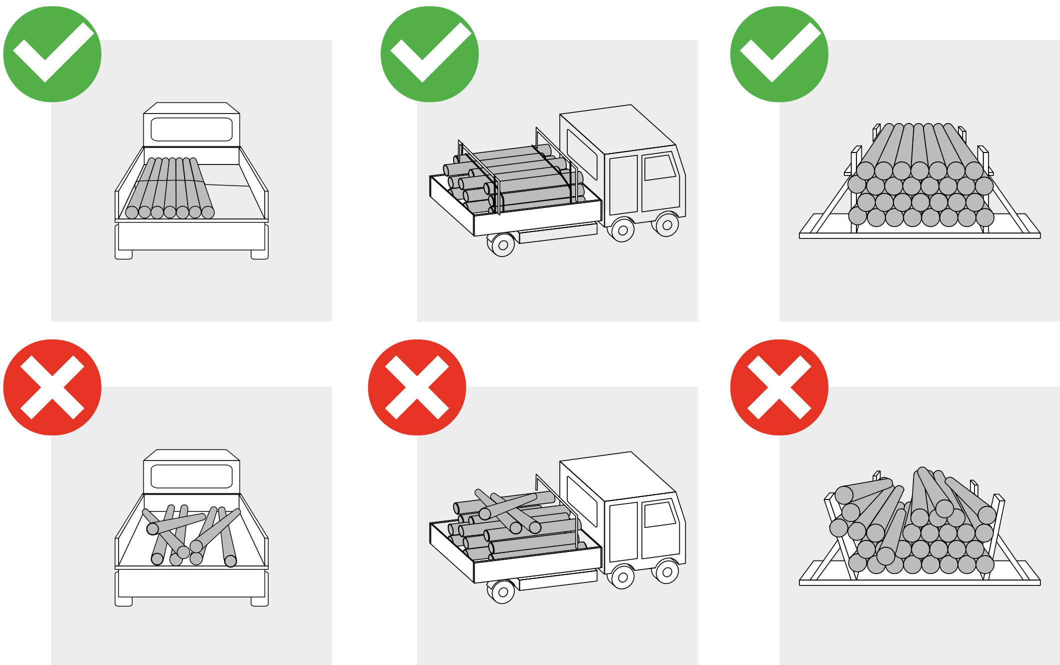
INSTALLATION

8
INSTALLATION

8.1 Transport and storage

The water supply system components must be handled with care and protected from dirt, water stagnation and damage during storage, transport and installation on site.
Otherwise, given the long storage time, there is a high risk of bacteria growth within the components before commissioning.
The rules below should be followed:

- During transport, all components must be stacked in an orderly and rational manner.
- Loading and unloading operations must be such as to avoid strong impacts, abrasions and deformations, especially in the seasons when low temperatures can be reached, which may result in embrittlement of the material.
- Store the pipes on horizontal and even surfaces; in case of pipes with film packaging, make them rest conveniently on wooden pallets (or on the packaging elements if this is structured and made for this purpose, with suitable material such as wood, foam or plastic in general).
- In order to avoid deformations or alterations to the geometry that may impair their operation, in particular in case of long storage periods, avoid the formation of piles higher than 2.5 m.
- Store the pipes and fittings in an environment protected from the weather, low temperatures and direct sunlight. Do not leave outdoor and exposed to direct sunlight for excessively long periods, up to 3 months with standard packaging and up to 18 months with protective PE cover.
- Do not glue protective films or similar that could damage the external layer of the pipe or fitting, for more details refer to resistance to chemicals (chapter 9.7).
- Remove protective elements of pipes and fittings (single bags, protective films and caps) only during installation, taking special care not to damage the pipe with cutting devices (e.g. cutters).



8.2 Installation

The indications given in this chapter are not intended to replace the provisions of standards or local regulations, which must always prevail when choosing and adopting a specific installation criterion.
In water supply plants, the pipes can be installed underground or laid inside the building and in the latter case, they can either be surface-mounted or laid in chases (hidden).

8.2.1 Underground installation

Local standards and regulations must be consulted on the possibility of underground installation and relative requirements. In any case, it is also recommended to take the following rules into consideration:

- Underground pipes must be laid at a distance of at least 1 m from any waste pipes and they must be positioned above the same.
- The pipes for water supply plants manufactured by Valsir do not require any protection in particular when laid underground, as long as an appropriate bedding is prepared for the pipes and the same are covered with a layer of at least 20 cm of fine sand or strained clay.
- Underground pipes that enter the building must be fitted with a sealed sleeve at the end, in order to prevent water, gas and animals from entering the building.

Figure 8.1 Laying for underground pipes.

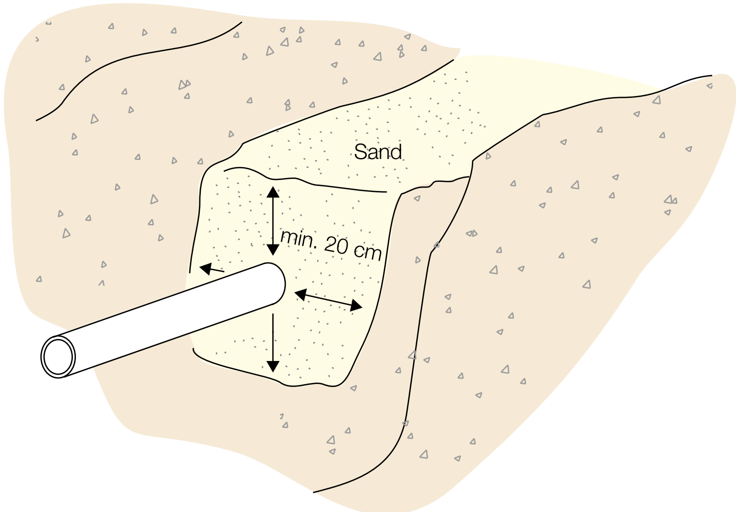
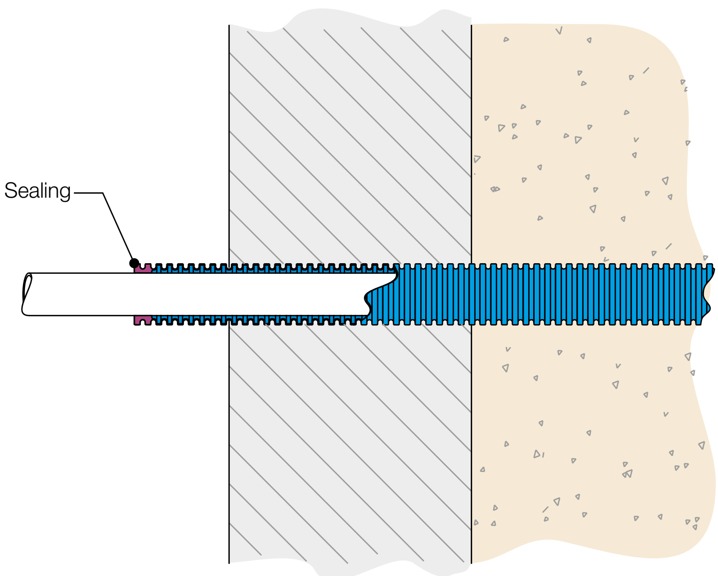


Figure 8.2 Pipes entering the building.



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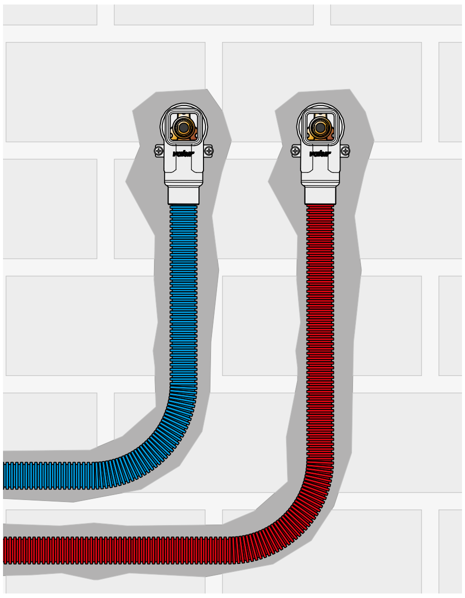
8.2.2 Laying in chases inside buildings

The pipes for water supply plants manufactured by Valsir have characteristics that allow them to be laid directly in concrete and inside the walls of the building; it is sufficient to mention that they are also used in floor heating and cooling applications where nearly the entire pipe is embedded in the structure.
In water supply plants, however, in the event of maintenance and servicing, and therefore for practical reasons, it is recommended to fit the pipe with a protective corrugated hose or thermal insulating material.
The following guidelines should be kept in mind when laying the pipes in chases:

- When the concrete is being applied it is important that no fluid cement mortars get into the gap between the pipe and the hose.
- The hoses must protrude from the floor by at least 25 to 30 mm to prevent liquids from entering; in rooms that are subject to washing/disinfection, it is advisable to increase the recommended length by at least 50 mm.
- Thermoline® pipes that are placed inside corrugated protective hoses should be laid with bending radii no smaller than 8 times the external diameter of the pipe to allow application and, if necessary, removal.
- Terminal fittings that are fitted at the end of pipes in chases can be placed inside suitable inspection boxes (Figure 8.3, for more information please see section “3.4 Connection to water outlets and appliances”).

Figure 8.3 Laying of pipes in chases with accessible protective boxes for the fittings.

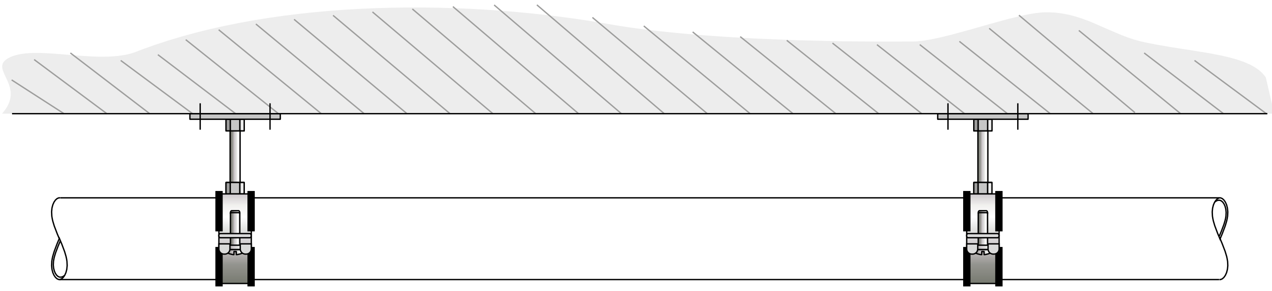


8.2.3 Surface mounting inside buildings

In surface mounting, pipe supports must be used (sliding brackets or anchor brackets) to permanently fix the pipes to the building structure in order to support the weight of the pipes, the relative components connected to them and the forces generated by water hammer or the activation of valves. Any pipes that need to be insulated after the installation must be installed leaving sufficient space between the pipe and the building structure such as to allow the correct application of the insulation. Where very long straight lengths (greater than 20 meters approximately) are to be surface mounted, methods must be used to accommodate thermal expansion (deflection arms, expansion joints, etc.).

The rules for the application of supports and the creation of systems to accommodate expansion are given later on in this manual.

Figure 8.4 Installation of surface mounted pipes.



8.2.4 General installation rules

The following is a list of general rules that should be followed for all of the abovementioned types of installation:

- The pipes must be installed at a certain distance from each other, leaving sufficient space to allow them to be removed or to allow the correct application of thermal insulation.
- The pipes must always be installed in an orderly manner, avoiding crossovers when possible; any pipe crossovers must be tied together to avoid friction caused by the normal movement of the pipes themselves (Figure 8.5).
- Horizontal cold water pipes must be installed below horizontal hot water pipes.
- The pipes must not be installed inside transformer cabinets, above electric control panels or electrical devices, inside rooms containing pollutants or substances that are dangerous when wet, inside chimneys, ventilation ducts, elevator shafts or garbage collection locations.
- The pipes must be installed in such a way as to prevent the formation of air sockets.
- The pipes must be equipped with drainage points in the lower sections of the system to allow the system to be emptied if necessary.
- In the case of passages through horizontal or vertical structures such as walls, ceilings and floors, the pipes must be protected with protective corrugated hoses with a diameter that is greater than the pipe diameter, including the thermal insulating sleeve.
- The pipes must not be bent over sharp edges in the building structure (Figure 8.6).
- If the fittings are surface mounted in particularly moist conditions (industrial kitchens, car washes, stables, slaughterhouses, naval installations, swimming pools, etc.) or embedded and subject to particularly aggressive compounds (such as some cement mortars) they need to be protected. In such cases, it is advisable to cover the fittings with self-amalgamating bituminous tape (Figure 8.7).
- Do not use excessive quantities of hemp on threaded joints that could cause the fitting to break. The use of Teflon tape or sealing liquid is recommended. For more details on the possibility of using hemp or other sealants in relation to the type of fitting chosen, please refer to the installation instructions and the chemical compatibility table in the appendix.
- During installation of the water supply system, a map of all the routes of the pipes and the position of the devices (valves, tanks, connections, etc.), should be made. On completion of the system, the map will constitute a representation of the system as installed "on site" and is to be handed over to the owner of the building.

Figure 8.5 Pipe crossovers.

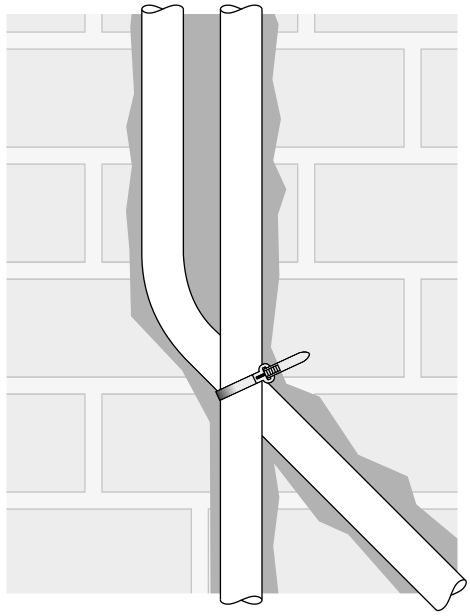


Figure 8.6 Passages through structures.

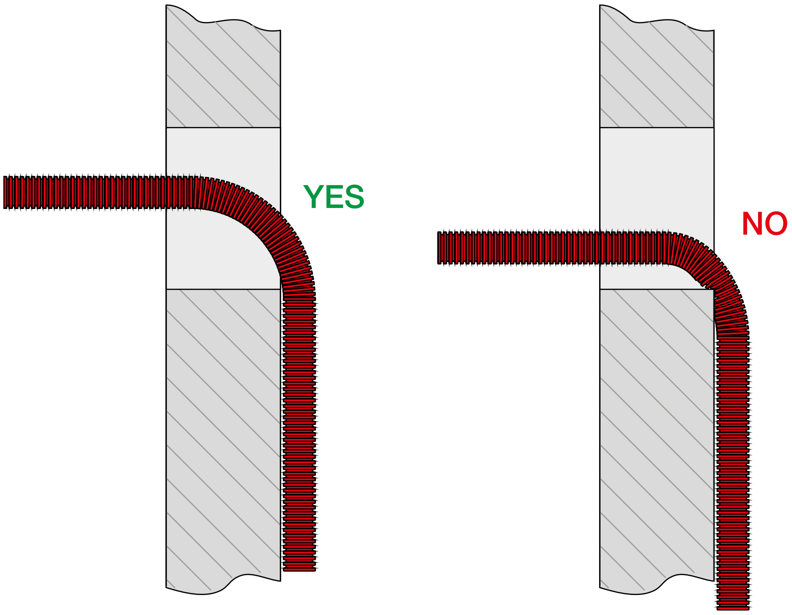
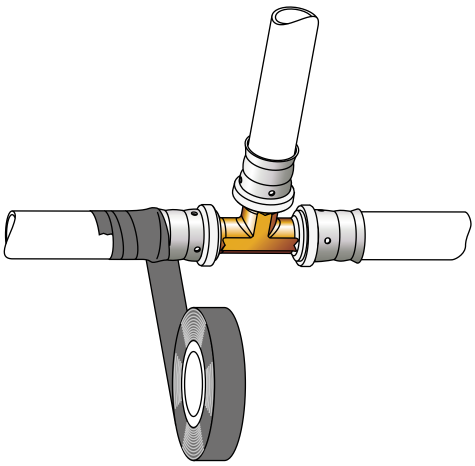


Figure 8.7 Protection of fittings with tape.



8.3 Bracketing

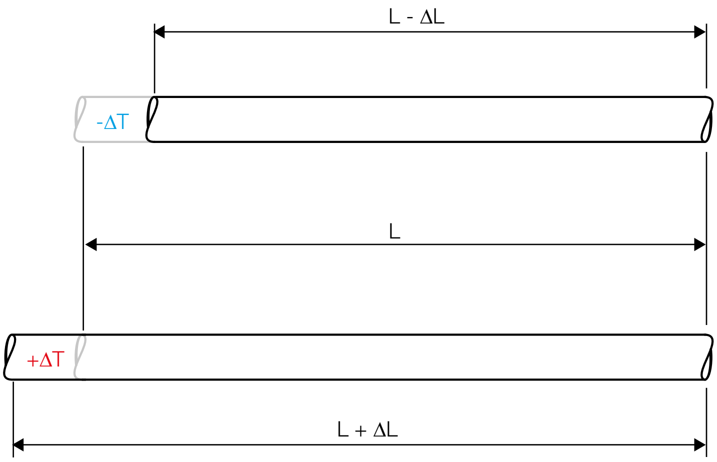
8.3.1 Preliminary considerations

All materials are subject to expansions or contractions, which are caused by the increase or decrease in temperature. The variation in length ΔL of a pipe of length L caused by a variation in temperature ΔT between the temperature at which the pipe was installed and the current temperature is given by:

$$\Delta L = \alpha \cdot L \cdot \Delta T \quad [8.1]$$

where, α is the coefficient of linear heat expansion of the material.
The following figure can be used to calculate the expansion or contraction of a pipe in relation to the difference in temperature to which it is subjected.

Figure 8.8 Contraction and expansion of a pipe.



The prevention of such a variation in length in the material would generate a tensile stress (with $\Delta T<0$) or a compression stress (with $\Delta T>0$) given by:

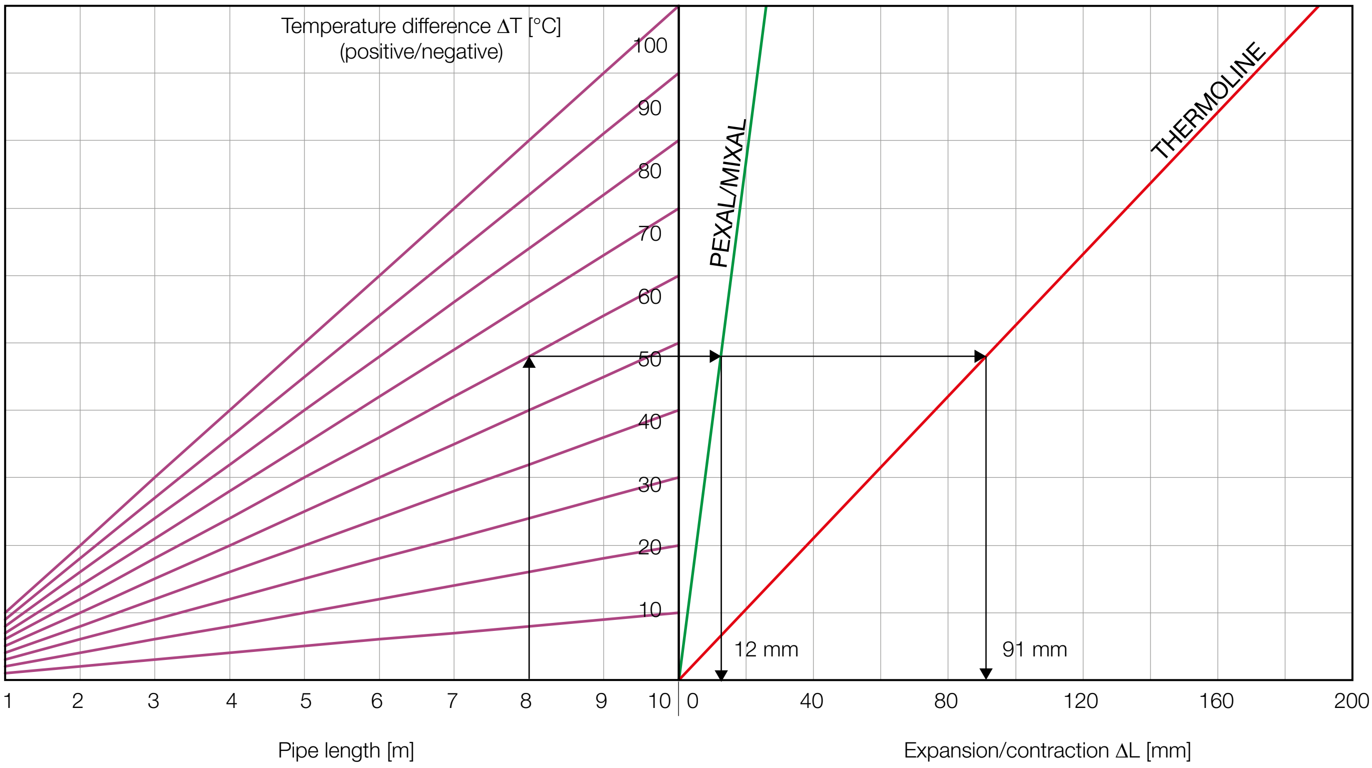
$$\sigma = E \cdot \alpha \cdot \Delta T \quad [8.2]$$

where, E is the modulus of elasticity of the material.
When calculating expansions or contractions, the difference between the temperature at which the pipe was (or will be) installed and the maximum/minimum temperature expected when the system is operating, must always be taken into consideration.

Table 8.1 Coefficient of linear heat expansion of some materials.

Pipe	Coefficient of linear heat expansion α [mm/m·°C]
Cast iron	0.010
Galvanized steel	0.012
Copper	0.017
Pexal® / Mixal®	0.026
Thermoline®	0.190
Polyethylene	0.200

Figure 8.9 Heat expansion/contraction of the pipes.



The effects of heat expansion and contraction of plastic materials influence the methods of installation of water supply systems, which require different rules according to the type of installation chosen (refer to the following sections for further details).

Example 1.
Calculate the linear heat expansion of an 8 m Pexal® pipe that is installed at a temperature of 10°C and is subject to a maximum temperature of 70°C.

By using the formula previously given and considering the heat expansion coefficient of the Pexal® pipe, we have:

$$\Delta L = \alpha \cdot L \cdot \Delta T = 0.026 \cdot 8 \cdot (70-10) = 12.5 \text{ mm} \quad [8.3]$$

The same result can be obtained by using the diagram indicated in Figure 8.9.

Example 2.
Calculate the linear heat expansion of an 8 m Thermoline® pipe that is installed at a temperature of 10°C and is subject to a maximum temperature of 70°C.

By using the formula previously given and considering the heat expansion coefficient of the Thermoline® pipe, we have:

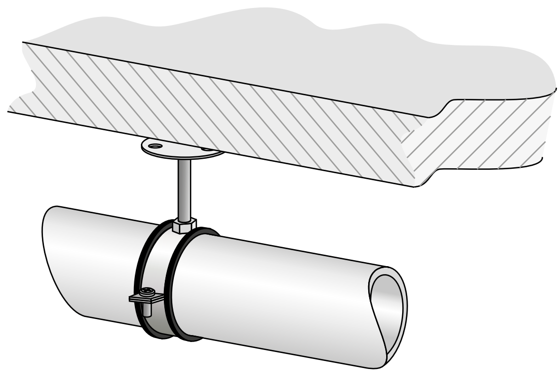
$$\Delta L = \alpha \cdot L \cdot \Delta T = 0.19 \cdot 8 \cdot (70-10) = 91 \text{ mm} \quad [8.4]$$

The same result can be obtained by using the diagram indicated in Figure 8.9.

8.3.2 Bracketing intervals

Surface mounting of pipes requires the use of suitable brackets that must withstand the weight of the pipe and the water inside the pipe, the stress induced by the forces of heat expansion and contraction and those caused by water hammer that arise when pumps are started up or with the sudden activation of valves.
The brackets must be installed at certain intervals that depend on the type of pipe and the type of bracket chosen: bracketing which accommodates expansion, rigid bracketing, bracketing with freedom of movement.
The following sections indicate the different types of bracketing and the corresponding distances between one bracket and another. Such distances are much closer for Thermoline® pipes than for Pexal® and Mixal® pipes since the latter have a much lower heat expansion (about 8 times lower).
The bracketing distances indicated in the following sections are in compliance with EN 806-4.

Figure 8.10 Pipe bracket.



8.3.3 Types of brackets

When installing pipes, the heat expansion/contraction of the pipes due to variations in ambient temperature and the fluid conveyed must be taken into consideration. In the case of embedded pipes, please refer to section 8.3.7 whereas for the installation of surface mounted pipes, subject to system requirements and constraints, the following types of bracketing can be used:

- Bracketing that accommodates expansion.
- Rigid bracketing.
- Bracketing with freedom of movement.

In relation to the expansion compensation methods that will be described later, there are also other methods, such as the use of expansion joints with bellows in metal, in rubber or telescopic that are not dealt with, however, in this manual.

Regardless of the type of bracketing used, the presence of anchor points (identified by the letter F), must always be calculated in order to direct and/or limit the heat expansion of the pipes, guaranteeing the absence of movement where the pipe is connected to the sanitary appliances, manifolds or in the vicinity of direction changes, (see Figure 8.11 where F - fixed point - indicates the position of the anchor point).

Pipe brackets cannot be considered a fixed point as they do not prevent longitudinal movements; however, when they are positioned near direction changes, then they can be considered a fixed point as they prevent the expansion/contraction movement of the pipe in a non-longitudinal direction (see Figure 8.12).

Figure 8.11 Positioning of anchor points (F) to direct the expansion.

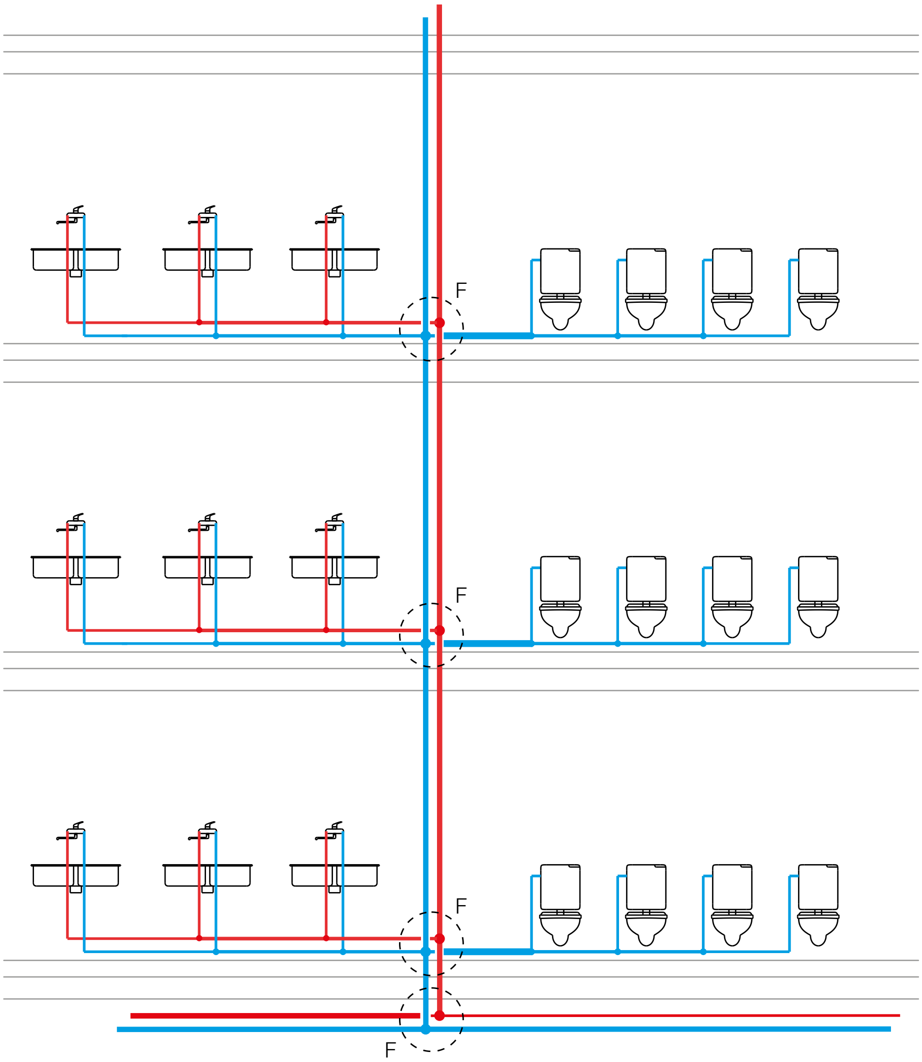
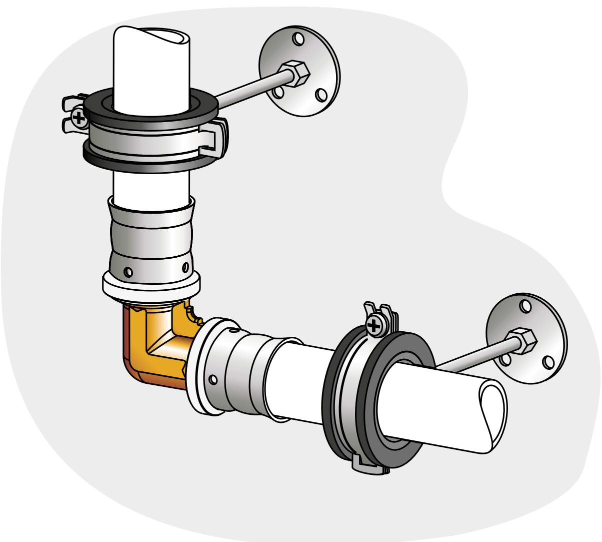
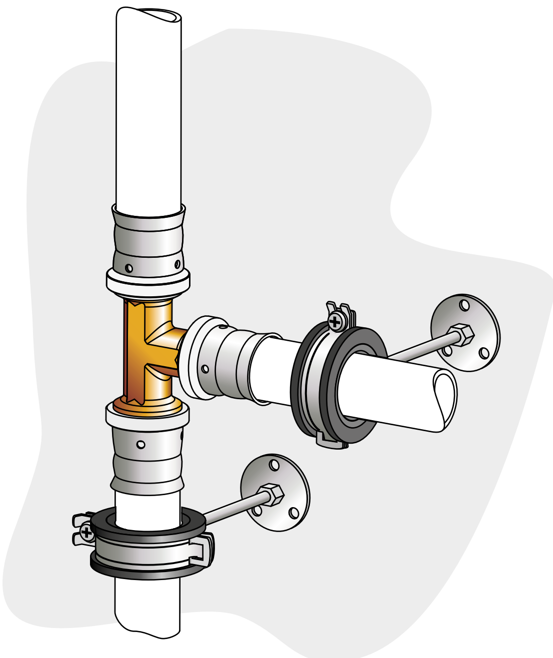


Figure 8.12 Example of an anchor point on an elbow or direction change with clips.





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Whether a certain type of bracketing is required or not depends on the type of pipe (Pexal®/Mixal® or Thermoline®), on the circuit (cold water or hot water), on the length of the straight pipe and on the diameter of the pipe, according to the following scheme.

Type of pipe	Circuit	Length of the straight pipe	Pipe diameter	Type of expansion compensation
Pexal®/Mixal®	Cold water	No limit	14÷110 mm	If the pipe is covered with a thermal insulating sleeve then no specific measures are required. The bracketing distance indicated in Table 8.2 must however be observed..
	Hot water	L≤12 m	14÷110 mm	
		L>12 m	14÷26 mm	
			32÷110 mm	The bracketing techniques indicated in sections 8.3.4 and 8.3.6 must be implemented.
Thermoline®	Hot and cold water	No limit	12÷25 mm	The bracketing techniques indicated in sections 8.3.4, 8.3.5 or 8.3.6 must be implemented.

8.3.4 Surface mounted pipes: bracketing that accommodates expansion

This type of bracketing makes use of the flexibility of the pipes to accommodate the expansion and contraction of the straight lengths of the water supply system. There are many techniques that can be adopted and all of them can be used for the Pexal®, Mixal® and Thermoline® pipes. For this type of bracketing, the intervals to be observed for the clips are those indicated in the following tables.

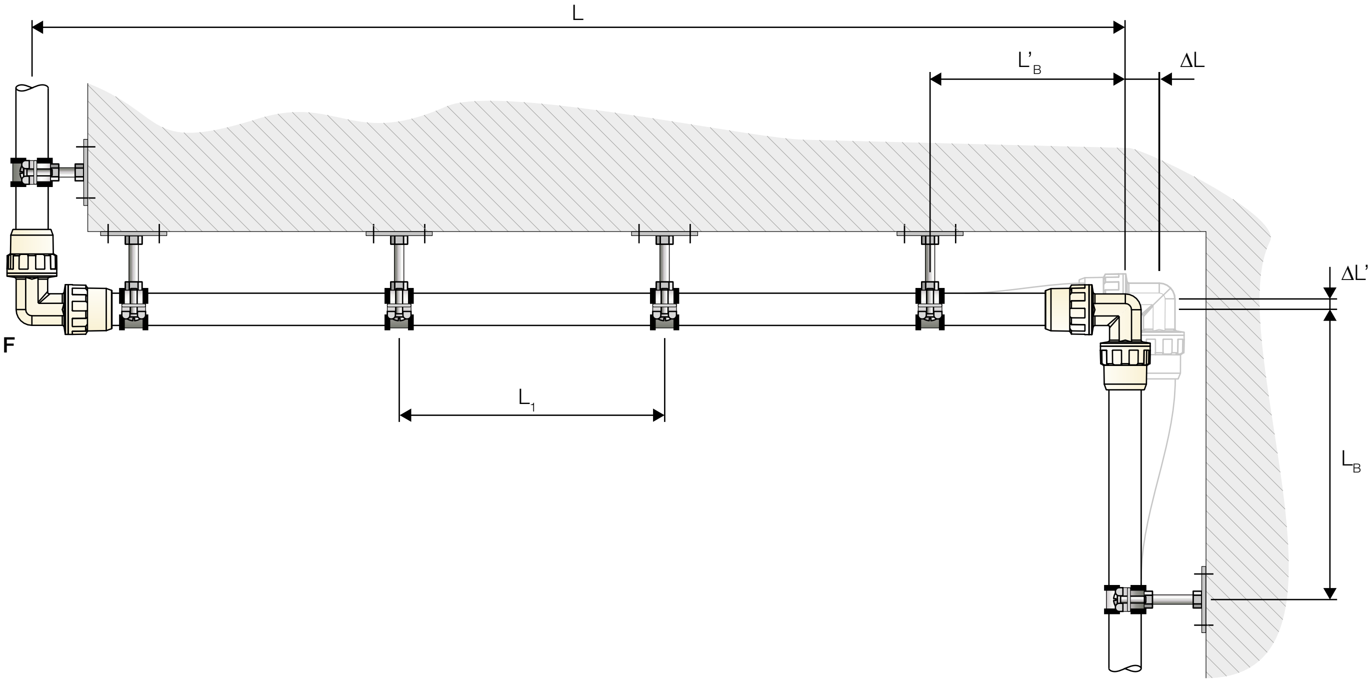
Table 8.2 Bracketing intervals with expansion compensation systems.

External diameter OD [mm]	Bracketing distance L_1 [mm]				
	Pexal®/Mixal®	Thermoline®			
	For horizontal and vertical pipes, for cold and hot water circuits	Horizontal pipes		Vertical pipes	
		Cold water	Hot water	Cold water	Hot water
14	750	750	400	980	520
16	1000	750	400	980	520
17		800	500	1040	650
18	1100				
20	1250	800	500	1040	650
25	1500				
26	1500				
32	2000				
40	2250				
50	2500				
63	2750				
75	2750				
90	2750				
110	2750				

A) Compensation using a flexible arm (Type L) for Pexal®, Mixal® and Thermoline® pipes

This type of compensation avails of the changes of direction of the pipes; the segment of pipe (flexible arm) of length L_B accommodates the movement as a result of the thermal expansion of a segment of pipe of length L perpendicular to it. In this case, the correct distance of the pipe from the walls must be guaranteed to allow the movement, it is therefore necessary to install the brackets according to the structure of the flexible arm.
The distance between the brackets L_1 is defined in Table 8.2 shown previously.

Figure 8.13 Compensation with flexible arm (L Type).



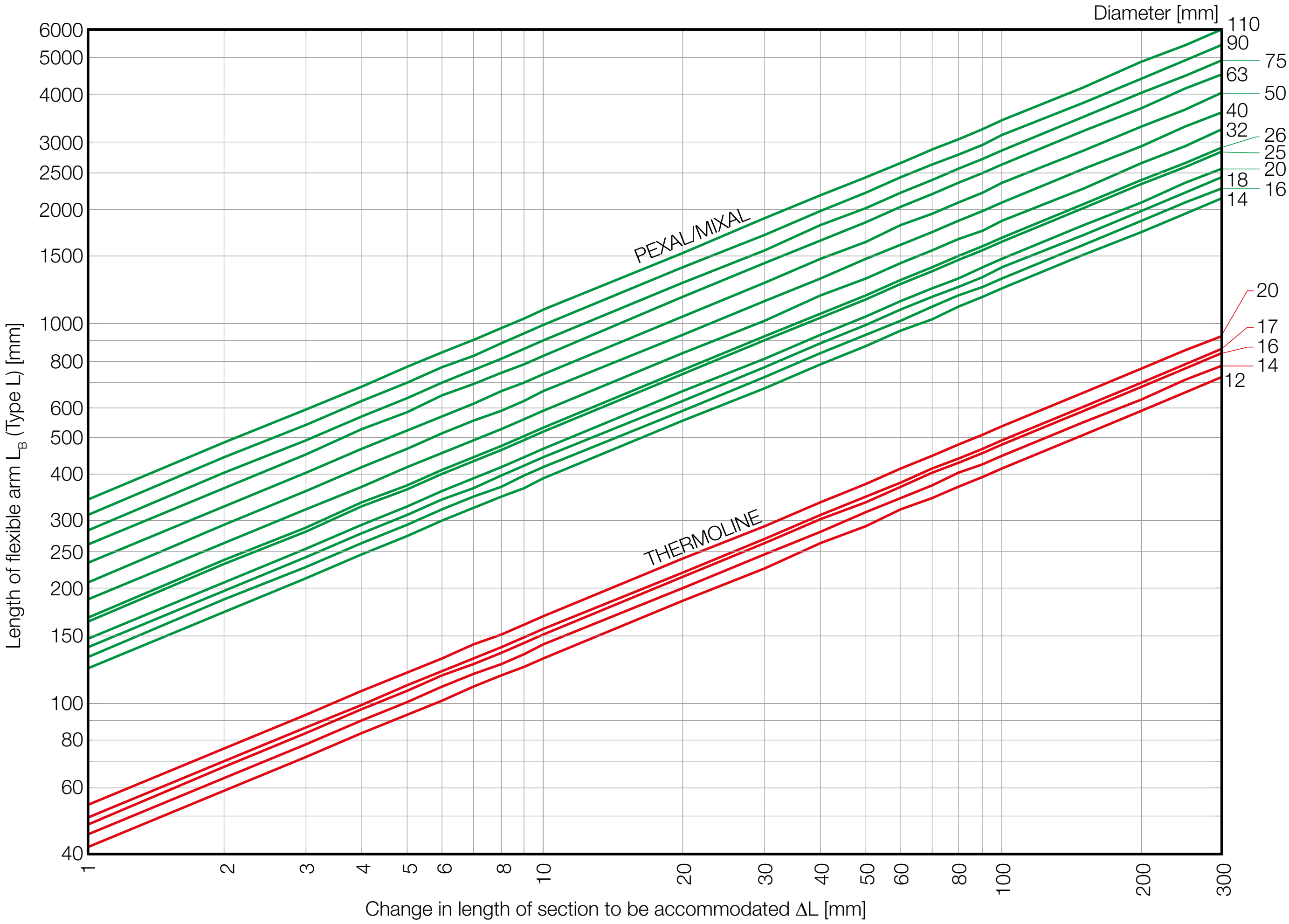
The length of the flexible arm L_B [mm] is calculated using the formula (represented also in the following diagram):

$$L_B = C \cdot \sqrt{OD \cdot \Delta L} \qquad [8.5]$$

where

C	is the material constant, which for Pexal®/Mixal® multilayer pipes is 33 and for Thermoline® pipes is 12,
OD	is the diameter of the pipe [mm],
ΔL	is the change in length of the segment of pipe to be accommodated.

Figure 8.14 Calculation of the compensation length using flexible arm (L Type).



Example 3.
Calculate the length of the flexible arm of a Pexal® pipe with a diameter of 75 mm and a length of 50 m that is installed at a temperature of 20°C and subject to a maximum temperature of 55°C.®

The thermal expansion of the section of pipe is:

$$\Delta L = \alpha \cdot L \cdot \Delta T = 0.026 \cdot 50 \cdot (55 - 20) = 45.5 \text{ mm} \quad [8.6]$$

and, using the formula or the diagram shown previously, the deflection arm L_B is calculated:

$$L_B = C \cdot \sqrt{OD \cdot \Delta L} = 33 \cdot \sqrt{75 \cdot 45.5} = 1927 \text{ mm} \quad [8.7]$$

The same flexible arm (L_B) is subject to a heat expansion of:

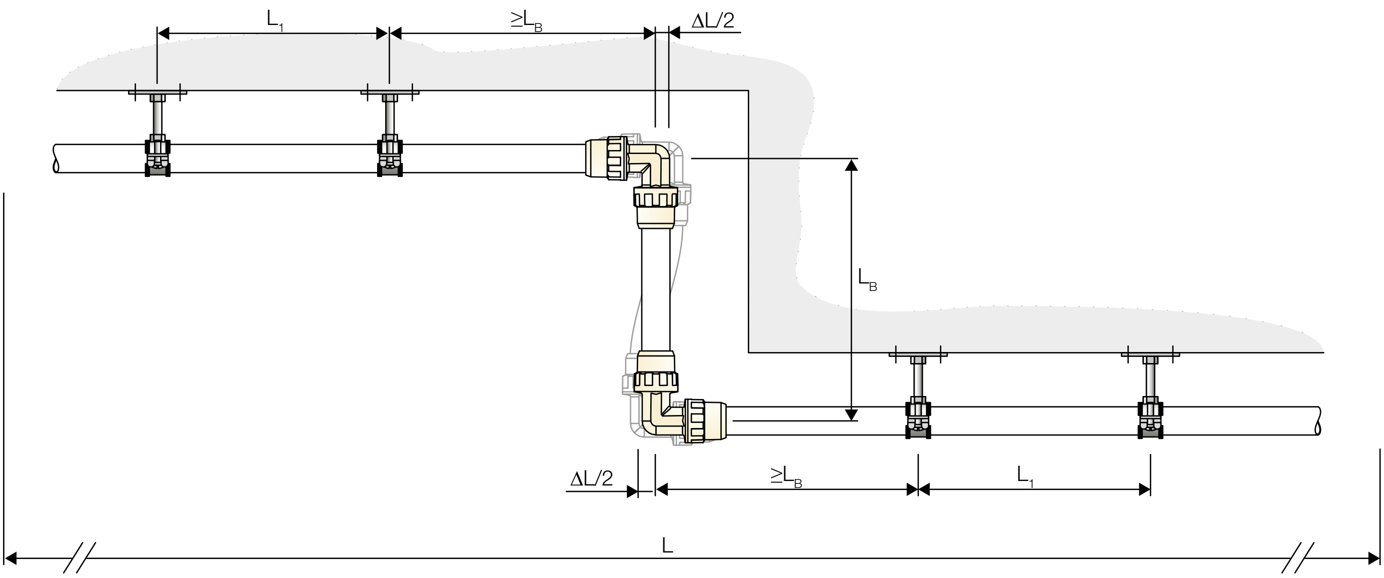
$$\Delta L' = \alpha \cdot L_B \cdot \Delta T = 0{,}026 \cdot 1.927 \cdot (55 - 20) = 1.75 \text{ mm} \quad [8.8]$$

and requires therefore that part of the main pipe section is free to accommodate this expansion, the arm that is free to expand is:

$$L'_B = C \cdot \sqrt{OD \cdot \Delta L'} = 33 \cdot \sqrt{75 \cdot 1.75} = 378 \text{ mm} \quad [8.9]$$

B) Compensation using flexible arm misalignment (Type Z) for Pexal®, Mixal® and Thermoline® pipes
This type of compensation avails of a misalignment of the pipe; the section of pipe (flexible arm) of length L_B accommodates the expansions of the pipe of length L perpendicular to it.
The distance between the brackets L_1 is defined in Table 8.2 shown previously, whereas the distance between the flexible arm and the brackets must not be shorter than the length of the flexible arm L_B.

Figure 8.15 Compensation using flexible arm misalignment (Type Z).



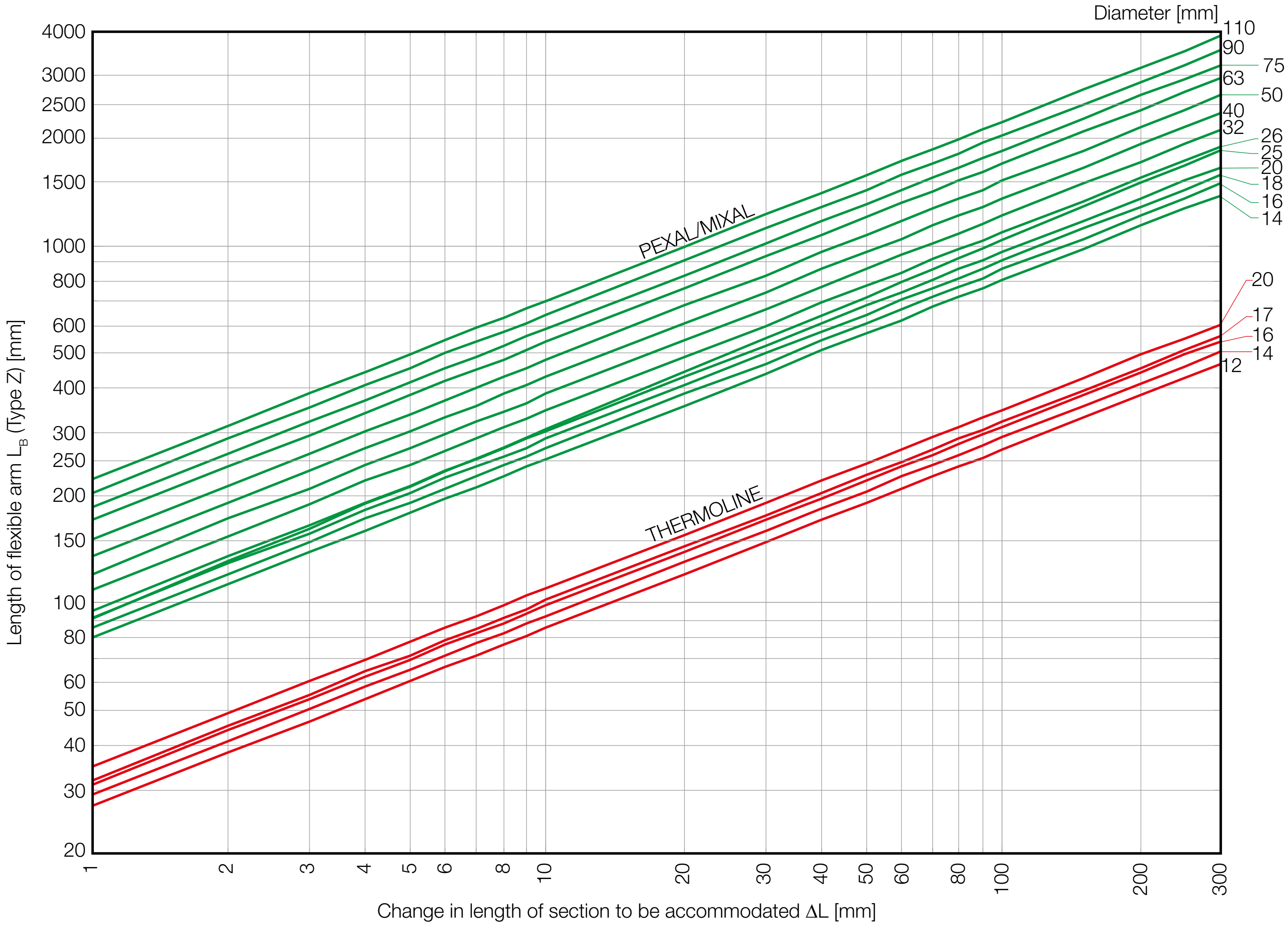
The length of the flexible arm L_B [mm] is calculated using the formula (also shown in the following diagram):

$$L_B = 0.65 \cdot C \cdot \sqrt{OD \cdot \Delta L} \quad [8.10]$$

where,

C is the material constant, which for Pexal®/Mixal® multilayer pipes is 33 and for Thermoline® pipes is 12,
OD is the pipe diameter [mm],
ΔL is the change in length of the segment of pipe to be accommodated.

Figure 8.16 Calculation of the compensation length using flexible arm misalignment (Type Z).



Example 4.
Calculate the length of the flexible arm misalignment of a Pexal® pipe with a 63 mm diameter and a length of 40 m installed at a temperature of 10°C and subject to a maximum temperature of 50°C.

The heat expansion of the section of pipe is:

$$\Delta L = \alpha \cdot L \cdot \Delta T = 0.026 \cdot 40 \cdot (50 - 10) = 41.6 \text{ mm} \quad [8.11]$$

and, using the formula or the diagram shown previously, the deflection arm L_B is calculated:

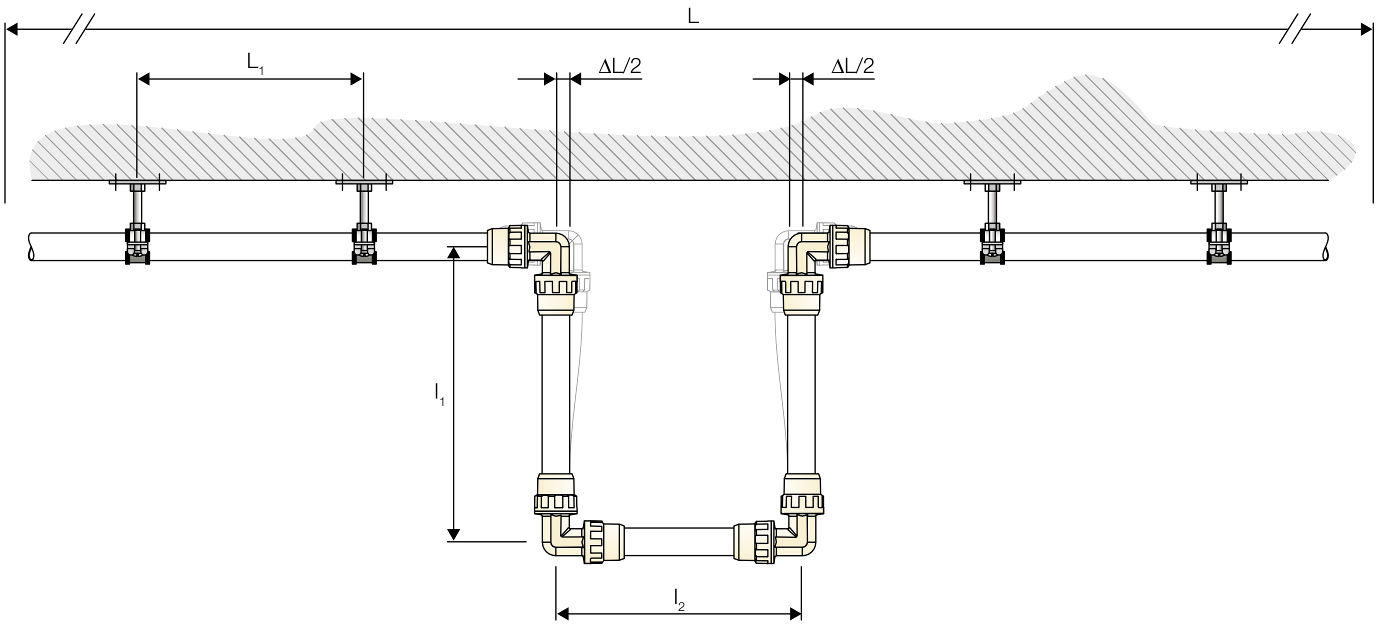
$$L_B = 0.65 \cdot C \cdot \sqrt{OD \cdot \Delta L} = 0.65 \cdot 33 \cdot \sqrt{63 \cdot 41.6} = 1098 \text{ mm} \quad [8.12]$$

C) “Omega” expansion bend (U type) for Pexal®, Mixal® and Thermoline® pipes

This type of compensation is generally employed in risers or in basement collectors when the expansions cannot be accommodated by the changes in direction of the pipes.

Whereas in the case of deflection arm compensation, changes in direction of the system are used, in this case the configuration must be created especially. The distance between the brackets L_1 is defined in Table 8.2 shown previously.

Figure 8.17 “Omega” expansion bend (U type).



The total length of the “omega” expansion bend L_B [mm] is calculated using the formula (also shown in the following diagram):

$$L_B = 2 \cdot l_1 + l_2 = C \cdot \sqrt{OD \cdot \Delta L} \qquad [8.13]$$

where

C is the material constant, which, for Pexal®/Mixal® multilayer pipes is 33 and for Thermoline® pipes is 12,

OD is the pipe diameter [mm],

ΔL is the change in length of the pipe section to be accommodated,

l_1 and l_2 are the sides of the “omega” expansion bend.

The “omega” compensation must be configured depending on the available space; however, where possible, it is recommended to maintain the following dimensional ratio:

$$l_1 = 2 \cdot l_2 \qquad [8.14]$$

and therefore:

$$l_1 = 0.4 \cdot L_B \quad l_2 = 0.2 \cdot L_B \qquad [8.15]$$

Figure 8.18 Calculation of the length of the arm l_1 of the “omega” (U type).

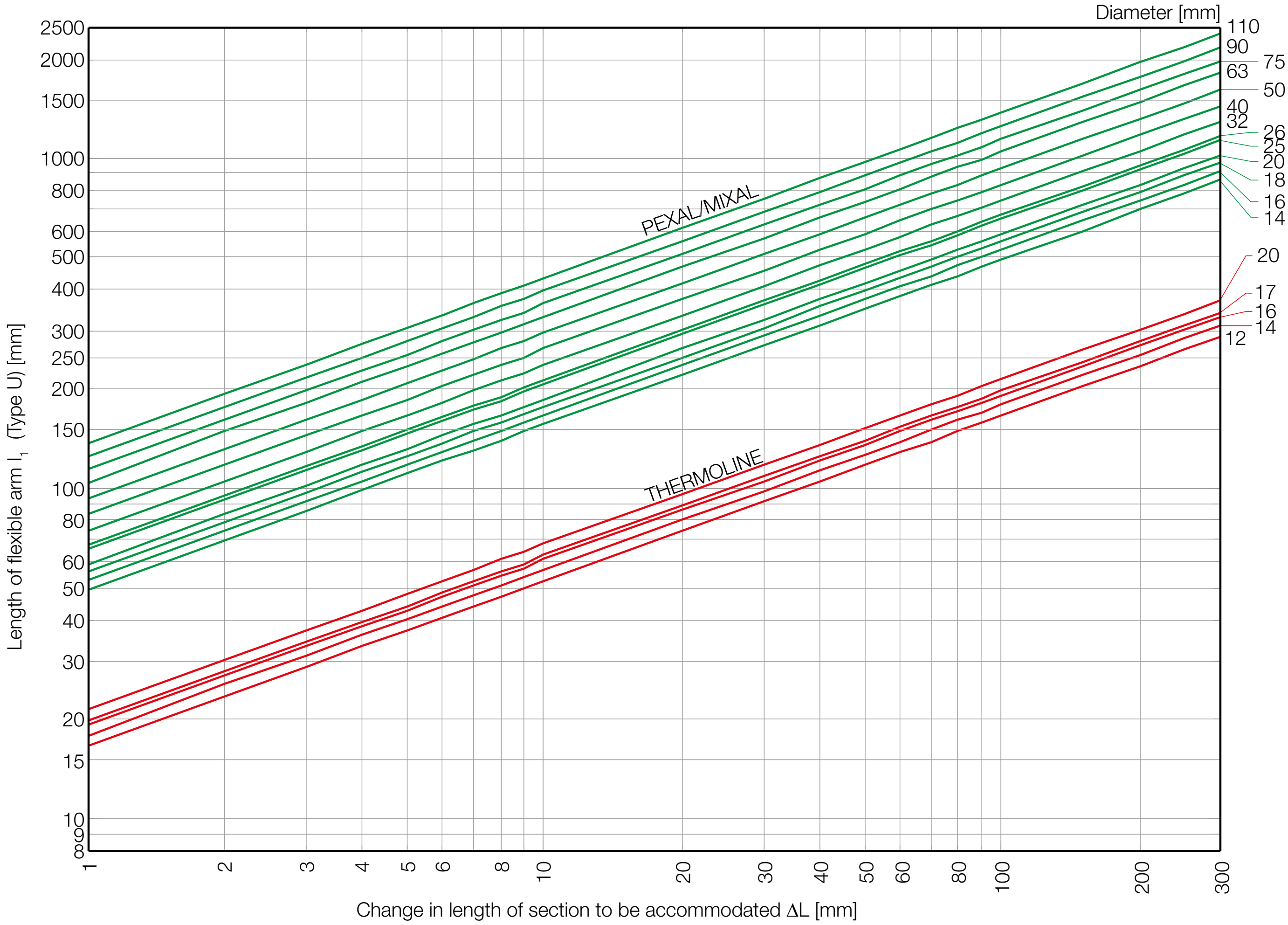
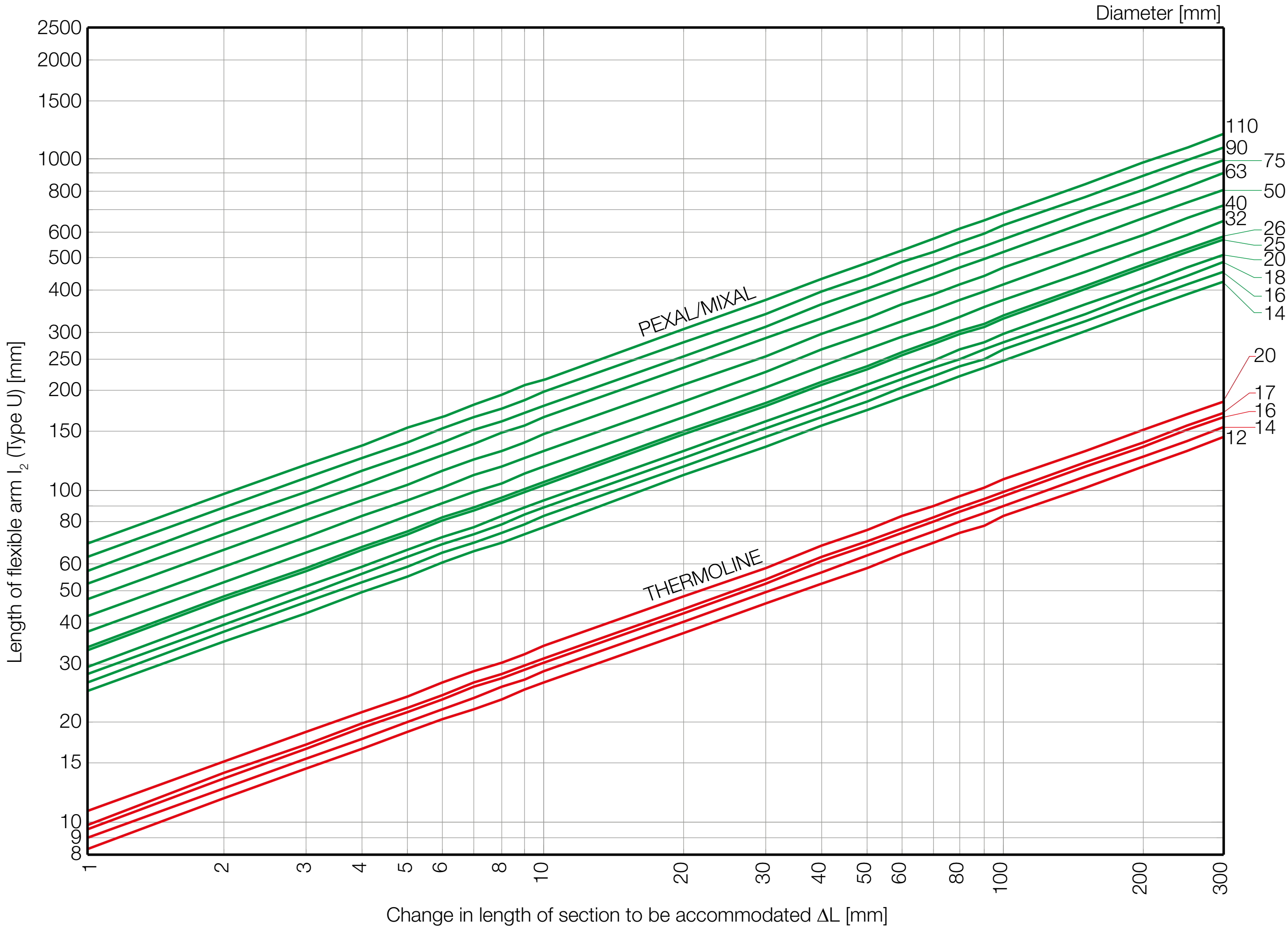


Figure 8.19 Calculation of the length of the arm l_2 of the “omega” (U type).



Example 5.
Calculate the “omega” expansion bend for the Pexal® pipe section of diameter 90 mm and 25 m length, installed at a temperature of 15°C and subject to a maximum temperature of 65°C.

The thermal expansion of the pipe section is:

$$\Delta L = \alpha \cdot L \cdot \Delta T = 0.026 \cdot 25 \cdot (65 - 15) = 32.5 \text{ mm} \quad [8.16]$$

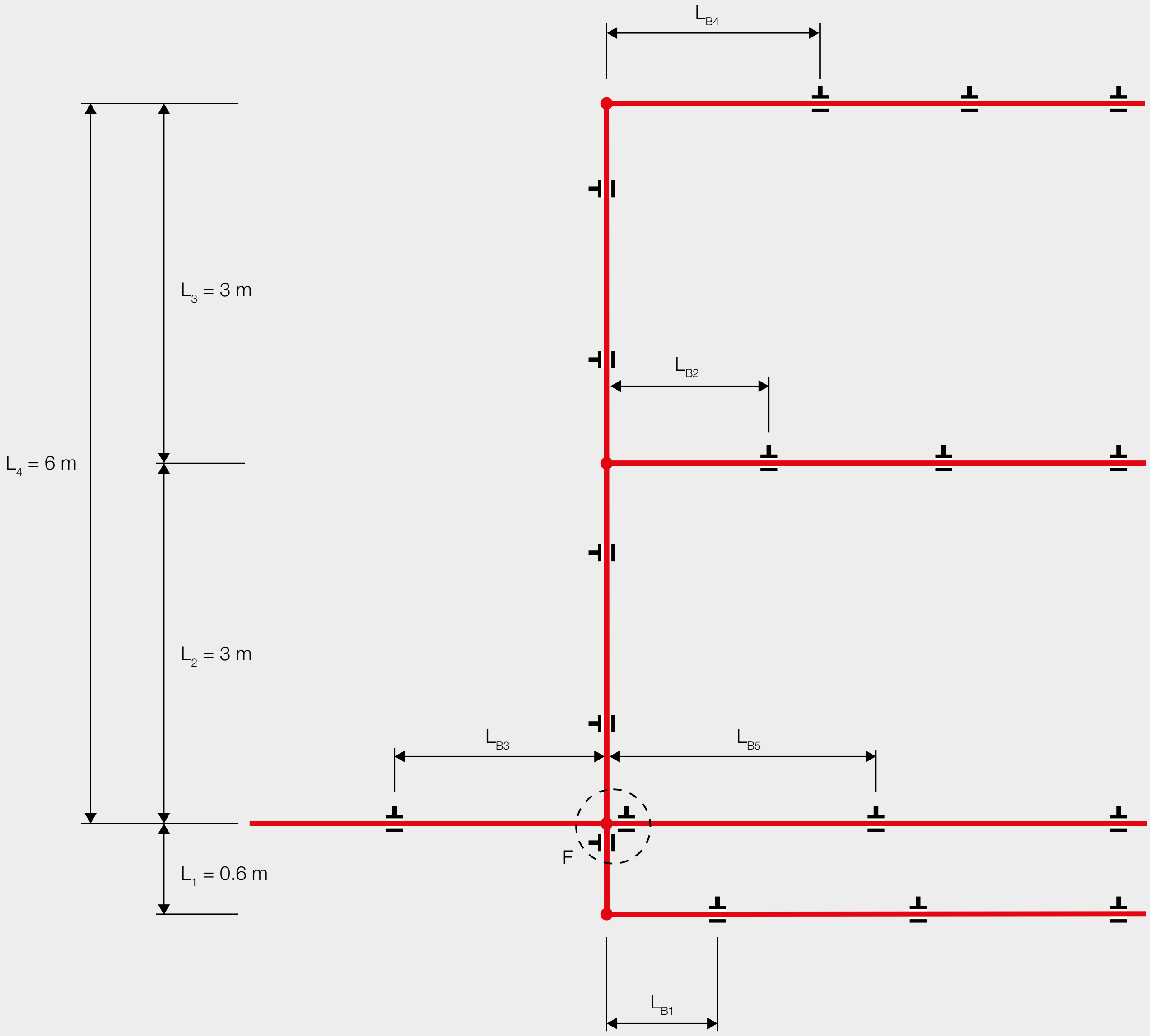
and, using the formula or the diagram seen previously, the total length is calculated for the “omega” L_B:

$$L_B = C \cdot \sqrt{OD \cdot \Delta L} = 33 \cdot \sqrt{90 \cdot 32.5} = 1784 \text{ mm} \quad [8.17]$$

and considering the dimensional ratio suggested, the result is:

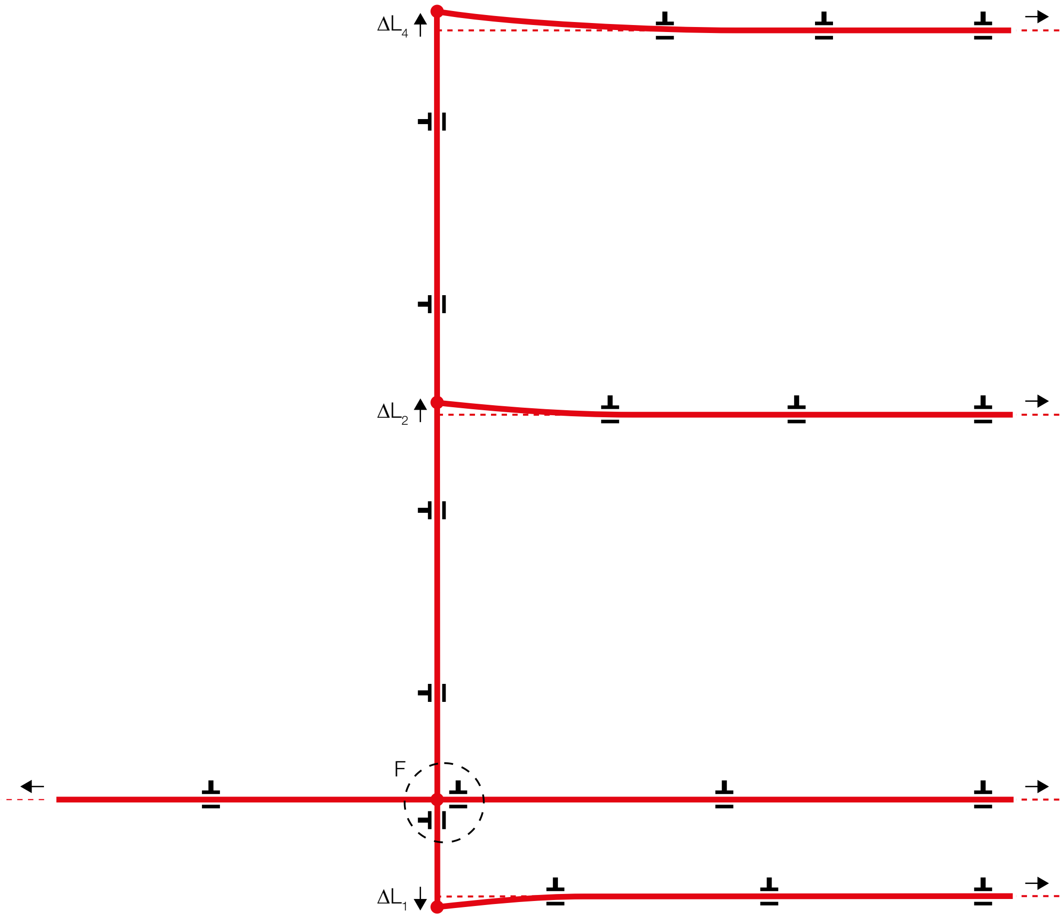
$$l_1 = 0.4 \cdot L_B = 0.4 \cdot 1784 = 713 \text{ mm}$$
$$l_2 = 0.2 \cdot L_B = 0.2 \cdot 1784 = 356 \text{ mm.} \quad [8.18]$$

Example 6.
Calculate the flexible arms for the water supply system indicated in the figure created with Pexal® pipe, installed at a temperature of 10°C and subject to a maximum temperature of 60°C.



The pipe sections L_{B3} and L_{B5} are not subject to flexure due to the anchor point (F) near the cross branch. The sections subject to flexure are:

L_{B1} which represents the flexible arm of section L_1,
L_{B2} which represents the flexible arm of L_2,
L_{B4} which represents the flexible arm of $L_4 = L_2 + L_3$.



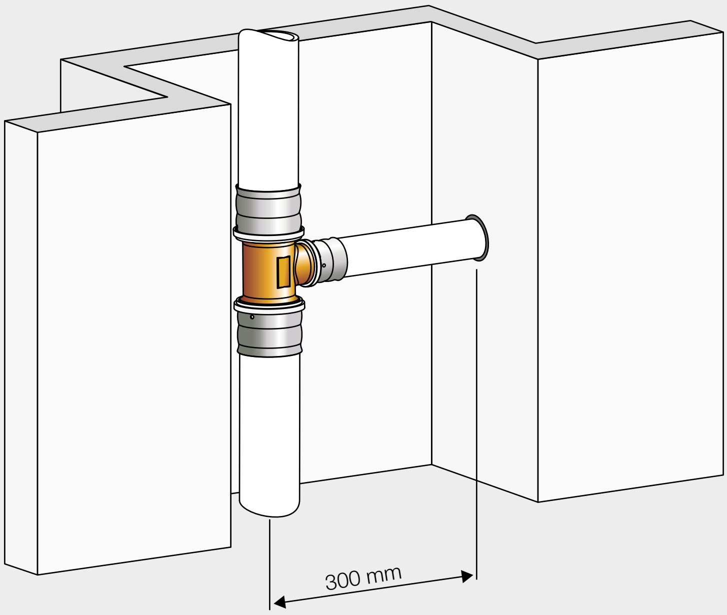
The extensions of the abovementioned sections are:

$$\Delta L_1 = \alpha \cdot L_1 \cdot \Delta T = 0.026 \cdot 0{,}6 \cdot (60 - 10) = 0.78 \text{ mm}$$
$$\Delta L_2 = \alpha \cdot L_2 \cdot \Delta T = 0.026 \cdot 3 \cdot (60 - 10) = 3.9 \text{ mm} \quad [8.19]$$
$$\Delta L_4 = \alpha \cdot L_4 \cdot \Delta T = 0.026 \cdot 6 \cdot (60 - 10) = 7.8 \text{ mm}$$

which correspond to the following flexible arms:

$$L_{B1} = C \cdot \sqrt{(OD_1 \cdot \Delta L_1)} = 33 \cdot \sqrt{(40 \cdot 0.78)} = 184 \text{ mm}$$
$$L_{B2} = C \cdot \sqrt{(OD_2 \cdot \Delta L_2)} = 33 \cdot \sqrt{(32 \cdot 3.9)} = 368 \text{ mm} \quad [8.20]$$
$$L_{B4} = C \cdot \sqrt{(OD_4 \cdot \Delta L_4)} = 33 \cdot \sqrt{(26 \cdot 7.8)} = 470 \text{ mm}$$

Example 7.
The figure shows a shaft in which a riser has been installed, using a Pexal® pipe, subject to a thermal expansion near the branch of 6.5 m.
Assess whether the change in direction made with a 20 mm Mixal® pipe is sufficient to accommodate such an expansion, keeping the geometries indicated in the figure in consideration.

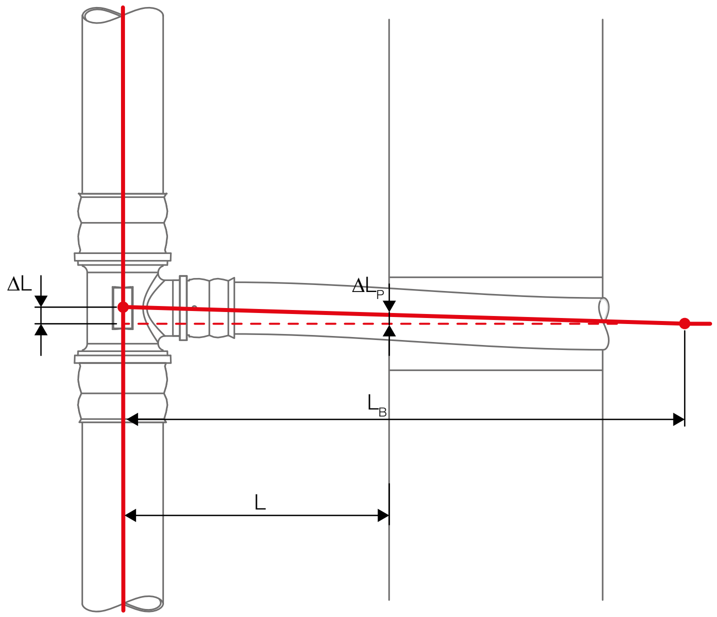


From the figure we can see that the available space for creating a flexible arm is L=300 mm, which is the distance between the wall, through which the change in direction passes, and the riser.
You need to ensure that this distance is sufficient to allow the pipe to flex without it being damaged, it is therefore necessary to calculate the actual length of the flexible arm and assess whether this is less than the available space.

At the point indicated, the expansion ΔL = 6.5 mm, the length of the actual flexible arm is therefore:

$$L_B = C \cdot \sqrt{OD \cdot \Delta L} = 33 \cdot \sqrt{20 \cdot 6.5} = 376 \text{ mm} > 300 \text{ mm} \qquad [8.21]$$

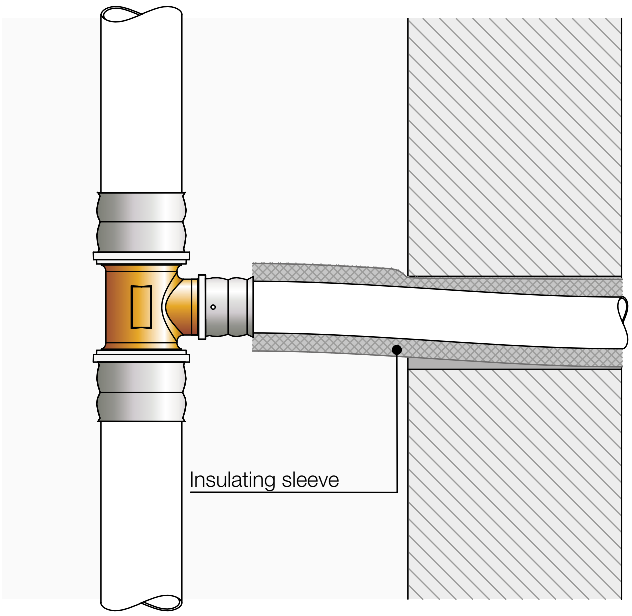
Greater space is required to give the pipe sufficient room for movement; however, if the Mixal® pipe is provided with insulation where it passes through the wall, this could be capable of absorbing part of the flexure that the pipe exerts inside the wall itself. It is possible to calculate approximately the extent of the movement of the pipe inside the wall to verify whether the insulation can absorb the movement.



$$\Delta L_p = \Delta L \cdot \frac{L_B - L}{L_B} = 6.5 \cdot \frac{76}{376} = 1.3 \text{ mm} \qquad [8.22]$$

8

If the 20 mm diameter Mixal® pipe is installed with a 6 mm insulation, the installation in the shaft as indicated in the figure can be done, since part of the movement (1.3 mm) is absorbed by the insulation inside the wall.



8.3.5 Surface mounting: rigid bracketing

This type of bracketing is suitable for Thermoline® pipes to prevent the expansion/contraction of the pipe by making it rigid with the application of brackets at reduced intervals with or without a continuous metal support.

A) Rigid bracketing without continuous support for Thermoline® pipes

This type of bracketing involves the positioning of brackets at intervals of L_1 indicated in the following table.

Figure 8.20 Rigid bracketing without continuous support.

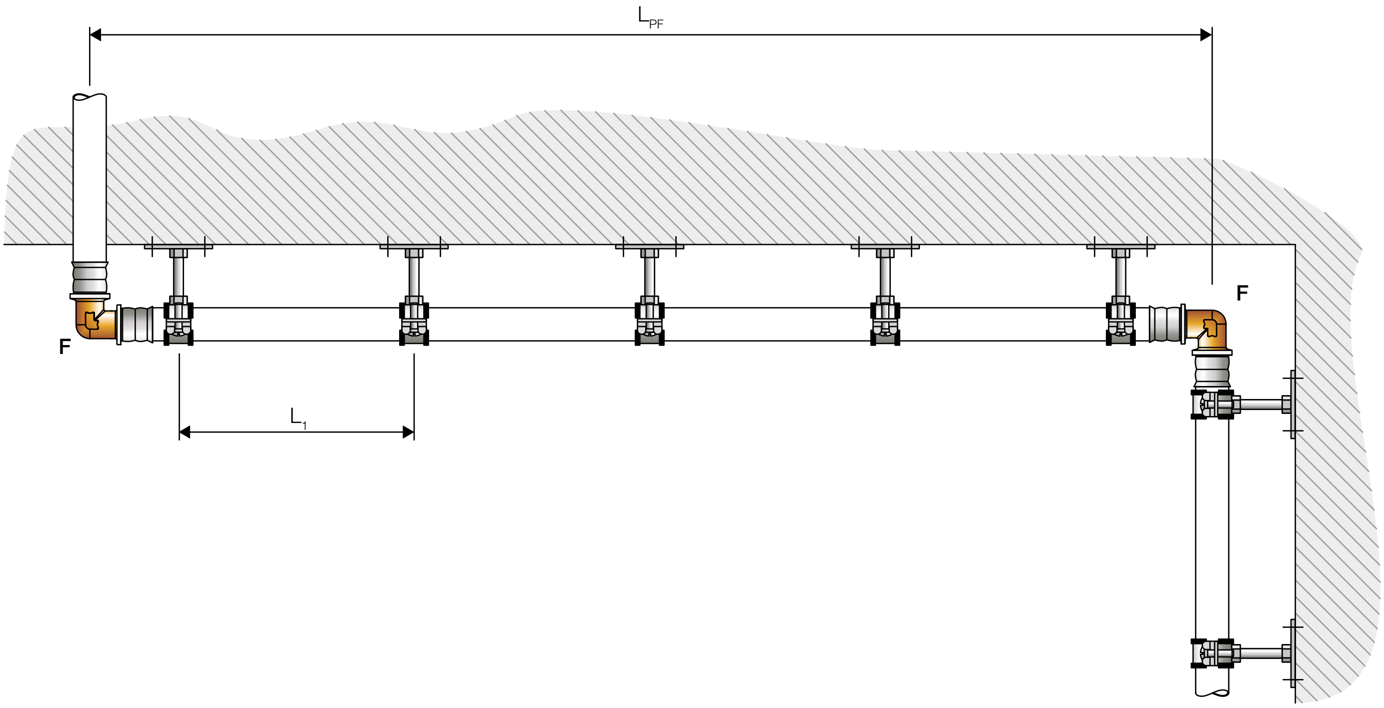


Table 8.3 Bracketing intervals for a rigid system without continuous support.

External diameter OD [mm]	Thermoline® Bracketing distance L_1 [mm] Cold water	Thermoline® Bracketing distance L_1 [mm] Hot water	Anchor point intervals L_{PF}
14	600	250	The maximum distance between the anchor points must be 6 m.
16	600	250	
17	700	300	
20	700	300	

8

B) Rigid bracketing with continuous support for Thermoline® pipes

This type of bracketing involves the positioning of brackets at intervals of L_1 and connections between the pipe and support at an interval of L_2 as indicated in the following table.

Figure 8.21 Rigid bracketing with continuous support.

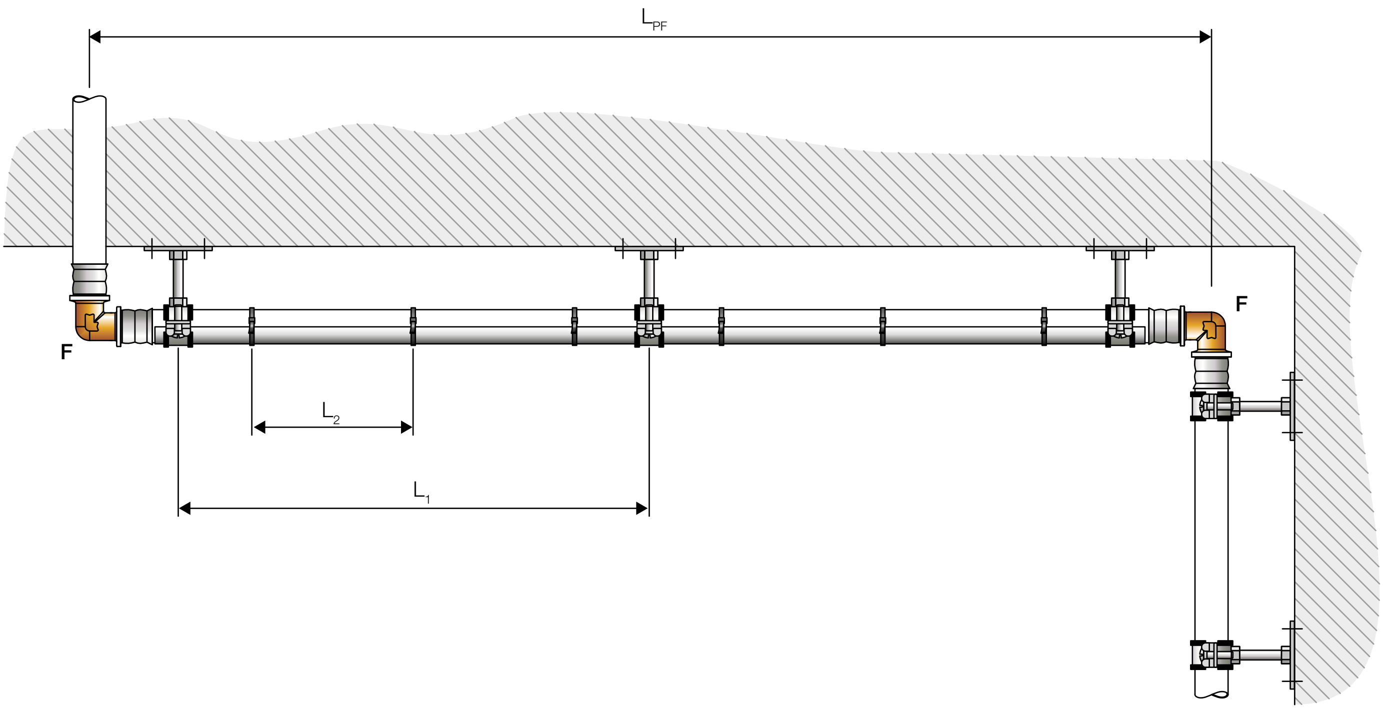


Figure 8.22 Rigid bracketing with continuous support (detail).

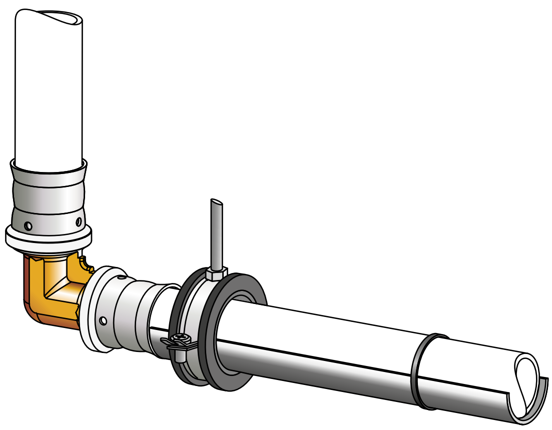


Table 8.4 Bracketing and connection intervals for a rigid system with continuous support.

External diameter OD [mm]	Thermoline®				
	Anchor point intervals L_1 [mm]		Distance of connections L_2 [mm]		Anchor point intervals L_{PF}
	Cold water	Hot water	Cold water	Hot water	
14	1500	1000	500	200	The maximum distance between the anchor points must be 6 m.
16	1500	1000	500	200	
17	1500	1000	500	200	
20	1500	1000	500	200	

valsir®

8.3.6 Surface mounting: bracketing with freedom of movement

Pexal®, Mixal® and Thermoline® pipes can be laid in horizontal ducts (such as those used for power cables) creating a coil in such a way that the expansions and contractions are accommodated by free movement. If the horizontal ducts are not closed then it is recommended to fix the pipe in such a way as to prevent them from moving vertically (for example with plastic clamps).

Figure 8.23 Pipe laid in horizontal duct.

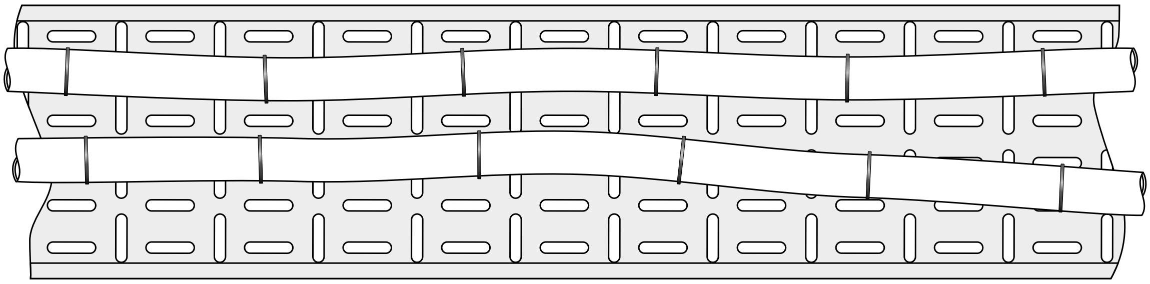
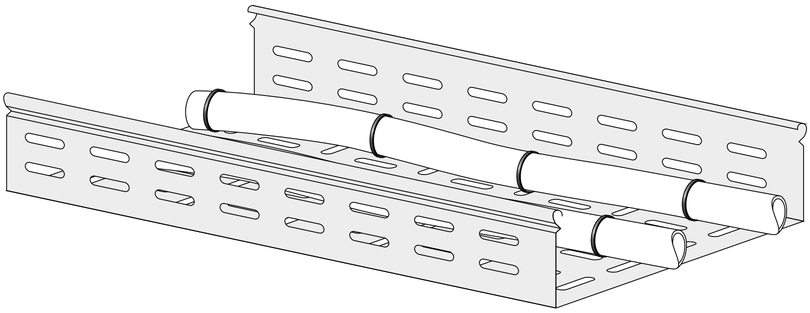


Figure 8.24 Pipe laid in horizontal duct (detail).



For Pexal®, Mixal® and Thermoline® pipes that are laid vertically where movement due to thermal expansion can be tolerated, also visually, the pipes can be bracketing using the intervals indicated in the following table. Both for horizontal and vertical pipes that are installed with freedom of movement, it is always necessary, however, to use anchor points near any changes in direction or connections.

Figure 8.25 Pipe installed vertically with freedom of movement.

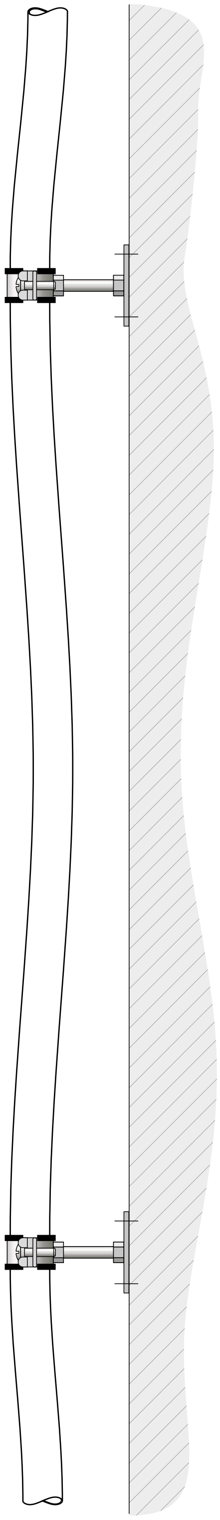


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Table 8.5 Bracketing intervals for vertical pipes with freedom of movement.

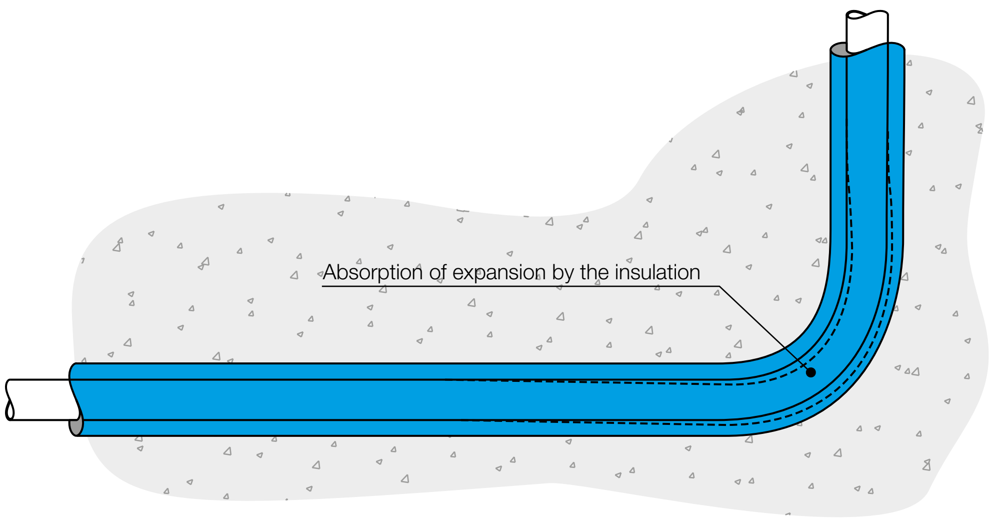
External diameter OD [mm]	Pexal®, Mixal®, Thermoline® Bracketing interval L_1 [mm]
14	3000
16	3000
17	3000
18	3000
20	3000
25/26	3000
32	3000
40	5000
50	5000
63	5000
75	5000
90	5000
110	5000

8

8.3.7 Embedded pipes

If the pipes are embedded without any insulation or protective corrugated hose (therefore embedded directly in the concrete), expansion is prevented, but the stress that is generated inside the wall of the pipe is very low thanks to the elastic nature of the material. In fact, a perfect example is the loops of the floor heating and cooling systems that are created using long lengths of pipe that are embedded inside the concrete.
This, therefore, allows the pipes to be completely covered with concrete without them being damaged by the stress that is generated inside their structure when they are subjected to temperature fluctuations.
If the pipes are embedded and insulated or placed in protective corrugated hoses, then the thermal expansions will be absorbed by the insulating layer or else they will result in movements (flexures) of the pipe inside the protective corrugated hose.

Figure 8.26 Accommodation of expansion of embedded pipes.



8.4 Anti-seismic systems

Every year, more than one hundred earthquakes of magnitude greater than 6 occur around the world. The damage to people and things is obviously proportional to the density and vulnerability of the buildings and to the seismic activity in the territory.

Figure 8.27 Seismic risk distribution on the Italian territory.

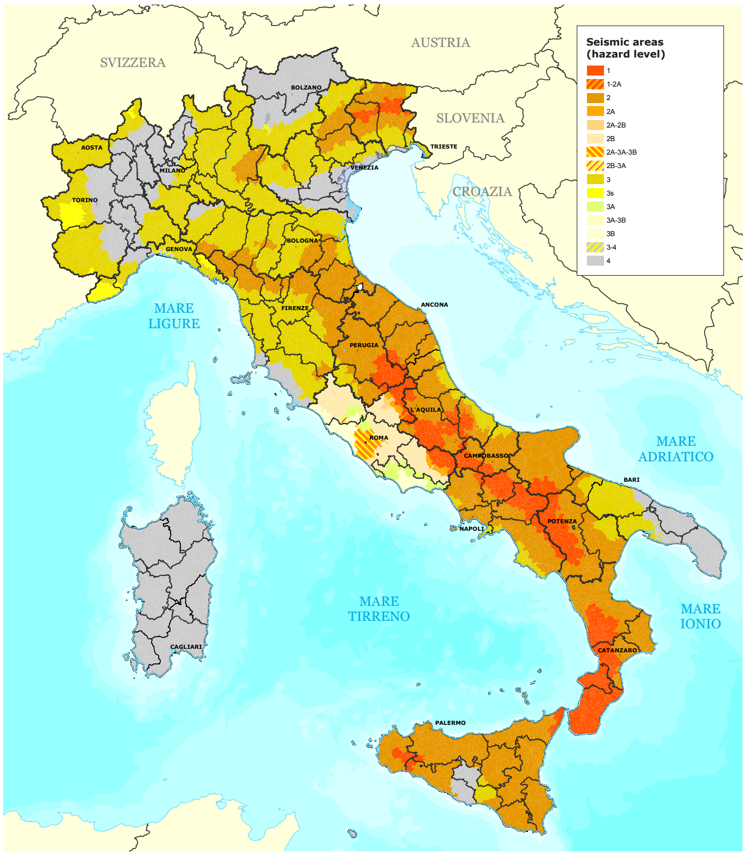
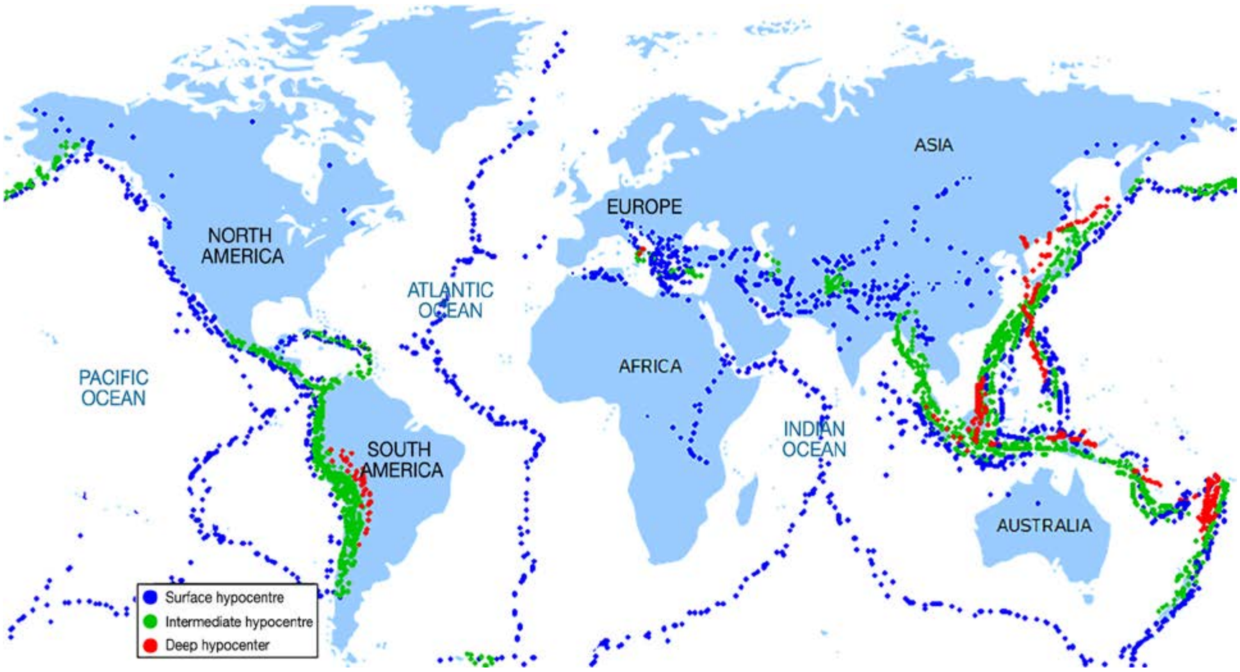


Figure 8.28 Worldwide seismic risk distribution. Source GMPE.

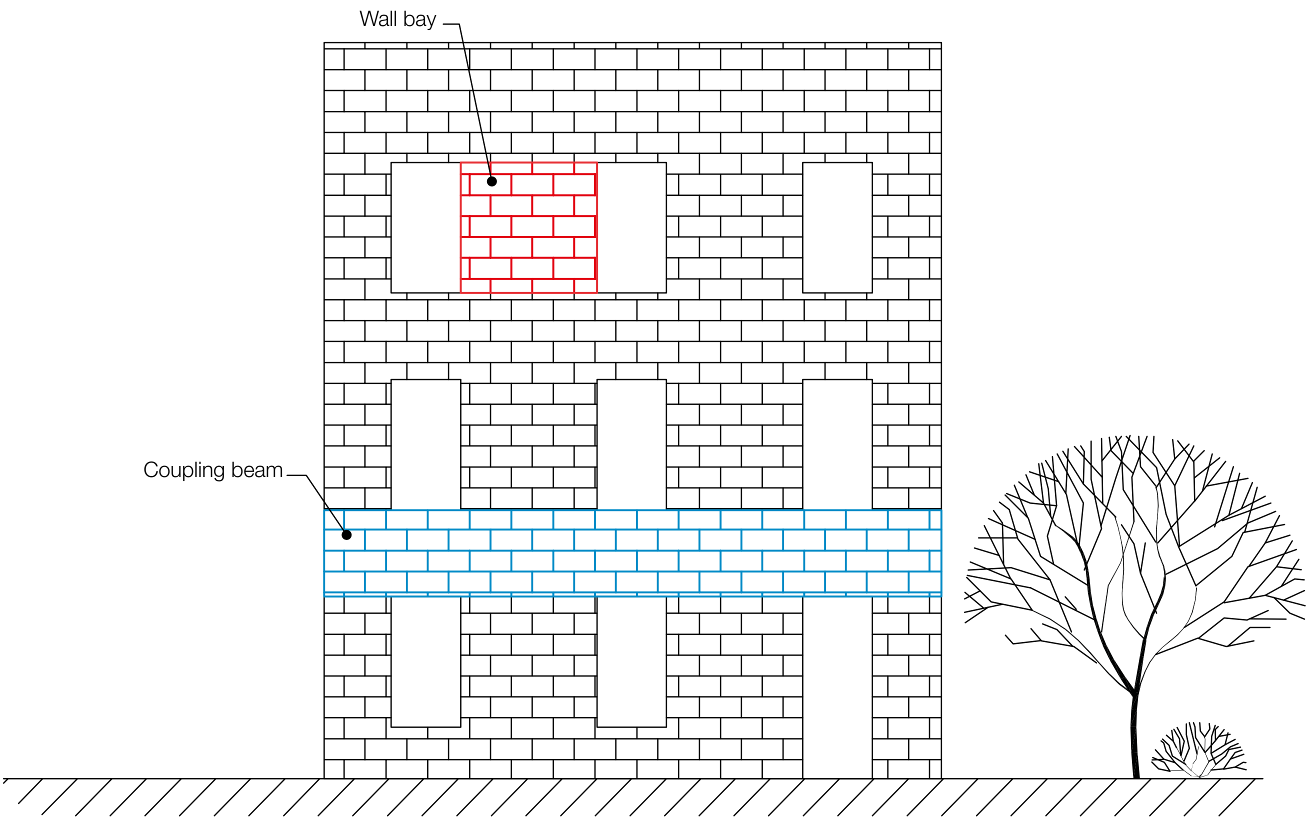


Over the years, science has made progress in the prevention of damage related to seismic events, in particular the principles on which construction technology is based have changed radically, but unfortunately the same cannot be said for aspects related to the plants.
But the plants are to be considered an integral part of a building, as their decommissioning makes a building unfit for use even if it is accessible from the structural point of view.
All types of plant are directly connected to the structure that supports them, so they must be able to sustain the same stress. This is even more true when we talk about pipes, elements often inserted inside screeds or infills and therefore obliged to follow the same movements.

The limitation of damage is achieved by working on the structure with reference to two aspects: deformations, induced by the relative movements between infills or between slab and walls, and vibrations that, if their frequency is equal to the natural frequency of the building, make the structure resonate, amplifying their amplitude and making them difficult to sustain. Both of the above parameters can be significantly reduced by using seismic isolators to separate the building from the ground as much as possible.

One of the most critical types of construction is that made by load-bearing masonry. It is atypical because, unlike other solutions, it relies on stiffness and hyperstability to respond to earthquakes rather than ductility. In these cases, it is essential to preserve the elements - coupling beams (parts of masonry between two floors) and wall bays (parts of masonry between two openings) - which ensure these characteristics in order to avoid the building collapse. Unfortunately, however, in these types of constructions the plant passages involve exactly these elements. The priority of an intervention on the existing building rather than the design of a new one must be to keep these elements unchanged, i.e. to avoid passages inside them by providing service ducts.

Figure 8.29 Load-bearing elements of the masonry structure.



8.4.1 The regulatory framework

The reference standard at European level is Eurocode 8 (EN 1998) which contains the calculation of seismic design actions to be used to verify the plants. The calculation method is based on a static analysis in order to reduce its complexity by applying safety factors. The verification must be done for each part of the plant, including connections and anchorages, but there are no practical indications regarding the implementation of the pipe brackets for which you can refer to the American regulations explained later in this paragraph

The Italian regulation is the Ministerial Decree 18 January 2018 implementing Eurocode 8 (UNI EN 1998). Useful indications are provided for the design and seismic installation of the plants, understood as the set of the actual plant, power devices, connections between the plants and the main structure. By equating plants with structural elements, it is required that their capacity be greater than the seismic demand. It is therefore the task of the structure designer to identify the seismic demand, in accordance with the requirements of the Eurocode. To simplify the process, the calculation is generally done on a static basis and, only for more complex buildings, a dynamic analysis is recommended. The Italian legislation requires that the plants are not brought to the collapse maintaining their stability, it requires instead that the functionality in sensitive buildings is also maintained (Class of use III and IV). The objective is to limit the risk of uncontrolled leakage of dangerous gases or fluids, to protect people from falling elements and, in case of strategic buildings, to safeguard their operation.

In non-European countries, an important standard is the American ASCE/SEI 7-05 for its specific content. Also in this case it is required that the plants resist to a seismic force equal to that of the structure increased by a safety coefficient depending on the type, but this standard is the richest in terms of indications concerning the installation of the elements and the sizing of the anchorages, focusing on some primary objectives, including avoiding the mutual impact of the elements or with the structure, maintaining the plant functionality, avoiding the plant content leakage.

8.4.2 Design criteria

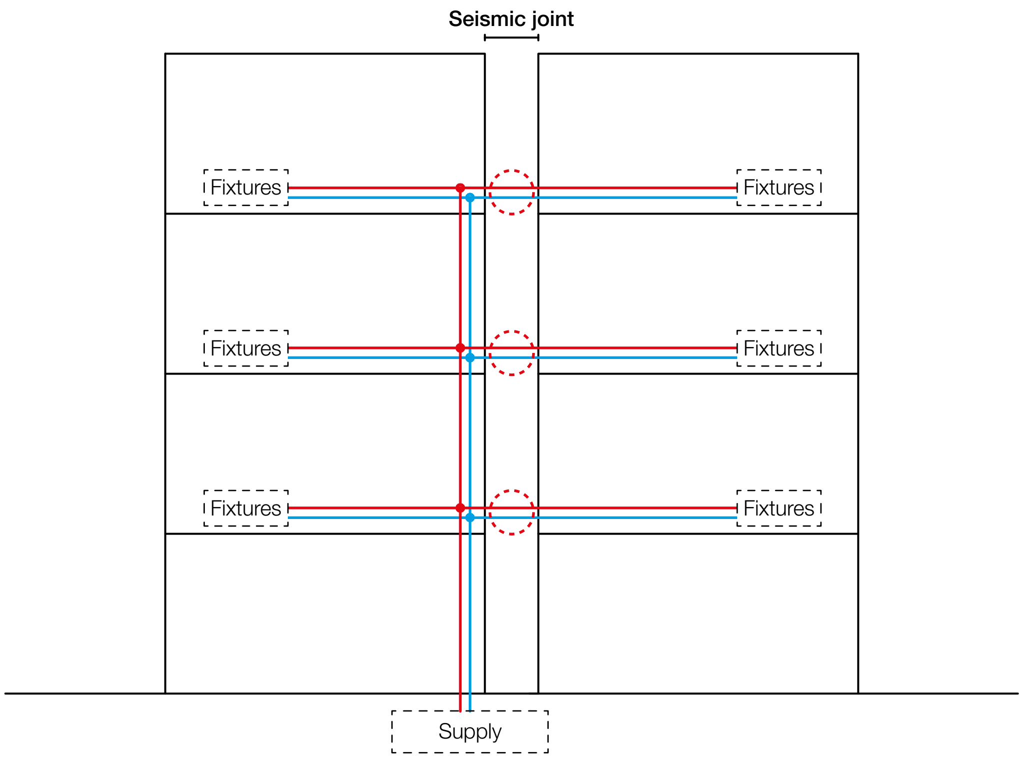
Compliance with the above regulatory requirements can be achieved by adopting design and sizing choices that involve the following aspects:

- Distribution layout.
- Types of components installed.
- Restraint devices.

8.4.2.1 Distribution layout

An accurate choice in the plant distribution allows eliminating some critical issues already in the preliminary phase. In the example of distribution diagram in Figure 8.30, it can be seen that an incorrect choice of plant type can create multiple critical issues.

Figure 8.30 Example of critical distribution layout.



The instructions to follow for a distribution layout are as follows:

1) Provide dedicated riser mains for the various seismic partitions of the building.
2) Place the largest system loads (e.g. AHUs, boilers, heat pumps, etc.) in the lowest part of the building, as the stress increases as the height increases.
3) Since the machine-plant connections are the weakest element, it is preferable to place the technical rooms in an area separated from the building or to provide seismic isolators.

8.4.2.2 Types of components installed

The stress on each installed component is a function of the seismic force calculated according to the regulations in force on the basis of which an appropriate sizing is necessary. In particular, the following elements are to be considered critical elements for which special attention is required.

Fittings. These are joining elements between the various parts of a plant and between different plant parts. These elements may be subject to breakage due to the relative movements. In order to limit damage, it is necessary to guarantee the solidarity of the pipes to the element to which they are fixed, thanks to rigid brackets suitably sized. When connecting pipes anchored to different elements, it is advisable to provide flexible joints able to absorb the relative movements. Since seismic stress is not only vertical (like static stress) but also transversal, it is necessary to provide wind bracing elements to prevent lateral movements of the plant resulting in breakage of the fittings.

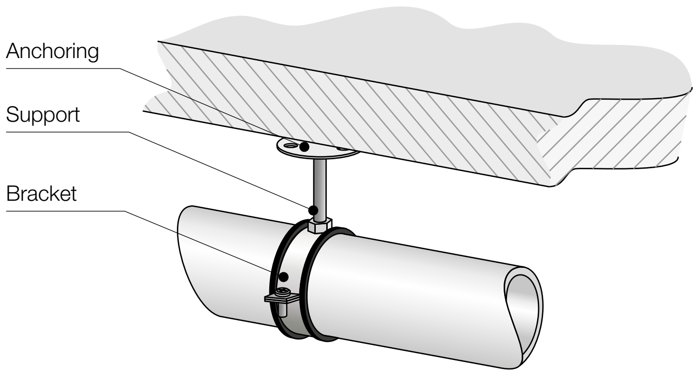
Seismic and thermal joints. The purpose of the joints is to allow free movements to the building, whether they are due to thermal expansion or seismic stress. It is therefore a good practice to avoid crossing these elements and, if this is not possible, it is necessary to install flexible sleeves on each pipe.

Free spaces for movement. To limit the damage, the interaction between different elements must be eliminated. When a pipe crosses a vertical or horizontal element, clearance must be provided to prevent mutual contact during an earthquake. For the pipes it is suggested to guarantee a clearance of at least
5 cm around the entire circumference and if there are any obstacles, the passage can be made using flexible sleeves.

8.4.2.3 Restraint devices

A restraint device is an elements that anchors the plant to the structure, ensuring uniform movement. This is achieved by giving adequate stiffness to the support system, stiffening is obtained by integrating the static brackets with special elements called wind braces. Brackets, whether static or wind bracing, consist of three parts, each of which is intended to transmit stress from the pipe to the structure.

Figure 8.31 Example of brackets for pipes.



Brackets consist of the following elements:

- Bracket. To transmit earthquake-induced inertia forces to the pipe, the most common types are clamps, U-shaped supports and steel profile shelves for pipe bundles.
- Supporting element. It is the connection between the bracket and the anchoring; cables or steel profiles are used. The steel profiles are considered rigid elements, therefore, during the earthquake-induced oscillations, they transmit a vertical force to the anchoring, which adds to the gravitational force of the weight, stressing the anchorage even more. The supporting element length is a function of the load, this for reasons of instability to longitudinal loads and the leverage effect of transversal loads. Cables are considered flexible elements, the connection nature means that there is no transmission of compressive stress to the anchoring.
- Anchoring. It is the point of contact with the structure, it is usually the most critical element of the entire bracketing system; in reinforced concrete, the most common anchoring types are the angle bars fixed to the structure with expansion bolts.

Since the seismic action acts in the plane according to two orthogonal elements, the restraint devices must be positioned so as to oppose both. The market offers four types of wind braces, depending on the movement they can prevent:

- Vertical: in addition to supporting the pipe weight, they prevent the duct oscillation in the vertical plane and are therefore required to work both in traction and compression. If a steel cable is used for connection, an appropriate stiffening element must be fitted on it to give it the required compressive strength.
- Lateral: they have a wind bracing function against lateral oscillations.
- Longitudinal: they prevent sliding along the pipe axis.
- Four-way: they prevent, in a plane, relative movements in any direction.

Below are general criteria to be followed when positioning and sizing restraint devices:

- For horizontal pipes, anchoring points must be provided at each change in direction and branch, they must be both vertical and lateral.
- For vertical pipes, four-way wind braces are used, as the restraint in the plane to the supporting element must be respected.
- Transversal and longitudinal wind braces must be installed at an angle of 45 degrees from horizontal.
- The maximum centre-to-centre distance, recommended by the American standard, between two consecutive transversal wind braces in a non-ductile plant (plastic pipes) is 6 m.
- The maximum centre-to-centre distance, recommended by the American standard, between two consecutive longitudinal wind braces in a non-ductile plant (plastic pipes) is 12 m.
- Do not use rigid and flexible wind braces (cables) on the same pipe at the same time.
- Never wind-brace a plant to two different parts of the structure that may respond differently during an earthquake.
- Any system passing through a separation joint or seismic joint shall be capable of withstanding design movements.

8.5 Bending

The pipes can be bent manually or mechanically; it is however necessary to observe the minimum radii indicated in the following table in relation to the diameter and the type of pipe (Pexal®, Mixal®, Thermoline®).
To bend the pipes manually, an internal spring is generally used to bend short lengths of pipe and an external spring is used, on the other hand, to bend long sections of pipe.
Pipes can be bent mechanically by using suitable tools equipped with manual or hydraulic actuation.

Figure 8.32 Manual bending.

Figure 8.33 Bending with internal spring.

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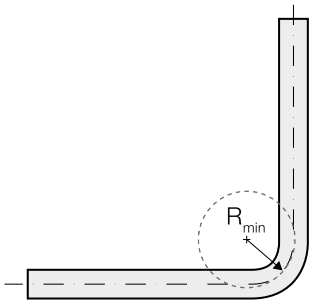
Figure 8.34 Bending with external spring.

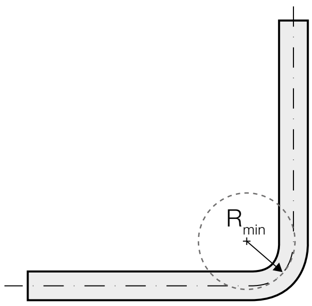
Figure 8.35 Mechanical bending.

Table 8.6 Bending radii for Pexal® and Mixal® pipes.



External diameter OD [mm]	Bending radius [mm]			
	Manual bending R_{min} = 5 x OD	Manual bending with internal spring R_{min} = 4 x OD	Manual bending with external spring R_{min} = 4 x OD	Mechanical bending
14	70	56	56	41
16	80	64	64	49
18	90	72	72	65
20	100	80	80	80
25/26	130	-	-	90
32	160	-	-	120
40	-	-	-	150
50	-	-	-	190
63	-	-	-	240
75	-	-	-	320
90	-	-	-	530

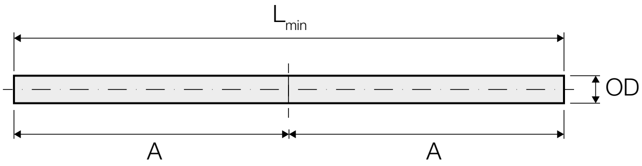
Table 8.7 Bending radii for Thermoline® pipes.



External diameter OD [mm]	Bending radius [mm] Manual bending R_{min} = 6 x OD
12	72
14	84
16	96
17	102
20	120

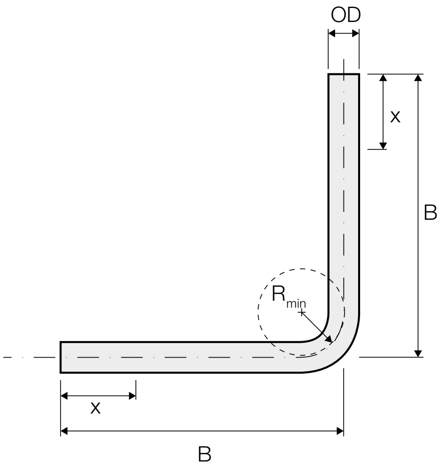
By using a hot air blower and heating the Thermoline® pipe until it becomes transparent (about 130°C) it is possible to create tighter bends or restore incorrect bends or accidental crushing.
This technique can only be used for pipes without EVOH oxygen barrier, so it is not applicable to the Valsir Thermoline® product.
If the pipe needs to be bent immediately after a Bravopress® fitting, first the pressing operation must be performed and then the pipe can be bent.

Table 8.8 Minimum pipe section length for bends up to 90°.



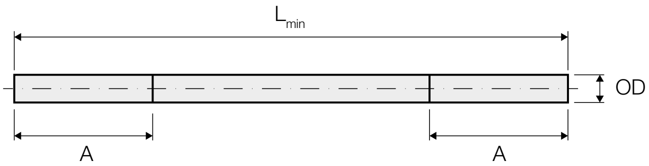
External diameter OD [mm]	A [mm]	L_{min} [mm]
14	78	156
16	78	156
18	100	200
20	117	234
25/26	125	250
32	145	290
40	250	480
50	300	600
63	350	700
75	505	1010
90	750	1500

Table 8.9 Minimum dimensions for making 90° bends.



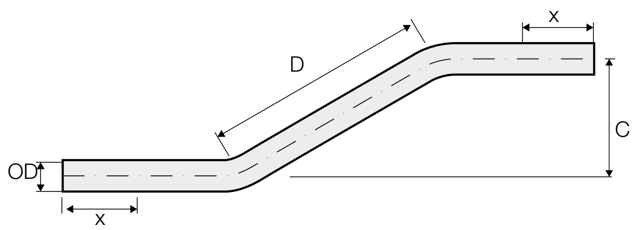
External diameter OD [mm]	B [mm]	X [mm]
14	91	25
16	92	28
18	126	31
20	150	33
25/26	152	42
32	175	50
40	290	60
50	350	73
63	392	95
75	592	115
90	950	120

Table 8.10 Minimum pipe section length for double bend up to 90°.



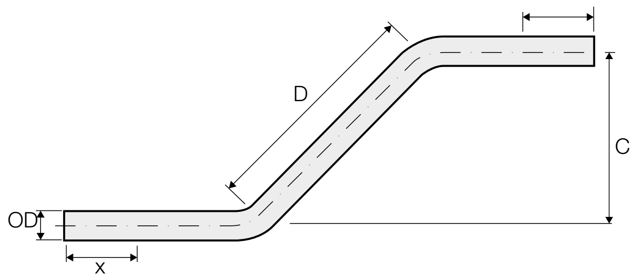
External diameter OD [mm]	A [mm]	L_{min} [mm]
14	78	275
16	78	275
18	100	350
20	140	417
25/26	125	450
32	145	450
40	250	810
50	300	930
63	350	990
75	592	1150
90	750	2300

Table 8.11 Minimum dimensions for making double 30° bends.



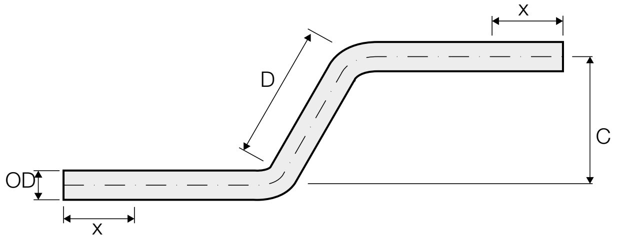
External diameter OD [mm]	C [mm]	D [mm]	X [mm]
14	18	35	25
16	20	40	28
18	26	52	31
20	35	70	33
25/26	52	104	42
32	55	110	50
40	62.5	125	60
50	93	186	73
63	106.5	213	95
75	162.5	325	115
90	247	494	120

Table 8.12 Minimum dimensions for making double 45° bends.



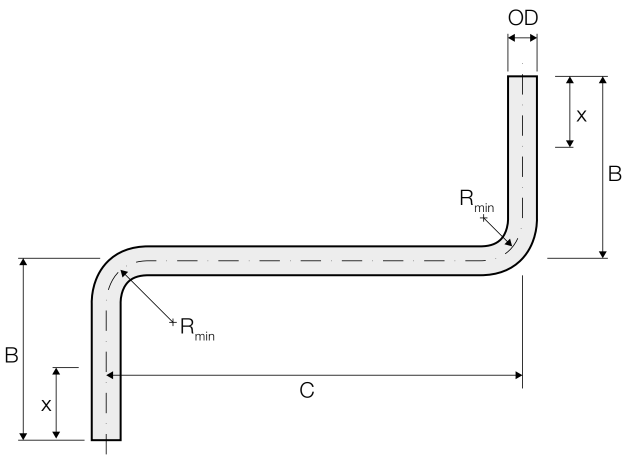
External diameter OD [mm]	C [mm]	D [mm]	X [mm]
14	39	54	25
16	45	63	28
18	61	85	31
20	74	105	33
25/26	91	129	42
32	107	152	50
40	123	174	60
50	170	240	73
63	194	275	95
75	269	380	115
90	373	525	120

Table 8.13 Minimum dimensions for making double 60° bends.



External diameter OD [mm]	C [mm]	D [mm]	X [mm]
14	57	65	25
16	73	84	28
18	75	90	31
20	100	115	33
25/26	128	148	42
32	165	190	50
40	225	260	60
50	294	340	73
63	355	410	95
75	405	468	115
90	433	534	120

Table 8.14 Minimum dimensions for making double 90° bends.



External diameter OD [mm]	B [mm]	C [mm]	X [mm]
14	91	144	25
16	92	144	28
18	126	173	31
20	150	195	33
25/26	152	234	42
32	175	287	50
40	260	480	60
50	331	520	73
63	392	607	95
75	592	995	115
90	950	1300	120

8.6 Insulation

Not only does the insulation reduce energy exchanges between the pipes and its surroundings but it also insulates them against noise, while providing at the same time protection.
The most commonly used materials for thermal insulation are polyurethane foam, polystyrene foam, polyethylene foam, mineral wool, glass wool, synthetic rubber and cork.

Figure 8.36 Insulation of a pipe.

On pipes used for transporting cold water, insulation is used to:

- Prevent the formation of condensation if the temperature and humidity of the air are such as to favour its formation.
- Reduce warming of the water.
- Reduce noise transmission.
- Protect the pipe.

On pipes used for transporting hot water, insulation is used to:

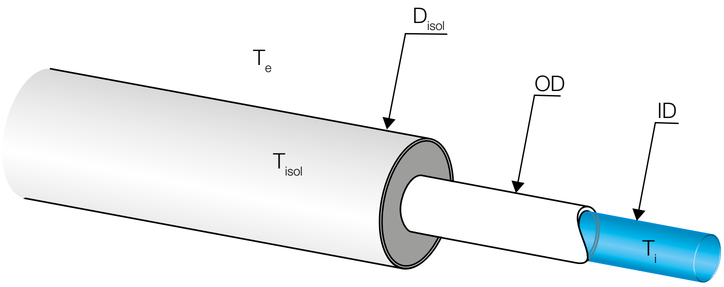
- Reduce energy loss and the consequent cooling of the water.
- Reduce noise transmission.
- Protect the pipe.
- Absorb heat expansion/contraction.

Valsir supplies some of its pipe diameters with a pre-mounted, flame-retardant, closed cell polyethylene foam insulation that speeds up and simplifies installation of the systems.
These pipes can be used for air-conditioning systems as long as the temperature and the pressure limits defined in chapter 2 are observed. The liquids that are typically used are water or water with glycol (ethylene or propylene) or other liquids as long as they are not aggressive towards crosslinked polyethylene; cryogenic liquids such as freon or ammonia, therefore, must not be used.
The choice of the insulation thickness depends on the application and the conditions of use, as described in the following paragraph and always in compliance with any local regulations or standards.

8.6.1 Insulation and condensation

Condensation forms when the humidity contained in the air comes into contact with the cold surface of the pipe, leading to the formation of small drops of water. This happens when the temperature of the pipe is lower than the dew point temperature that is, the temperature at which the air is saturated with vapour and therefore starts to condensate. To avoid this happening, a suitable layer of insulating material should be placed around the pipe that increases the temperature of the surface with which the damp air comes into contact.

Figure 8.37 Insulation of a pipe against the formation of condensation.



The temperature of the surface of the insulating layer of a pipe can be calculated using the following formula which depends on the characteristics of the pipe, the insulating layer and the temperatures:

$$T_{isol} = \frac{T_i \cdot \left(\frac{1}{h_a \cdot D_{isol}}\right) + T_e \cdot \left(\frac{1}{2 \cdot \lambda_t} \cdot \ln\frac{OD}{ID} + \frac{1}{2 \cdot \lambda_{isol}} \cdot \ln\frac{D_{isol}}{OD}\right)}{\frac{1}{h_a \cdot D_{isol}} + \frac{1}{2 \cdot \lambda_t} \cdot \ln\frac{OD}{ID} + \frac{1}{2 \cdot \lambda_{isol}} \cdot \ln\frac{D_{isol}}{OD}} \quad [8.23]$$

where

T_{iso}	is the temperature of the surface of the insulating layer [°C],
T_i	is the temperature of the water inside the pipe [°C],
T_e	is the temperature of the air [°C],
OD and ID	are respectively the external and internal diameters of the pipe [m],
D_{isol}	is the external diameter of the insulating layer [m],
λ_t and λ_{isol}	are respectively the coefficients of thermal conductivity of the pipe and the insulating material [W/m·K],
h_a	is the coefficient of convective heat exchange of the air with the pipe [5.28 W/m²·K].

The layer of insulating material is sufficient when the temperature of the insulation T_{isol} is greater than that of the dew point T_{DP}, it must therefore be:

$$T_{isol} > T_{DP}$$

The dew point temperature can be read from the psychometric diagram (Mollier) in relation to air temperature T_e and humidity UR. The following tables indicate the minimum thickness of the insulation required to prevent the formation of condensation in relation to the type of pipe, the temperature of the water and the temperature and humidity of the air.

Table 8.15 Minimum insulation thickness for Thermoline® pipes.

Pipe diameter OD	Temperature of the water T_i	Temperature of the air T_e [°C]																								
		10					20					30					40					50				
		Relative humidity of the air UR [%]																								
		50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90
12	20												1	4	8	18	4	6	10	16	32	7	10	14	22	42
	15									3	10	2	5	8	13	26	6	9	13	20	38	8	12	17	26	48
	12								3	7	16	4	6	10	16	31	7	10	14	22	42	9	13	18	27	51
	10							2	5	9	20	5	7	11	17	34	8	11	15	24	44	10	14	19	29	53
	7					5	2	4	7	12	25	6	9	13	20	38	9	12	17	26	48	11	15	20	30	56
	5				3	11	3	5	9	14	28	6	10	14	21	41	9	13	18	27	50	11	15	21	32	58
	0		3	5	10	21	5	8	12	19	36	8	12	17	25	47	11	15	20	30	56	13	17	23	35	64
	-5	3	6	9	15	30	7	10	15	23	43	10	14	19	29	53	12	16	23	34	62	14	19	25	37	69
14	20												1	4	9	19	4	7	10	17	33	7	10	15	23	43
	15									3	10	2	5	8	14	27	6	9	13	21	40	9	12	17	26	49
	12								3	7	16	4	6	10	16	32	7	10	15	23	43	10	13	19	28	53
	10							2	5	9	20	5	7	11	18	35	8	11	16	25	46	10	14	20	30	55
	7					6	2	4	7	13	26	6	9	13	21	39	9	12	18	27	50	11	15	21	32	58
	5				3	11	3	5	9	15	29	7	10	14	22	42	9	13	19	28	52	12	16	22	33	60
	0		3	6	10	22	5	8	12	19	37	9	12	17	26	49	11	15	21	31	58	13	18	24	36	66
	-5	3	6	10	16	31	7	11	15	24	45	10	14	20	30	55	13	17	23	35	64	14	19	26	39	71
16	20												1	4	9	20	4	7	11	17	34	7	11	15	24	45
	15									3	10	2	5	8	14	28	6	9	14	21	41	9	13	18	27	51
	12								3	7	17	4	6	10	17	33	7	11	15	24	45	10	14	19	29	54
	10							2	5	10	21	5	8	12	19	36	8	11	16	25	47	10	14	20	31	57
	7					6	2	4	7	13	27	6	9	14	21	40	9	13	18	28	51	11	16	22	33	60
	5				4	11	3	5	9	15	30	7	10	15	23	43	10	14	19	29	54	12	16	23	34	62
	0		3	6	11	23	5	8	13	20	38	9	12	18	27	50	11	16	22	32	60	13	18	25	37	68
	-5	3	6	10	16	32	8	11	16	25	46	11	15	20	31	57	13	17	24	36	66	15	20	27	40	73
17	20												1	4	9	20	4	7	11	18	34	7	11	16	24	46
	15									3	10	2	5	8	14	29	6	9	14	22	41	9	13	18	28	52
	12								3	7	17	4	7	10	17	33	7	11	16	24	46	10	14	20	30	55
	10							2	5	10	21	5	8	12	19	37	8	12	17	26	48	11	15	21	31	58
	7					6	2	4	8	13	27	6	9	14	22	41	9	13	18	28	52	12	16	22	33	61
	5				4	11	3	5	9	15	30	7	10	15	23	44	10	14	19	29	55	12	17	23	34	63
	0		3	6	11	23	5	8	13	20	39	9	13	18	27	51	11	16	22	33	61	14	18	25	38	69
	-5	4	6	10	17	33	8	11	16	25	47	11	15	21	31	58	13	18	24	36	67	15	20	27	41	74
20	20												1	4	9	21	4	7	11	18	36	8	11	16	25	47
	15									3	11	2	5	9	15	30	6	10	14	23	43	9	13	19	29	54
	12								3	7	18	4	7	11	18	35	8	11	16	25	47	10	14	20	31	57
	10							2	5	10	22	5	8	12	20	38	8	12	17	27	50	11	15	21	32	60
	7					6	2	4	8	14	28	6	9	14	22	43	9	13	19	29	54	12	16	23	34	63
	5				4	12	3	6	9	16	32	7	10	15	24	46	10	14	20	31	57	13	17	24	36	66
	0		3	6	11	24	6	9	13	21	40	9	13	19	28	53	12	16	23	34	63	14	19	26	39	72
	-5	4	6	10	17	34	8	11	17	26	49	11	15	22	32	60	14	18	25	38	70	16	21	29	42	77

Note. Minimum thickness is calculated taking into account a heat conductivity of the insulation of 0.0397 W/m·K.

Table 8.16 Minimum insulation thickness for Pexal®/Mixal® pipes.

Pipe diameter OD	Temperature of the water T_i	Temperature of the air T_e [°C]																								
		10					20					30					40					50				
		Relative humidity of the air UR [%]																								
		50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90
14	20												1	4	9	19	4	7	10	17	33	7	10	15	23	44
	15									3	10	2	5	8	14	27	6	9	13	21	40	9	12	17	26	49
	12								3	7	16	4	6	10	16	32	7	10	15	23	44	10	13	19	28	53
	10							2	5	9	20	5	7	11	18	35	8	11	16	25	46	10	14	20	30	55
	7					6	2	4	7	13	26	6	9	13	21	39	9	12	18	27	50	11	15	21	32	58
	5				4	11	3	5	9	15	29	7	10	14	22	42	9	13	19	28	52	12	16	22	33	61
	0		3	6	10	22	5	8	12	19	37	9	12	17	26	49	11	15	21	32	58	13	18	24	36	66
	-5	3	6	10	16	31	7	11	15	24	45	10	14	20	30	55	13	17	23	35	64	14	19	26	39	71
16	20												1	4	9	20	4	7	11	17	34	7	11	15	24	45
	15									3	10	2	5	8	14	28	6	9	14	22	41	9	13	18	27	51
	12								3	7	17	4	6	10	17	33	7	11	15	24	45	10	14	19	29	54
	10							2	5	10	21	5	8	12	19	36	8	11	17	25	48	11	15	20	31	57
	7					6	2	4	8	13	27	6	9	14	21	41	9	13	18	28	51	11	16	22	33	60
	5				4	11	3	5	9	15	30	7	10	15	23	43	10	14	19	29	54	12	16	23	34	62
	0		3	6	11	23	5	8	13	20	38	9	12	18	27	50	11	16	22	33	60	13	18	25	37	68
	-5	4	6	10	16	32	8	11	16	25	46	11	15	21	31	57	13	17	24	36	66	15	20	27	40	73
18	20												1	4	9	20	4	7	11	18	35	7	11	16	24	46
	15									3	11	2	5	8	14	29	6	9	14	22	42	9	13	18	28	52
	12								3	7	17	4	7	11	17	34	7	11	16	25	46	10	14	20	30	56
	10							2	5	10	22	5	8	12	19	37	8	12	17	26	49	11	15	21	32	58
	7					6	2	4	8	13	27	6	9	14	22	42	9	13	19	28	53	12	16	22	34	62
	5				4	12	3	6	9	16	31	7	10	15	24	45	10	14	20	30	55	12	17	23	35	64
	0		3	6	11	23	5	9	13	21	39	9	13	18	28	52	12	16	22	33	62	14	19	26	38	70
	-5	4	6	10	17	33	8	11	16	25	48	11	15	21	32	59	13	18	25	37	68	15	20	28	41	75
20	20												1	4	9	21	4	7	11	18	36	8	11	16	25	47
	15									3	11	2	5	9	15	30	6	10	14	23	43	9	13	19	29	54
	12								3	8	18	4	7	11	18	35	8	11	16	25	47	10	14	20	31	57
	10							2	5	10	22	5	8	12	20	38	8	12	17	27	50	11	15	21	32	60
	7					6	2	4	8	14	28	6	9	14	22	43	9	13	19	29	54	12	16	23	34	63
	5				4	12	3	6	9	16	32	7	11	16	24	46	10	14	20	31	57	13	17	24	36	66
	0		3	6	11	24	6	9	13	21	40	9	13	19	28	53	12	16	23	34	63	14	19	26	39	72
	-5	4	6	10	17	34	8	11	17	26	49	11	15	22	33	60	14	18	25	38	70	16	21	29	42	77
26	20												1	4	10	22	4	7	12	19	38	8	11	17	26	50
	15									3	11	2	5	9	15	31	6	10	15	24	46	10	14	20	30	57
	12								3	8	19	4	7	11	19	37	8	11	17	26	50	11	15	21	33	61
	10							2	5	10	23	5	8	13	21	40	9	12	18	28	53	11	16	23	34	63
	7					6	2	4	8	14	30	6	10	15	24	45	10	14	20	31	57	12	17	24	36	67
	5				4	12	3	6	10	17	33	7	11	16	25	48	11	15	21	32	60	13	18	25	38	70
	0		3	6	12	25	6	9	14	22	43	9	14	20	30	56	12	17	24	36	67	15	20	28	41	76
	-5	4	7	11	18	36	8	12	18	27	52	11	16	23	34	64	14	19	27	40	74	16	22	30	45	82
32	20												1	5	10	23	4	7	12	20	40	8	12	18	28	53
	15									3	12	2	5	9	16	33	7	10	16	25	48	10	14	21	32	60
	12								3	8	20	4	7	12	19	39	8	12	18	28	53	11	16	22	34	64
	10							2	5	11	24	5	8	13	22	42	9	13	19	29	56	12	17	24	36	67
	7					6	2	4	8	15	31	7	10	15	25	47	10	14	21	32	60	13	18	25	38	71
	5				4	13	3	6	10	17	35	7	11	17	27	51	11	15	22	34	63	14	19	26	40	73
	0		3	6	12	26	6	9	14	23	45	10	14	20	31	59	13	18	25	38	70	15	21	29	43	80
	-5	4	7	11	19	38	8	12	18	29	54	12	17	24	36	67	15	20	28	42	77	17	23	32	47	86

Note 1. Minimum thickness is calculated taking into account a heat conductivity of the insulation of 0.0397 W/m·K.
Note 2. Thickness values covered by the 6 mm pre-insulated multilayer pipes are shown in orange, thickness values covered by the 10 mm pre-insulated multilayer pipes are shown in green and thickness values covered by the 13 mm pre-insulated multilayer pipes are shown in light blue.

valsir®

Table 8.16 Minimum insulation thickness for Pexal®/Mixal® pipes (continues).

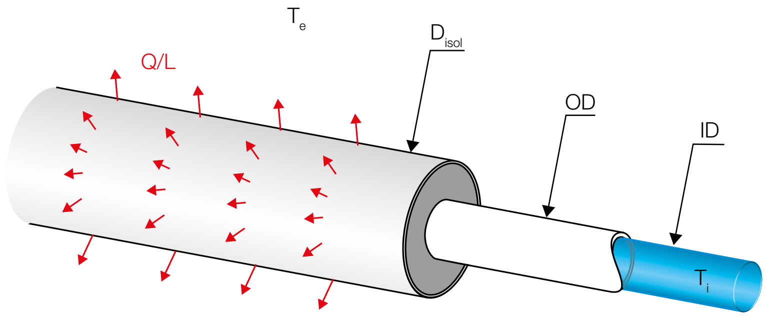
Pipe diameter OD	Temperature of the water T_i	Temperature of the air T_e [°C]																								
		10					20					30					40					50				
		Relative humidity of the air UR [%]																								
		50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90	50	60	70	80	90
40	20												1	5	10	24	4	8	12	21	42	8	12	18	29	55
	15									3	12	2	5	9	17	34	7	11	16	26	50	10	15	21	33	63
	12								3	8	20	4	7	12	20	40	8	12	18	29	55	11	16	23	36	67
	10							2	5	11	25	5	9	14	22	44	9	13	20	31	59	12	17	25	37	70
	7					6	2	4	8	15	32	7	10	16	26	50	10	15	22	34	63	13	19	26	40	74
	5				4	13	3	6	10	18	37	8	12	18	28	53	11	16	23	35	66	14	19	27	42	77
	0		3	6	12	27	6	10	15	24	47	10	15	21	33	62	13	18	26	40	74	16	22	30	45	84
	-5	4	7	11	20	39	9	13	19	30	57	12	17	25	38	70	15	21	29	44	81	18	24	33	49	90
50	20												1	5	10	24	4	8	13	22	44	8	13	19	30	58
	15									3	12	2	5	10	17	36	7	11	17	27	53	10	15	22	35	66
	12								3	8	21	4	7	12	21	42	8	13	19	30	58	12	17	24	37	71
	10							2	5	11	26	5	9	14	23	46	9	14	20	32	62	13	18	26	39	74
	7					6	2	4	9	16	34	7	11	17	27	52	11	15	23	35	67	14	19	27	42	78
	5				4	14	3	6	11	19	38	8	12	18	29	56	11	17	24	37	70	14	20	29	44	81
	0		3	6	13	28	6	10	15	25	49	10	15	22	34	65	14	19	27	42	78	16	23	32	48	88
	-5	4	7	12	20	41	9	13	20	31	60	13	18	26	40	74	16	22	31	46	86	18	25	35	52	95
63	20												1	5	11	25	4	8	13	22	46	8	13	20	31	61
	15									3	13	2	5	10	18	38	7	11	17	28	55	11	16	23	36	69
	12								3	8	22	4	7	13	22	44	8	13	20	31	61	12	17	25	39	74
	10							2	5	12	27	5	9	14	24	49	9	14	21	34	65	13	18	27	41	78
	7					6	2	4	9	16	35	7	11	17	28	55	11	16	23	37	70	14	20	29	44	82
	5				4	14	3	6	11	19	40	8	12	19	30	59	12	17	25	39	74	15	21	30	46	85
	0		3	6	13	30	6	10	16	26	52	10	15	23	36	69	14	20	28	44	82	17	23	33	50	93
	-5	4	7	12	21	43	9	13	20	32	63	13	18	27	41	78	16	22	32	48	90	19	26	36	54	100
75	20												1	5	11	26	4	8	13	23	47	9	13	20	32	63
	15									3	13	2	5	10	18	39	7	11	18	29	57	11	16	24	38	72
	12								3	9	22	4	7	13	22	46	9	13	20	32	63	12	18	26	40	77
	10							2	5	12	28	5	9	15	25	50	10	14	22	35	67	13	19	27	42	80
	7					6	2	4	9	17	36	7	11	17	29	57	11	16	24	38	73	14	20	29	45	85
	5				4	14	3	6	11	20	42	8	12	19	31	61	12	17	26	40	76	15	21	31	47	89
	0		3	6	13	31	6	10	16	27	54	11	16	23	37	71	14	20	29	45	85	17	24	34	52	97
	-5	4	7	12	21	45	9	14	21	33	65	13	19	28	43	81	17	23	33	50	94	19	26	37	56	104
90	20												1	4	11	27	4	8	13	23	49	8	13	20	33	65
	15									3	13	2	5	10	18	40	7	11	18	30	59	11	16	24	39	75
	12								3	8	23	4	7	13	23	47	8	13	20	33	65	12	18	26	42	80
	10							2	5	12	29	5	9	15	25	52	9	14	22	36	69	13	19	28	44	83
	7					6	1	4	9	17	37	7	11	18	29	59	11	16	24	39	75	14	21	30	47	89
	5				4	14	3	6	11	20	43	8	12	19	32	63	12	18	26	41	79	15	22	31	49	92
	0		2	6	13	31	6	10	16	27	56	11	16	24	38	74	14	21	30	47	88	17	24	35	53	100
	-5	3	7	12	22	46	9	14	21	34	67	13	19	28	44	84	17	23	34	52	97	20	27	38	58	108
110	20												1	4	10	27	4	8	13	24	50	8	13	20	34	68
	15									2	13	2	5	10	18	41	7	11	18	30	61	11	16	24	39	77
	12								2	8	23	3	7	13	23	48	8	13	20	34	68	12	18	27	43	83
	10							1	5	12	29	5	9	15	26	53	9	14	22	36	72	13	19	28	45	87
	7					6	1	4	8	17	38	6	11	18	30	61	11	16	25	40	78	14	21	30	48	92
	5				3	14	2	6	11	20	44	8	12	19	32	65	12	18	26	42	82	15	22	32	50	96
	0		2	6	13	32	6	10	16	28	57	10	16	24	39	76	14	21	30	48	92	17	25	36	55	104
	-5	3	7	12	22	47	9	14	21	35	70	13	19	28	45	87	17	24	34	53	101	20	27	39	60	113

Note 1. Minimum thickness is calculated taking into account a heat conductivity of the insulation of 0.0397 W/m·K.
Note 2. Thickness values covered by the 6 mm pre-insulated multilayer pipes are shown in orange, thickness values covered by the 10 mm pre-insulated multilayer pipes are shown in green and thickness values covered by the 13 mm pre-insulated multilayer pipes are shown in light blue.

8.6.2 Insulation and energy losses

The thermal insulation of pipes is used to reduce energy loss and allows the temperature of the water to be kept as constant as possible, from the source to the point of use. If the water has a higher temperature than the ambient temperature then there will be a loss of thermal energy causing the temperature of the water to drop, if on the other hand, the temperature of the water is lower that the ambient temperature, then the water will increase in temperature.

Figure 8.38 Insulation of a pipe to reduce energy loss.



In relation to the characteristics of the insulation, the pipe and the temperature of the air and the water, it is possible to calculate the energy loss (or accumulation) along the pipe:

8

$$\frac{\dot{Q}}{L} = \frac{T_i - T_e}{\frac{1}{\pi \cdot h_a \cdot D_{isol}} + \frac{1}{2 \cdot \pi \cdot \lambda_t} \cdot \ln \frac{OD}{ID} + \frac{1}{2 \cdot \pi \cdot \lambda_{isol}} \cdot \ln \frac{D_{isol}}{OD}} \quad [8.24]$$

where

$\dot{Q}$	is the energy loss or accumulation along the pipe [W],
L	is the length of the pipe [m],
T_i	is the temperature of the water inside the pipe [°C],
T_e	is the temperature of the air [°C],
OD and ID	are respectively the external and internal diameters of the pipe [m],
D_{isol}	is the external diameter of the insulating layer [m],
λ_t and λ_{isol}	are respectively the coefficients of thermal conductivity of the pipe and the insulating material [W/m·K],
h_a	is the convective heat exchange coefficient of the air and the pipe [5.28 W/m²·K].

By using the following tables, it is possible to calculate the energy lost or accumulated along a pipe and the temperature of the surface of the insulation T_{isol} in relation to the thickness of the insulation s_{isol} and the difference between the temperature of the water and the ambient temperature T_i - T_e.

Table 8.17 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 14 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (22.6)	53 (20.3)	67 (18.3)	74 (17.1)	77 (16.4)	83 (15)	87 (14)	89 (13.1)	91 (12.5)	92 (11.9)	93 (11.4)	94 (11)	95 (10.7)	95 (10.4)	96 (10.1)	96 (9.9)	96 (9.7)	97 (9.5)
90	3 (20.3)	48 (18.3)	61 (16.5)	67 (15.4)	70 (14.8)	75 (13.5)	78 (12.6)	80 (11.8)	82 (11.2)	83 (10.7)	84 (10.3)	85 (9.9)	85 (9.6)	86 (9.3)	86 (9.1)	87 (8.9)	87 (8.7)	87 (8.5)
80	2 (18.1)	42 (16.2)	54 (14.7)	59 (13.7)	62 (13.1)	67 (12)	69 (11.2)	71 (10.5)	73 (10)	74 (9.5)	75 (9.1)	75 (8.8)	76 (8.6)	76 (8.3)	77 (8.1)	77 (7.9)	77 (7.7)	77 (7.6)
70	2 (15.8)	37 (14.2)	47 (12.8)	52 (12)	54 (11.5)	58 (10.5)	61 (9.8)	63 (9.2)	64 (8.7)	65 (8.3)	65 (8)	66 (7.7)	66 (7.5)	67 (7.3)	67 (7.1)	67 (6.9)	68 (6.8)	68 (6.6)
60	2 (13.5)	32 (12.2)	40 (11)	45 (10.3)	46 (9.9)	50 (9)	52 (8.4)	54 (7.9)	55 (7.5)	55 (7.1)	56 (6.9)	56 (6.6)	57 (6.4)	57 (6.2)	57 (6.1)	58 (5.9)	58 (5.8)	58 (5.7)
50	1 (11.3)	26 (10.2)	34 (9.2)	37 (8.6)	39 (8.2)	42 (7.5)	43 (7)	45 (6.6)	46 (6.2)	46 (6)	47 (5.7)	47 (5.5)	47 (5.3)	48 (5.2)	48 (5.1)	48 (4.9)	48 (4.8)	48 (4.7)
40	1 (9)	21 (8.1)	27 (7.3)	30 (6.8)	31 (6.6)	33 (6)	35 (5.6)	36 (5.3)	36 (5)	37 (4.8)	37 (4.6)	38 (4.4)	38 (4.3)	38 (4.2)	38 (4)	38 (3.9)	39 (3.9)	39 (3.8)
30	1 (6.8)	16 (6.1)	20 (5.5)	22 (5.1)	23 (4.9)	25 (4.5)	26 (4.2)	27 (3.9)	27 (3.7)	28 (3.6)	28 (3.4)	28 (3.3)	28 (3.2)	29 (3.1)	29 (3)	29 (3)	29 (2.9)	29 (2.8)
25	1 (5.6)	13 (5.1)	17 (4.6)	19 (4.3)	19 (4.1)	21 (3.8)	22 (3.5)	22 (3.3)	23 (3.1)	23 (3)	23 (2.9)	24 (2.8)	24 (2.7)	24 (2.6)	24 (2.5)	24 (2.5)	24 (2.4)	24 (2.4)
20	1 (4.5)	11 (4.1)	13 (3.7)	15 (3.4)	15 (3.3)	17 (3)	17 (2.8)	18 (2.6)	18 (2.5)	18 (2.4)	19 (2.3)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)	19 (2)	19 (1.9)	19 (1.9)
15	0 (3.4)	8 (3)	10 (2.7)	11 (2.6)	12 (2.5)	12 (2.3)	13 (2.1)	13 (2)	14 (1.9)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.5)	14 (1.5)	14 (1.4)	15 (1.4)
10	0 (2.3)	5 (2)	7 (1.8)	7 (1.7)	8 (1.6)	8 (1.5)	9 (1.4)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.1)	9 (1.1)	9 (1.1)	10 (1)	10 (1)	10 (1)	10 (1)	10 (0.9)
5	0 (1.1)	3 (1)	3 (0.9)	4 (0.9)	4 (0.8)	4 (0.8)	4 (0.7)	4 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.1)	-3 (-1)	-3 (-0.9)	-4 (-0.9)	-4 (-0.8)	-4 (-0.8)	-4 (-0.7)	-4 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.3)	-5 (-2)	-7 (-1.8)	-7 (-1.7)	-8 (-1.6)	-8 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.1)	-9 (-1.1)	-9 (-1.1)	-10 (-1)	-10 (-1)	-10 (-1)	-10 (-1)	-10 (-0.9)
-15	0 (-3.4)	-8 (-3)	-10 (-2.7)	-11 (-2.6)	-12 (-2.5)	-12 (-2.3)	-13 (-2.1)	-13 (-2)	-14 (-1.9)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)	-14 (-1.5)	-14 (-1.4)	-15 (-1.4)
-20	-1 (-4.5)	-11 (-4.1)	-13 (-3.7)	-15 (-3.4)	-15 (-3.3)	-17 (-3)	-17 (-2.8)	-18 (-2.6)	-18 (-2.5)	-18 (-2.4)	-19 (-2.3)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)	-19 (-2)	-19 (-1.9)	-19 (-1.9)
-25	-1 (-5.6)	-13 (-5.1)	-17 (-4.6)	-19 (-4.3)	-19 (-4.1)	-21 (-3.8)	-22 (-3.5)	-22 (-3.3)	-23 (-3.1)	-23 (-3)	-23 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.6)	-24 (-2.5)	-24 (-2.5)	-24 (-2.4)	-24 (-2.4)
-30	-1 (-6.8)	-16 (-6.1)	-20 (-5.5)	-22 (-5.1)	-23 (-4.9)	-25 (-4.5)	-26 (-4.2)	-27 (-3.9)	-27 (-3.7)	-28 (-3.6)	-28 (-3.4)	-28 (-3.3)	-28 (-3.2)	-29 (-3.1)	-29 (-3)	-29 (-3)	-29 (-2.9)	-29 (-2.8)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.18 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 16 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference T_i – T_{isol} [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (25.8)	52 (22.2)	67 (19.9)	73 (18.5)	77 (17.7)	83 (16.1)	86 (14.9)	89 (14)	91 (13.2)	92 (12.6)	93 (12.1)	94 (11.7)	95 (11.3)	95 (11)	96 (10.7)	96 (10.4)	96 (10.2)	97 (9.9)
90	2 (23.2)	47 (20)	60 (17.9)	66 (16.6)	69 (15.9)	74 (14.5)	78 (13.4)	80 (12.6)	82 (11.9)	83 (11.4)	84 (10.9)	85 (10.5)	85 (10.2)	86 (9.9)	86 (9.6)	86 (9.4)	87 (9.1)	87 (8.9)
80	2 (20.6)	42 (17.8)	53 (15.9)	59 (14.8)	61 (14.2)	66 (12.9)	69 (11.9)	71 (11.2)	73 (10.6)	74 (10.1)	74 (9.7)	75 (9.3)	76 (9)	76 (8.8)	76 (8.5)	77 (8.3)	77 (8.1)	77 (8)
70	2 (18.1)	37 (15.5)	47 (13.9)	51 (12.9)	54 (12.4)	58 (11.3)	60 (10.4)	62 (9.8)	64 (9.3)	64 (8.8)	65 (8.5)	66 (8.2)	66 (7.9)	67 (7.7)	67 (7.5)	67 (7.3)	67 (7.1)	68 (7)
60	2 (15.5)	31 (13.3)	40 (11.9)	44 (11.1)	46 (10.6)	50 (9.7)	52 (9)	53 (8.4)	54 (7.9)	55 (7.6)	56 (7.3)	56 (7)	57 (6.8)	57 (6.6)	57 (6.4)	58 (6.2)	58 (6.1)	58 (6)
50	1 (12.9)	26 (11.1)	33 (9.9)	37 (9.2)	38 (8.8)	41 (8.1)	43 (7.5)	44 (7)	45 (6.6)	46 (6.3)	47 (6.1)	47 (5.8)	47 (5.6)	48 (5.5)	48 (5.3)	48 (5.2)	48 (5.1)	48 (5)
40	1 (10.3)	21 (8.9)	27 (7.9)	29 (7.4)	31 (7.1)	33 (6.4)	35 (6)	36 (5.6)	36 (5.3)	37 (5.1)	37 (4.8)	38 (4.7)	38 (4.5)	38 (4.4)	38 (4.3)	38 (4.2)	39 (4.1)	39 (4)
30	1 (7.7)	16 (6.7)	20 (6)	22 (5.5)	23 (5.3)	25 (4.8)	26 (4.5)	27 (4.2)	27 (4)	28 (3.8)	28 (3.6)	28 (3.5)	28 (3.4)	29 (3.3)	29 (3.2)	29 (3.1)	29 (3)	29 (3)
25	1 (6.5)	13 (5.6)	17 (5)	18 (4.6)	19 (4.4)	21 (4)	22 (3.7)	22 (3.5)	23 (3.3)	23 (3.2)	23 (3)	23 (2.9)	24 (2.8)	24 (2.7)	24 (2.7)	24 (2.6)	24 (2.5)	24 (2.5)
20	1 (5.2)	10 (4.4)	13 (4)	15 (3.7)	15 (3.5)	17 (3.2)	17 (3)	18 (2.8)	18 (2.6)	18 (2.5)	19 (2.4)	19 (2.3)	19 (2.3)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)	19 (2)
15	0 (3.9)	8 (3.3)	10 (3)	11 (2.8)	12 (2.7)	12 (2.4)	13 (2.2)	13 (2.1)	14 (2)	14 (1.9)	14 (1.8)	14 (1.8)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.6)	14 (1.5)	14 (1.5)
10	0 (2.6)	5 (2.2)	7 (2)	7 (1.8)	8 (1.8)	8 (1.6)	9 (1.5)	9 (1.4)	9 (1.3)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.1)	10 (1.1)	10 (1.1)	10 (1)	10 (1)	10 (1)
5	0 (1.3)	3 (1.1)	3 (1)	4 (0.9)	4 (0.9)	4 (0.8)	4 (0.7)	4 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.3)	-3 (-1.1)	-3 (-1)	-4 (-0.9)	-4 (-0.9)	-4 (-0.8)	-4 (-0.7)	-4 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.6)	-5 (-2.2)	-7 (-2)	-7 (-1.8)	-8 (-1.8)	-8 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.1)	-10 (-1.1)	-10 (-1.1)	-10 (-1)	-10 (-1)	-10 (-1)
-15	0 (-3.9)	-8 (-3.3)	-10 (-3)	-11 (-2.8)	-12 (-2.7)	-12 (-2.4)	-13 (-2.2)	-13 (-2.1)	-14 (-2)	-14 (-1.9)	-14 (-1.8)	-14 (-1.8)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)	-14 (-1.5)
-20	-1 (-5.2)	-10 (-4.4)	-13 (-4)	-15 (-3.7)	-15 (-3.5)	-17 (-3.2)	-17 (-3)	-18 (-2.8)	-18 (-2.6)	-18 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.3)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)	-19 (-2)
-25	-1 (-6.5)	-13 (-5.6)	-17 (-5)	-18 (-4.6)	-19 (-4.4)	-21 (-4)	-22 (-3.7)	-22 (-3.5)	-23 (-3.3)	-23 (-3.2)	-23 (-3)	-23 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.7)	-24 (-2.6)	-24 (-2.5)	-24 (-2.5)
-30	-1 (-7.7)	-16 (-6.7)	-20 (-6)	-22 (-5.5)	-23 (-5.3)	-25 (-4.8)	-26 (-4.5)	-27 (-4.2)	-27 (-4)	-28 (-3.8)	-28 (-3.6)	-28 (-3.5)	-28 (-3.4)	-29 (-3.3)	-29 (-3.2)	-29 (-3.1)	-29 (-3)	-29 (-3)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.19 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 18 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (29.1)	52 (24.1)	66 (21.4)	73 (19.8)	76 (18.9)	82 (17.2)	86 (15.9)	89 (14.8)	90 (14)	92 (13.3)	93 (12.8)	94 (12.3)	94 (11.9)	95 (11.5)	95 (11.2)	96 (10.9)	96 (10.6)	96 (10.4)
90	2 (26.1)	46 (21.7)	59 (19.3)	66 (17.8)	69 (17)	74 (15.5)	77 (14.3)	80 (13.3)	81 (12.6)	83 (12)	84 (11.5)	84 (11.1)	85 (10.7)	85 (10.4)	86 (10.1)	86 (9.8)	87 (9.6)	87 (9.4)
80	2 (23.2)	41 (19.3)	53 (17.1)	58 (15.9)	61 (15.1)	66 (13.7)	69 (12.7)	71 (11.9)	72 (11.2)	73 (10.7)	74 (10.2)	75 (9.8)	76 (9.5)	76 (9.2)	76 (8.9)	77 (8.7)	77 (8.5)	77 (8.3)
70	2 (20.3)	36 (16.9)	46 (15)	51 (13.9)	53 (13.3)	58 (12)	60 (11.1)	62 (10.4)	63 (9.8)	64 (9.3)	65 (8.9)	66 (8.6)	66 (8.3)	66 (8.1)	67 (7.8)	67 (7.6)	67 (7.4)	68 (7.3)
60	2 (17.4)	31 (14.5)	40 (12.8)	44 (11.9)	46 (11.4)	49 (10.3)	52 (9.5)	53 (8.9)	54 (8.4)	55 (8)	56 (7.7)	56 (7.4)	57 (7.1)	57 (6.9)	57 (6.7)	58 (6.5)	58 (6.4)	58 (6.2)
50	1 (14.5)	26 (12)	33 (10.7)	36 (9.9)	38 (9.5)	41 (8.6)	43 (7.9)	44 (7.4)	45 (7)	46 (6.7)	46 (6.4)	47 (6.1)	47 (5.9)	47 (5.8)	48 (5.6)	48 (5.4)	48 (5.3)	48 (5.2)
40	1 (11.6)	21 (9.6)	26 (8.6)	29 (7.9)	30 (7.6)	33 (6.9)	34 (6.3)	35 (5.9)	36 (5.6)	37 (5.3)	37 (5.1)	37 (4.9)	38 (4.7)	38 (4.6)	38 (4.5)	38 (4.4)	38 (4.3)	39 (4.2)
30	1 (8.7)	15 (7.2)	20 (6.4)	22 (5.9)	23 (5.7)	25 (5.2)	26 (4.8)	27 (4.4)	27 (4.2)	28 (4)	28 (3.8)	28 (3.7)	28 (3.6)	28 (3.5)	29 (3.4)	29 (3.3)	29 (3.2)	29 (3.1)
25	1 (7.3)	13 (6)	17 (5.3)	18 (5)	19 (4.7)	21 (4.3)	21 (4)	22 (3.7)	23 (3.5)	23 (3.3)	23 (3.2)	23 (3.1)	24 (3)	24 (2.9)	24 (2.8)	24 (2.7)	24 (2.7)	24 (2.6)
20	1 (5.8)	10 (4.8)	13 (4.3)	15 (4)	15 (3.8)	16 (3.4)	17 (3.2)	18 (3)	18 (2.8)	18 (2.7)	19 (2.6)	19 (2.5)	19 (2.4)	19 (2.3)	19 (2.2)	19 (2.2)	19 (2.1)	19 (2.1)
15	0 (4.4)	8 (3.6)	10 (3.2)	11 (3)	11 (2.8)	12 (2.6)	13 (2.4)	13 (2.2)	14 (2.1)	14 (2)	14 (1.9)	14 (1.8)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.6)
10	0 (2.9)	5 (2.4)	7 (2.1)	7 (2)	8 (1.9)	8 (1.7)	9 (1.6)	9 (1.5)	9 (1.4)	9 (1.3)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.2)	10 (1.1)	10 (1.1)	10 (1.1)	10 (1)
5	0 (1.5)	3 (1.2)	3 (1.1)	4 (1)	4 (0.9)	4 (0.9)	4 (0.8)	4 (0.7)	5 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.5)	-3 (-1.2)	-3 (-1.1)	-4 (-1)	-4 (-0.9)	-4 (-0.9)	-4 (-0.8)	-4 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.9)	-5 (-2.4)	-7 (-2.1)	-7 (-2)	-8 (-1.9)	-8 (-1.7)	-9 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.2)	-10 (-1.1)	-10 (-1.1)	-10 (-1.1)	-10 (-1)
-15	0 (-4.4)	-8 (-3.6)	-10 (-3.2)	-11 (-3)	-11 (-2.8)	-12 (-2.6)	-13 (-2.4)	-13 (-2.2)	-14 (-2.1)	-14 (-2)	-14 (-1.9)	-14 (-1.8)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.6)
-20	-1 (-5.8)	-10 (-4.8)	-13 (-4.3)	-15 (-4)	-15 (-3.8)	-16 (-3.4)	-17 (-3.2)	-18 (-3)	-18 (-2.8)	-18 (-2.7)	-19 (-2.6)	-19 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.2)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)
-25	-1 (-7.3)	-13 (-6)	-17 (-5.3)	-18 (-5)	-19 (-4.7)	-21 (-4.3)	-21 (-4)	-22 (-3.7)	-23 (-3.5)	-23 (-3.3)	-23 (-3.2)	-23 (-3.1)	-24 (-3)	-24 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.7)	-24 (-2.6)
-30	-1 (-8.7)	-15 (-7.2)	-20 (-6.4)	-22 (-5.9)	-23 (-5.7)	-25 (-5.2)	-26 (-4.8)	-27 (-4.4)	-27 (-4.2)	-28 (-4)	-28 (-3.8)	-28 (-3.7)	-28 (-3.6)	-28 (-3.5)	-29 (-3.4)	-29 (-3.3)	-29 (-3.2)	-29 (-3.1)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.20 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 20 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (32.3)	51 (26)	65 (22.9)	72 (21.1)	76 (20.2)	82 (18.2)	86 (16.8)	88 (15.6)	90 (14.7)	92 (14)	93 (13.4)	94 (12.9)	94 (12.4)	95 (12)	95 (11.7)	96 (11.4)	96 (11.1)	96 (10.8)
90	2 (29.1)	46 (23.4)	59 (20.6)	65 (19)	68 (18.1)	74 (16.4)	77 (15.1)	79 (14.1)	81 (13.3)	82 (12.6)	83 (12.1)	84 (11.6)	85 (11.2)	85 (10.8)	86 (10.5)	86 (10.2)	86 (10)	87 (9.8)
80	2 (25.8)	41 (20.8)	52 (18.3)	58 (16.9)	61 (16.1)	65 (14.6)	68 (13.4)	71 (12.5)	72 (11.8)	73 (11.2)	74 (10.7)	75 (10.3)	75 (9.9)	76 (9.6)	76 (9.3)	77 (9.1)	77 (8.9)	77 (8.7)
70	2 (22.6)	36 (18.2)	46 (16)	51 (14.8)	53 (14.1)	57 (12.7)	60 (11.7)	62 (10.9)	63 (10.3)	64 (9.8)	65 (9.4)	65 (9)	66 (8.7)	66 (8.4)	67 (8.2)	67 (8)	67 (7.8)	67 (7.6)
60	2 (19.4)	31 (15.6)	39 (13.7)	43 (12.7)	45 (12.1)	49 (10.9)	51 (10.1)	53 (9.4)	54 (8.8)	55 (8.4)	56 (8)	56 (7.7)	57 (7.5)	57 (7.2)	57 (7)	57 (6.8)	58 (6.7)	58 (6.5)
50	1 (16.1)	26 (13)	33 (11.4)	36 (10.6)	38 (10.1)	41 (9.1)	43 (8.4)	44 (7.8)	45 (7.4)	46 (7)	46 (6.7)	47 (6.4)	47 (6.2)	47 (6)	48 (5.8)	48 (5.7)	48 (5.5)	48 (5.4)
40	1 (12.9)	20 (10.4)	26 (9.2)	29 (8.5)	30 (8.1)	33 (7.3)	34 (6.7)	35 (6.3)	36 (5.9)	37 (5.6)	37 (5.4)	37 (5.1)	38 (5)	38 (4.8)	38 (4.7)	38 (4.5)	38 (4.4)	39 (4.3)
30	1 (9.7)	15 (7.8)	20 (6.9)	22 (6.3)	23 (6)	25 (5.5)	26 (5)	26 (4.7)	27 (4.4)	27 (4.2)	28 (4)	28 (3.9)	28 (3.7)	28 (3.6)	29 (3.5)	29 (3.4)	29 (3.3)	29 (3.3)
25	1 (8.1)	13 (6.5)	16 (5.7)	18 (5.3)	19 (5)	20 (4.6)	21 (4.2)	22 (3.9)	23 (3.7)	23 (3.5)	23 (3.3)	23 (3.2)	24 (3.1)	24 (3)	24 (2.9)	24 (2.8)	24 (2.8)	24 (2.7)
20	1 (6.5)	10 (5.2)	13 (4.6)	14 (4.2)	15 (4)	16 (3.6)	17 (3.4)	18 (3.1)	18 (2.9)	18 (2.8)	19 (2.7)	19 (2.6)	19 (2.5)	19 (2.4)	19 (2.3)	19 (2.3)	19 (2.2)	19 (2.2)
15	0 (4.8)	8 (3.9)	10 (3.4)	11 (3.2)	11 (3)	12 (2.7)	13 (2.5)	13 (2.3)	14 (2.2)	14 (2.1)	14 (2)	14 (1.9)	14 (1.9)	14 (1.8)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)
10	0 (3.2)	5 (2.6)	7 (2.3)	7 (2.1)	8 (2)	8 (1.8)	9 (1.7)	9 (1.6)	9 (1.5)	9 (1.4)	9 (1.3)	9 (1.3)	9 (1.2)	9 (1.2)	10 (1.2)	10 (1.1)	10 (1.1)	10 (1.1)
5	0 (1.6)	3 (1.3)	3 (1.1)	4 (1.1)	4 (1)	4 (0.9)	4 (0.8)	4 (0.8)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.6)	-3 (-1.3)	-3 (-1.1)	-4 (-1.1)	-4 (-1)	-4 (-0.9)	-4 (-0.8)	-4 (-0.8)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)
-10	0 (-3.2)	-5 (-2.6)	-7 (-2.3)	-7 (-2.1)	-8 (-2)	-8 (-1.8)	-9 (-1.7)	-9 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-10 (-1.2)	-10 (-1.1)	-10 (-1.1)	-10 (-1.1)
-15	0 (-4.8)	-8 (-3.9)	-10 (-3.4)	-11 (-3.2)	-11 (-3)	-12 (-2.7)	-13 (-2.5)	-13 (-2.3)	-14 (-2.2)	-14 (-2.1)	-14 (-2)	-14 (-1.9)	-14 (-1.9)	-14 (-1.8)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)
-20	-1 (-6.5)	-10 (-5.2)	-13 (-4.6)	-14 (-4.2)	-15 (-4)	-16 (-3.6)	-17 (-3.4)	-18 (-3.1)	-18 (-2.9)	-18 (-2.8)	-19 (-2.7)	-19 (-2.6)	-19 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.3)	-19 (-2.2)	-19 (-2.2)
-25	-1 (-8.1)	-13 (-6.5)	-16 (-5.7)	-18 (-5.3)	-19 (-5)	-20 (-4.6)	-21 (-4.2)	-22 (-3.9)	-23 (-3.7)	-23 (-3.5)	-23 (-3.3)	-23 (-3.2)	-24 (-3.1)	-24 (-3)	-24 (-2.9)	-24 (-2.8)	-24 (-2.8)	-24 (-2.7)
-30	-1 (-9.7)	-15 (-7.8)	-20 (-6.9)	-22 (-6.3)	-23 (-6)	-25 (-5.5)	-26 (-5)	-26 (-4.7)	-27 (-4.4)	-27 (-4.2)	-28 (-4)	-28 (-3.9)	-28 (-3.7)	-28 (-3.6)	-29 (-3.5)	-29 (-3.4)	-29 (-3.3)	-29 (-3.3)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.21 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 25/26 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	4 (41.4)	50 (31.2)	65 (27.1)	71 (24.8)	75 (23.5)	81 (21.1)	85 (19.3)	87 (17.9)	89 (16.8)	91 (15.9)	92 (15.1)	93 (14.5)	94 (13.9)	94 (13.5)	95 (13)	95 (12.7)	96 (12.3)	96 (12)
90	4 (37.3)	45 (28.1)	58 (24.4)	64 (22.3)	67 (21.2)	73 (19)	76 (17.3)	79 (16.1)	81 (15.1)	82 (14.3)	83 (13.6)	84 (13)	84 (12.5)	85 (12.1)	85 (11.7)	86 (11.4)	86 (11.1)	86 (10.8)
80	3 (33.1)	40 (25)	52 (21.7)	57 (19.8)	60 (18.8)	65 (16.9)	68 (15.4)	70 (14.3)	72 (13.4)	73 (12.7)	74 (12.1)	74 (11.6)	75 (11.2)	76 (10.8)	76 (10.4)	76 (10.1)	77 (9.9)	77 (9.6)
70	3 (29)	35 (21.8)	45 (18.9)	50 (17.3)	52 (16.5)	57 (14.8)	59 (13.5)	61 (12.5)	63 (11.7)	64 (11.1)	64 (10.6)	65 (10.1)	66 (9.8)	66 (9.4)	66 (9.1)	67 (8.9)	67 (8.6)	67 (8.4)
60	2 (24.8)	30 (18.7)	39 (16.2)	43 (14.9)	45 (14.1)	48 (12.6)	51 (11.6)	52 (10.7)	54 (10.1)	55 (9.5)	55 (9.1)	56 (8.7)	56 (8.4)	57 (8.1)	57 (7.8)	57 (7.6)	57 (7.4)	58 (7.2)
50	2 (20.7)	25 (15.6)	32 (13.5)	36 (12.4)	37 (11.8)	40 (10.5)	42 (9.6)	44 (8.9)	45 (8.4)	45 (7.9)	46 (7.6)	47 (7.2)	47 (7)	47 (6.7)	47 (6.5)	48 (6.3)	48 (6.2)	48 (6)
40	2 (16.6)	20 (12.5)	26 (10.8)	29 (9.9)	30 (9.4)	32 (8.4)	34 (7.7)	35 (7.2)	36 (6.7)	36 (6.3)	37 (6)	37 (5.8)	38 (5.6)	38 (5.4)	38 (5.2)	38 (5.1)	38 (4.9)	38 (4.8)
30	1 (12.4)	15 (9.4)	19 (8.1)	21 (7.4)	22 (7.1)	24 (6.3)	25 (5.8)	26 (5.4)	27 (5)	27 (4.8)	28 (4.5)	28 (4.3)	28 (4.2)	28 (4)	28 (3.9)	29 (3.8)	29 (3.7)	29 (3.6)
25	1 (10.3)	13 (7.8)	16 (6.8)	18 (6.2)	19 (5.9)	20 (5.3)	21 (4.8)	22 (4.5)	22 (4.2)	23 (4)	23 (3.8)	23 (3.6)	23 (3.5)	24 (3.4)	24 (3.3)	24 (3.2)	24 (3.1)	24 (3)
20	1 (8.3)	10 (6.2)	13 (5.4)	14 (5)	15 (4.7)	16 (4.2)	17 (3.9)	17 (3.6)	18 (3.4)	18 (3.2)	18 (3)	19 (2.9)	19 (2.8)	19 (2.7)	19 (2.6)	19 (2.5)	19 (2.5)	19 (2.4)
15	1 (6.2)	8 (4.7)	10 (4.1)	11 (3.7)	11 (3.5)	12 (3.2)	13 (2.9)	13 (2.7)	13 (2.5)	14 (2.4)	14 (2.3)	14 (2.2)	14 (2.1)	14 (2)	14 (2)	14 (1.9)	14 (1.9)	14 (1.8)
10	0 (4.1)	5 (3.1)	6 (2.7)	7 (2.5)	7 (2.4)	8 (2.1)	8 (1.9)	9 (1.8)	9 (1.7)	9 (1.6)	9 (1.5)	9 (1.4)	9 (1.4)	9 (1.3)	9 (1.3)	10 (1.3)	10 (1.2)	10 (1.2)
5	0 (2.1)	3 (1.6)	3 (1.4)	4 (1.2)	4 (1.2)	4 (1.1)	4 (1)	4 (0.9)	4 (0.8)	5 (0.8)	5 (0.8)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-2.1)	-3 (-1.6)	-3 (-1.4)	-4 (-1.2)	-4 (-1.2)	-4 (-1.1)	-4 (-1)	-4 (-0.9)	-4 (-0.8)	-5 (-0.8)	-5 (-0.8)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)
-10	0 (-4.1)	-5 (-3.1)	-6 (-2.7)	-7 (-2.5)	-7 (-2.4)	-8 (-2.1)	-8 (-1.9)	-9 (-1.8)	-9 (-1.7)	-9 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-10 (-1.3)	-10 (-1.2)	-10 (-1.2)
-15	-1 (-6.2)	-8 (-4.7)	-10 (-4.1)	-11 (-3.7)	-11 (-3.5)	-12 (-3.2)	-13 (-2.9)	-13 (-2.7)	-13 (-2.5)	-14 (-2.4)	-14 (-2.3)	-14 (-2.2)	-14 (-2.1)	-14 (-2)	-14 (-2)	-14 (-1.9)	-14 (-1.9)	-14 (-1.8)
-20	-1 (-8.3)	-10 (-6.2)	-13 (-5.4)	-14 (-5)	-15 (-4.7)	-16 (-4.2)	-17 (-3.9)	-17 (-3.6)	-18 (-3.4)	-18 (-3.2)	-18 (-3)	-19 (-2.9)	-19 (-2.8)	-19 (-2.7)	-19 (-2.6)	-19 (-2.5)	-19 (-2.5)	-19 (-2.4)
-25	-1 (-10.3)	-13 (-7.8)	-16 (-6.8)	-18 (-6.2)	-19 (-5.9)	-20 (-5.3)	-21 (-4.8)	-22 (-4.5)	-22 (-4.2)	-23 (-4)	-23 (-3.8)	-23 (-3.6)	-23 (-3.5)	-24 (-3.4)	-24 (-3.3)	-24 (-3.2)	-24 (-3.1)	-24 (-3)
-30	-1 (-12.4)	-15 (-9.4)	-19 (-8.1)	-21 (-7.4)	-22 (-7.1)	-24 (-6.3)	-25 (-5.8)	-26 (-5.4)	-27 (-5)	-27 (-4.8)	-28 (-4.5)	-28 (-4.3)	-28 (-4.2)	-28 (-4)	-28 (-3.9)	-29 (-3.8)	-29 (-3.7)	-29 (-3.6)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.22 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 32 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference T_i – T_{isol} [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}$/L [W/m])																	
100	4 (51)	50 (36.7)	64 (31.4)	70 (28.6)	74 (27)	80 (24)	84 (21.8)	87 (20.1)	89 (18.8)	90 (17.7)	92 (16.8)	93 (16.1)	93 (15.4)	94 (14.9)	95 (14.4)	95 (13.9)	96 (13.6)	96 (13.2)
90	4 (45.9)	45 (33)	57 (28.3)	63 (25.7)	66 (24.3)	72 (21.6)	76 (19.6)	78 (18.1)	80 (16.9)	81 (16)	83 (15.2)	83 (14.5)	84 (13.9)	85 (13.4)	85 (12.9)	86 (12.6)	86 (12.2)	86 (11.9)
80	3 (40.8)	40 (29.4)	51 (25.1)	56 (22.9)	59 (21.6)	64 (19.2)	67 (17.5)	69 (16.1)	71 (15.1)	72 (14.2)	73 (13.5)	74 (12.9)	75 (12.4)	75 (11.9)	76 (11.5)	76 (11.2)	76 (10.8)	77 (10.6)
70	3 (35.7)	35 (25.7)	45 (22)	49 (20)	52 (18.9)	56 (16.8)	59 (15.3)	61 (14.1)	62 (13.2)	63 (12.4)	64 (11.8)	65 (11.3)	65 (10.8)	66 (10.4)	66 (10.1)	67 (9.8)	67 (9.5)	67 (9.2)
60	2 (30.6)	30 (22)	38 (18.9)	42 (17.1)	44 (16.2)	48 (14.4)	50 (13.1)	52 (12.1)	53 (11.3)	54 (10.6)	55 (10.1)	56 (9.7)	56 (9.3)	56 (8.9)	57 (8.6)	57 (8.4)	57 (8.1)	58 (7.9)
50	2 (25.5)	25 (18.4)	32 (15.7)	35 (14.3)	37 (13.5)	40 (12)	42 (10.9)	43 (10.1)	44 (9.4)	45 (8.9)	46 (8.4)	46 (8)	47 (7.7)	47 (7.4)	47 (7.2)	48 (7)	48 (6.8)	48 (6.6)
40	2 (20.4)	20 (14.7)	25 (12.6)	28 (11.4)	29 (10.8)	32 (9.6)	34 (8.7)	35 (8.1)	36 (7.5)	36 (7.1)	37 (6.7)	37 (6.4)	37 (6.2)	38 (6)	38 (5.8)	38 (5.6)	38 (5.4)	38 (5.3)
30	1 (15.3)	15 (11)	19 (9.4)	21 (8.6)	22 (8.1)	24 (7.2)	25 (6.5)	26 (6)	27 (5.6)	27 (5.3)	28 (5.1)	28 (4.8)	28 (4.6)	28 (4.5)	28 (4.3)	29 (4.2)	29 (4.1)	29 (4)
25	1 (12.7)	12 (9.2)	16 (7.9)	18 (7.1)	18 (6.8)	20 (6)	21 (5.5)	22 (5)	22 (4.7)	23 (4.4)	23 (4.2)	23 (4)	23 (3.9)	24 (3.7)	24 (3.6)	24 (3.5)	24 (3.4)	24 (3.3)
20	1 (10.2)	10 (7.3)	13 (6.3)	14 (5.7)	15 (5.4)	16 (4.8)	17 (4.4)	17 (4)	18 (3.8)	18 (3.5)	18 (3.4)	19 (3.2)	19 (3.1)	19 (3)	19 (2.9)	19 (2.8)	19 (2.7)	19 (2.6)
15	1 (7.6)	7 (5.5)	10 (4.7)	11 (4.3)	11 (4.1)	12 (3.6)	13 (3.3)	13 (3)	13 (2.8)	14 (2.7)	14 (2.5)	14 (2.4)	14 (2.3)	14 (2.2)	14 (2.2)	14 (2.1)	14 (2)	14 (2)
10	0 (5.1)	5 (3.7)	6 (3.1)	7 (2.9)	7 (2.7)	8 (2.4)	8 (2.2)	9 (2)	9 (1.9)	9 (1.8)	9 (1.7)	9 (1.6)	9 (1.5)	9 (1.5)	9 (1.4)	10 (1.4)	10 (1.4)	10 (1.3)
5	0 (2.5)	2 (1.8)	3 (1.6)	4 (1.4)	4 (1.4)	4 (1.2)	4 (1.1)	4 (1)	4 (0.9)	5 (0.9)	5 (0.8)	5 (0.8)	5 (0.8)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.7)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-2.5)	-2 (-1.8)	-3 (-1.6)	-4 (-1.4)	-4 (-1.4)	-4 (-1.2)	-4 (-1.1)	-4 (-1)	-4 (-0.9)	-5 (-0.9)	-5 (-0.8)	-5 (-0.8)	-5 (-0.8)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)
-10	0 (-5.1)	-5 (-3.7)	-6 (-3.1)	-7 (-2.9)	-7 (-2.7)	-8 (-2.4)	-8 (-2.2)	-9 (-2)	-9 (-1.9)	-9 (-1.8)	-9 (-1.7)	-9 (-1.6)	-9 (-1.5)	-9 (-1.5)	-9 (-1.4)	-10 (-1.4)	-10 (-1.4)	-10 (-1.3)
-15	-1 (-7.6)	-7 (-5.5)	-10 (-4.7)	-11 (-4.3)	-11 (-4.1)	-12 (-3.6)	-13 (-3.3)	-13 (-3)	-13 (-2.8)	-14 (-2.7)	-14 (-2.5)	-14 (-2.4)	-14 (-2.3)	-14 (-2.2)	-14 (-2.2)	-14 (-2.1)	-14 (-2)	-14 (-2)
-20	-1 (-10.2)	-10 (-7.3)	-13 (-6.3)	-14 (-5.7)	-15 (-5.4)	-16 (-4.8)	-17 (-4.4)	-17 (-4)	-18 (-3.8)	-18 (-3.5)	-18 (-3.4)	-19 (-3.2)	-19 (-3.1)	-19 (-3)	-19 (-2.9)	-19 (-2.8)	-19 (-2.7)	-19 (-2.6)
-25	-1 (-12.7)	-12 (-9.2)	-16 (-7.9)	-18 (-7.1)	-18 (-6.8)	-20 (-6)	-21 (-5.5)	-22 (-5)	-22 (-4.7)	-23 (-4.4)	-23 (-4.2)	-23 (-4)	-23 (-3.9)	-24 (-3.7)	-24 (-3.6)	-24 (-3.5)	-24 (-3.4)	-24 (-3.3)
-30	-1 (-15.3)	-15 (-11)	-19 (-9.4)	-21 (-8.6)	-22 (-8.1)	-24 (-7.2)	-25 (-6.5)	-26 (-6)	-27 (-5.6)	-27 (-5.3)	-28 (-5.1)	-28 (-4.8)	-28 (-4.6)	-28 (-4.5)	-28 (-4.3)	-29 (-4.2)	-29 (-4.1)	-29 (-4)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.23 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 40 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	5 (63.4)	49 (43.8)	63 (37)	69 (33.4)	73 (31.5)	79 (27.8)	83 (25)	86 (23)	88 (21.4)	90 (20.1)	91 (19)	92 (18.1)	93 (17.3)	94 (16.7)	94 (16.1)	95 (15.5)	95 (15.1)	96 (14.7)
90	4 (57)	44 (39.4)	57 (33.3)	63 (30.1)	66 (28.3)	71 (25)	75 (22.5)	78 (20.7)	79 (19.3)	81 (18.1)	82 (17.1)	83 (16.3)	84 (15.6)	84 (15)	85 (14.5)	85 (14)	86 (13.6)	86 (13.2)
80	4 (50.7)	39 (35.1)	50 (29.6)	56 (26.7)	58 (25.2)	63 (22.2)	67 (20)	69 (18.4)	71 (17.1)	72 (16.1)	73 (15.2)	74 (14.5)	74 (13.9)	75 (13.3)	75 (12.8)	76 (12.4)	76 (12.1)	76 (11.7)
70	3 (44.4)	34 (30.7)	44 (25.9)	49 (23.4)	51 (22)	55 (19.4)	58 (17.5)	60 (16.1)	62 (15)	63 (14.1)	64 (13.3)	65 (12.7)	65 (12.1)	66 (11.7)	66 (11.2)	66 (10.9)	67 (10.6)	67 (10.3)
60	3 (38)	30 (26.3)	38 (22.2)	42 (20.1)	44 (18.9)	47 (16.7)	50 (15)	52 (13.8)	53 (12.8)	54 (12.1)	55 (11.4)	55 (10.9)	56 (10.4)	56 (10)	57 (9.6)	57 (9.3)	57 (9)	57 (8.8)
50	2 (31.7)	25 (21.9)	31 (18.5)	35 (16.7)	36 (15.7)	40 (13.9)	42 (12.5)	43 (11.5)	44 (10.7)	45 (10)	46 (9.5)	46 (9.1)	47 (8.7)	47 (8.3)	47 (8)	47 (7.8)	48 (7.5)	48 (7.3)
40	2 (25.3)	20 (17.5)	25 (14.8)	28 (13.4)	29 (12.6)	32 (11.1)	33 (10)	34 (9.2)	35 (8.6)	36 (8)	36 (7.6)	37 (7.2)	37 (6.9)	37 (6.7)	38 (6.4)	38 (6.2)	38 (6)	38 (5.9)
30	1 (19)	15 (13.1)	19 (11.1)	21 (10)	22 (9.4)	24 (8.3)	25 (7.5)	26 (6.9)	26 (6.4)	27 (6)	27 (5.7)	28 (5.4)	28 (5.2)	28 (5)	28 (4.8)	28 (4.7)	29 (4.5)	29 (4.4)
25	1 (15.8)	12 (11)	16 (9.3)	17 (8.4)	18 (7.9)	20 (6.9)	21 (6.3)	22 (5.8)	22 (5.3)	22 (5)	23 (4.8)	23 (4.5)	23 (4.3)	23 (4.2)	24 (4)	24 (3.9)	24 (3.8)	24 (3.7)
20	1 (12.7)	10 (8.8)	13 (7.4)	14 (6.7)	15 (6.3)	16 (5.6)	17 (5)	17 (4.6)	18 (4.3)	18 (4)	18 (3.8)	18 (3.6)	19 (3.5)	19 (3.3)	19 (3.2)	19 (3.1)	19 (3)	19 (2.9)
15	1 (9.5)	7 (6.6)	9 (5.6)	10 (5)	11 (4.7)	12 (4.2)	12 (3.8)	13 (3.5)	13 (3.2)	13 (3)	14 (2.9)	14 (2.7)	14 (2.6)	14 (2.5)	14 (2.4)	14 (2.3)	14 (2.3)	14 (2.2)
10	0 (6.3)	5 (4.4)	6 (3.7)	7 (3.3)	7 (3.1)	8 (2.8)	8 (2.5)	9 (2.3)	9 (2.1)	9 (2)	9 (1.9)	9 (1.8)	9 (1.7)	9 (1.7)	9 (1.6)	9 (1.6)	10 (1.5)	10 (1.5)
5	0 (3.2)	2 (2.2)	3 (1.9)	3 (1.7)	4 (1.6)	4 (1.4)	4 (1.3)	4 (1.2)	4 (1.1)	4 (1)	5 (1)	5 (0.9)	5 (0.9)	5 (0.8)	5 (0.8)	5 (0.8)	5 (0.8)	5 (0.7)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-3.2)	-2 (-2.2)	-3 (-1.9)	-3 (-1.7)	-4 (-1.6)	-4 (-1.4)	-4 (-1.3)	-4 (-1.2)	-4 (-1.1)	-4 (-1)	-5 (-1)	-5 (-0.9)	-5 (-0.9)	-5 (-0.8)	-5 (-0.8)	-5 (-0.8)	-5 (-0.8)	-5 (-0.7)
-10	0 (-6.3)	-5 (-4.4)	-6 (-3.7)	-7 (-3.3)	-7 (-3.1)	-8 (-2.8)	-8 (-2.5)	-9 (-2.3)	-9 (-2.1)	-9 (-2)	-9 (-1.9)	-9 (-1.8)	-9 (-1.7)	-9 (-1.7)	-9 (-1.6)	-9 (-1.6)	-10 (-1.5)	-10 (-1.5)
-15	-1 (-9.5)	-7 (-6.6)	-9 (-5.6)	-10 (-5)	-11 (-4.7)	-12 (-4.2)	-12 (-3.8)	-13 (-3.5)	-13 (-3.2)	-13 (-3)	-14 (-2.9)	-14 (-2.7)	-14 (-2.6)	-14 (-2.5)	-14 (-2.4)	-14 (-2.3)	-14 (-2.3)	-14 (-2.2)
-20	-1 (-12.7)	-10 (-8.8)	-13 (-7.4)	-14 (-6.7)	-15 (-6.3)	-16 (-5.6)	-17 (-5)	-17 (-4.6)	-18 (-4.3)	-18 (-4)	-18 (-3.8)	-18 (-3.6)	-19 (-3.5)	-19 (-3.3)	-19 (-3.2)	-19 (-3.1)	-19 (-3)	-19 (-2.9)
-25	-1 (-15.8)	-12 (-11)	-16 (-9.3)	-17 (-8.4)	-18 (-7.9)	-20 (-6.9)	-21 (-6.3)	-22 (-5.8)	-22 (-5.3)	-22 (-5)	-23 (-4.8)	-23 (-4.5)	-23 (-4.3)	-23 (-4.2)	-24 (-4)	-24 (-3.9)	-24 (-3.8)	-24 (-3.7)
-30	-1 (-19)	-15 (-13.1)	-19 (-11.1)	-21 (-10)	-22 (-9.4)	-24 (-8.3)	-25 (-7.5)	-26 (-6.9)	-26 (-6.4)	-27 (-6)	-27 (-5.7)	-28 (-5.4)	-28 (-5.2)	-28 (-5)	-28 (-4.8)	-28 (-4.7)	-29 (-4.5)	-29 (-4.4)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.24 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 50 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	5 (78.7)	49 (52.7)	62 (44)	69 (39.4)	72 (37)	78 (32.4)	83 (29)	85 (26.5)	88 (24.5)	89 (22.9)	91 (21.6)	92 (20.5)	93 (19.6)	93 (18.8)	94 (18.1)	94 (17.4)	95 (16.9)	95 (16.4)
90	5 (70.9)	44 (47.4)	56 (39.6)	62 (35.5)	65 (33.3)	70 (29.1)	74 (26.1)	77 (23.9)	79 (22.1)	80 (20.6)	82 (19.5)	83 (18.5)	83 (17.6)	84 (16.9)	85 (16.3)	85 (15.7)	85 (15.2)	86 (14.7)
80	4 (63)	39 (42.1)	50 (35.2)	55 (31.5)	58 (29.6)	63 (25.9)	66 (23.2)	68 (21.2)	70 (19.6)	71 (18.4)	73 (17.3)	73 (16.4)	74 (15.7)	75 (15)	75 (14.5)	76 (14)	76 (13.5)	76 (13.1)
70	4 (55.1)	34 (36.9)	43 (30.8)	48 (27.6)	50 (25.9)	55 (22.6)	58 (20.3)	60 (18.6)	61 (17.2)	63 (16.1)	63 (15.1)	64 (14.4)	65 (13.7)	65 (13.1)	66 (12.6)	66 (12.2)	66 (11.8)	67 (11.5)
60	3 (47.2)	29 (31.6)	37 (26.4)	41 (23.7)	43 (22.2)	47 (19.4)	50 (17.4)	51 (15.9)	53 (14.7)	54 (13.8)	54 (13)	55 (12.3)	56 (11.8)	56 (11.3)	56 (10.8)	57 (10.5)	57 (10.1)	57 (9.8)
50	3 (39.4)	24 (26.3)	31 (22)	34 (19.7)	36 (18.5)	39 (16.2)	41 (14.5)	43 (13.3)	44 (12.3)	45 (11.5)	45 (10.8)	46 (10.3)	46 (9.8)	47 (9.4)	47 (9)	47 (8.7)	47 (8.4)	48 (8.2)
40	2 (31.5)	20 (21.1)	25 (17.6)	27 (15.8)	29 (14.8)	31 (12.9)	33 (11.6)	34 (10.6)	35 (9.8)	36 (9.2)	36 (8.7)	37 (8.2)	37 (7.8)	37 (7.5)	38 (7.2)	38 (7)	38 (6.8)	38 (6.6)
30	2 (23.6)	15 (15.8)	19 (13.2)	21 (11.8)	22 (11.1)	23 (9.7)	25 (8.7)	26 (8)	26 (7.4)	27 (6.9)	27 (6.5)	28 (6.2)	28 (5.9)	28 (5.6)	28 (5.4)	28 (5.2)	28 (5.1)	29 (4.9)
25	1 (19.7)	12 (13.2)	16 (11)	17 (9.9)	18 (9.3)	20 (8.1)	21 (7.3)	21 (6.6)	22 (6.1)	22 (5.7)	23 (5.4)	23 (5.1)	23 (4.9)	23 (4.7)	23 (4.5)	24 (4.4)	24 (4.2)	24 (4.1)
20	1 (15.7)	10 (10.5)	12 (8.8)	14 (7.9)	14 (7.4)	16 (6.5)	17 (5.8)	17 (5.3)	18 (4.9)	18 (4.6)	18 (4.3)	18 (4.1)	19 (3.9)	19 (3.8)	19 (3.6)	19 (3.5)	19 (3.4)	19 (3.3)
15	1 (11.8)	7 (7.9)	9 (6.6)	10 (5.9)	11 (5.6)	12 (4.9)	12 (4.4)	13 (4)	13 (3.7)	13 (3.4)	14 (3.2)	14 (3.1)	14 (2.9)	14 (2.8)	14 (2.7)	14 (2.6)	14 (2.5)	14 (2.5)
10	1 (7.9)	5 (5.3)	6 (4.4)	7 (3.9)	7 (3.7)	8 (3.2)	8 (2.9)	9 (2.7)	9 (2.5)	9 (2.3)	9 (2.2)	9 (2.1)	9 (2)	9 (1.9)	9 (1.8)	9 (1.7)	9 (1.7)	10 (1.6)
5	0 (3.9)	2 (2.6)	3 (2.2)	3 (2)	4 (1.9)	4 (1.6)	4 (1.5)	4 (1.3)	4 (1.2)	4 (1.1)	5 (1.1)	5 (1)	5 (1)	5 (0.9)	5 (0.9)	5 (0.9)	5 (0.8)	5 (0.8)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-3.9)	-2 (-2.6)	-3 (-2.2)	-3 (-2)	-4 (-1.9)	-4 (-1.6)	-4 (-1.5)	-4 (-1.3)	-4 (-1.2)	-4 (-1.1)	-5 (-1.1)	-5 (-1)	-5 (-1)	-5 (-0.9)	-5 (-0.9)	-5 (-0.9)	-5 (-0.8)	-5 (-0.8)
-10	-1 (-7.9)	-5 (-5.3)	-6 (-4.4)	-7 (-3.9)	-7 (-3.7)	-8 (-3.2)	-8 (-2.9)	-9 (-2.7)	-9 (-2.5)	-9 (-2.3)	-9 (-2.2)	-9 (-2.1)	-9 (-2)	-9 (-1.9)	-9 (-1.8)	-9 (-1.7)	-9 (-1.7)	-10 (-1.6)
-15	-1 (-11.8)	-7 (-7.9)	-9 (-6.6)	-10 (-5.9)	-11 (-5.6)	-12 (-4.9)	-12 (-4.4)	-13 (-4)	-13 (-3.7)	-13 (-3.4)	-14 (-3.2)	-14 (-3.1)	-14 (-2.9)	-14 (-2.8)	-14 (-2.7)	-14 (-2.6)	-14 (-2.5)	-14 (-2.5)
-20	-1 (-15.7)	-10 (-10.5)	-12 (-8.8)	-14 (-7.9)	-14 (-7.4)	-16 (-6.5)	-17 (-5.8)	-17 (-5.3)	-18 (-4.9)	-18 (-4.6)	-18 (-4.3)	-18 (-4.1)	-19 (-3.9)	-19 (-3.8)	-19 (-3.6)	-19 (-3.5)	-19 (-3.4)	-19 (-3.3)
-25	-1 (-19.7)	-12 (-13.2)	-16 (-11)	-17 (-9.9)	-18 (-9.3)	-20 (-8.1)	-21 (-7.3)	-21 (-6.6)	-22 (-6.1)	-22 (-5.7)	-23 (-5.4)	-23 (-5.1)	-23 (-4.9)	-23 (-4.7)	-23 (-4.5)	-24 (-4.4)	-24 (-4.2)	-24 (-4.1)
-30	-2 (-23.6)	-15 (-15.8)	-19 (-13.2)	-21 (-11.8)	-22 (-11.1)	-23 (-9.7)	-25 (-8.7)	-26 (-8)	-26 (-7.4)	-27 (-6.9)	-27 (-6.5)	-28 (-6.2)	-28 (-5.9)	-28 (-5.6)	-28 (-5.4)	-28 (-5.2)	-28 (-5.1)	-29 (-4.9)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.25 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 63 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	6 (98.6)	48 (64.1)	62 (52.9)	68 (47.2)	71 (44.1)	78 (38.3)	82 (34.1)	85 (31)	87 (28.5)	89 (26.6)	90 (24.9)	91 (23.6)	92 (22.4)	93 (21.5)	94 (20.6)	94 (19.8)	95 (19.1)	95 (18.5)
90	5 (88.8)	44 (57.7)	55 (47.7)	61 (42.5)	64 (39.7)	70 (34.4)	74 (30.7)	76 (27.9)	78 (25.7)	80 (23.9)	81 (22.5)	82 (21.2)	83 (20.2)	84 (19.3)	84 (18.5)	85 (17.8)	85 (17.2)	85 (16.7)
80	5 (78.9)	39 (51.3)	49 (42.4)	54 (37.7)	57 (35.3)	62 (30.6)	65 (27.3)	68 (24.8)	70 (22.8)	71 (21.2)	72 (20)	73 (18.9)	74 (18)	74 (17.2)	75 (16.5)	75 (15.9)	76 (15.3)	76 (14.8)
70	4 (69)	34 (44.9)	43 (37.1)	48 (33)	50 (30.9)	54 (26.8)	57 (23.9)	59 (21.7)	61 (20)	62 (18.6)	63 (17.5)	64 (16.5)	65 (15.7)	65 (15)	65 (14.4)	66 (13.9)	66 (13.4)	66 (13)
60	3 (59.2)	29 (38.5)	37 (31.8)	41 (28.3)	43 (26.5)	47 (23)	49 (20.5)	51 (18.6)	52 (17.1)	53 (15.9)	54 (15)	55 (14.2)	55 (13.5)	56 (12.9)	56 (12.4)	56 (11.9)	57 (11.5)	57 (11.1)
50	3 (49.3)	24 (32.1)	31 (26.5)	34 (23.6)	36 (22.1)	39 (19.1)	41 (17)	42 (15.5)	44 (14.3)	44 (13.3)	45 (12.5)	46 (11.8)	46 (11.2)	46 (10.7)	47 (10.3)	47 (9.9)	47 (9.6)	47 (9.3)
40	2 (39.4)	19 (25.6)	25 (21.2)	27 (18.9)	29 (17.6)	31 (15.3)	33 (13.6)	34 (12.4)	35 (11.4)	36 (10.6)	36 (10)	37 (9.4)	37 (9)	37 (8.6)	37 (8.2)	38 (7.9)	38 (7.7)	38 (7.4)
30	2 (29.6)	15 (19.2)	18 (15.9)	20 (14.2)	21 (13.2)	23 (11.5)	25 (10.2)	25 (9.3)	26 (8.6)	27 (8)	27 (7.5)	27 (7.1)	28 (6.7)	28 (6.4)	28 (6.2)	28 (5.9)	28 (5.7)	28 (5.6)
25	1 (24.7)	12 (16)	15 (13.2)	17 (11.8)	18 (11)	19 (9.6)	20 (8.5)	21 (7.7)	22 (7.1)	22 (6.6)	23 (6.2)	23 (5.9)	23 (5.6)	23 (5.4)	23 (5.1)	24 (5)	24 (4.8)	24 (4.6)
20	1 (19.7)	10 (12.8)	12 (10.6)	14 (9.4)	14 (8.8)	16 (7.7)	16 (6.8)	17 (6.2)	17 (5.7)	18 (5.3)	18 (5)	18 (4.7)	18 (4.5)	19 (4.3)	19 (4.1)	19 (4)	19 (3.8)	19 (3.7)
15	1 (14.8)	7 (9.6)	9 (7.9)	10 (7.1)	11 (6.6)	12 (5.7)	12 (5.1)	13 (4.6)	13 (4.3)	13 (4)	14 (3.7)	14 (3.5)	14 (3.4)	14 (3.2)	14 (3.1)	14 (3)	14 (2.9)	14 (2.8)
10	1 (9.9)	5 (6.4)	6 (5.3)	7 (4.7)	7 (4.4)	8 (3.8)	8 (3.4)	8 (3.1)	9 (2.9)	9 (2.7)	9 (2.5)	9 (2.4)	9 (2.2)	9 (2.1)	9 (2.1)	9 (2)	9 (1.9)	9 (1.9)
5	0 (4.9)	2 (3.2)	3 (2.6)	3 (2.4)	4 (2.2)	4 (1.9)	4 (1.7)	4 (1.5)	4 (1.4)	4 (1.3)	5 (1.2)	5 (1.2)	5 (1.1)	5 (1.1)	5 (1)	5 (1)	5 (1)	5 (0.9)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-4.9)	-2 (-3.2)	-3 (-2.6)	-3 (-2.4)	-4 (-2.2)	-4 (-1.9)	-4 (-1.7)	-4 (-1.5)	-4 (-1.4)	-4 (-1.3)	-5 (-1.2)	-5 (-1.2)	-5 (-1.1)	-5 (-1.1)	-5 (-1)	-5 (-1)	-5 (-1)	-5 (-0.9)
-10	-1 (-9.9)	-5 (-6.4)	-6 (-5.3)	-7 (-4.7)	-7 (-4.4)	-8 (-3.8)	-8 (-3.4)	-8 (-3.1)	-9 (-2.9)	-9 (-2.7)	-9 (-2.5)	-9 (-2.4)	-9 (-2.2)	-9 (-2.1)	-9 (-2.1)	-9 (-2)	-9 (-1.9)	-9 (-1.9)
-15	-1 (-14.8)	-7 (-9.6)	-9 (-7.9)	-10 (-7.1)	-11 (-6.6)	-12 (-5.7)	-12 (-5.1)	-13 (-4.6)	-13 (-4.3)	-13 (-4)	-14 (-3.7)	-14 (-3.5)	-14 (-3.4)	-14 (-3.2)	-14 (-3.1)	-14 (-3)	-14 (-2.9)	-14 (-2.8)
-20	-1 (-19.7)	-10 (-12.8)	-12 (-10.6)	-14 (-9.4)	-14 (-8.8)	-16 (-7.7)	-16 (-6.8)	-17 (-6.2)	-17 (-5.7)	-18 (-5.3)	-18 (-5)	-18 (-4.7)	-18 (-4.5)	-19 (-4.3)	-19 (-4.1)	-19 (-4)	-19 (-3.8)	-19 (-3.7)
-25	-1 (-24.7)	-12 (-16)	-15 (-13.2)	-17 (-11.8)	-18 (-11)	-19 (-9.6)	-20 (-8.5)	-21 (-7.7)	-22 (-7.1)	-22 (-6.6)	-23 (-6.2)	-23 (-5.9)	-23 (-5.6)	-23 (-5.4)	-23 (-5.1)	-24 (-5)	-24 (-4.8)	-24 (-4.6)
-30	-2 (-29.6)	-15 (-19.2)	-18 (-15.9)	-20 (-14.2)	-21 (-13.2)	-23 (-11.5)	-25 (-10.2)	-25 (-9.3)	-26 (-8.6)	-27 (-8)	-27 (-7.5)	-27 (-7.1)	-28 (-6.7)	-28 (-6.4)	-28 (-6.2)	-28 (-5.9)	-28 (-5.7)	-28 (-5.6)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.26 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 75 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	6 (116.7)	48 (74.6)	61 (61.2)	68 (54.3)	71 (50.6)	77 (43.7)	81 (38.7)	84 (35)	87 (32.1)	88 (29.8)	90 (27.9)	91 (26.4)	92 (25)	93 (23.9)	93 (22.8)	94 (22)	94 (21.2)	95 (20.5)
90	6 (105)	43 (67.1)	55 (55)	61 (48.8)	64 (45.5)	69 (39.3)	73 (34.8)	76 (31.5)	78 (28.9)	80 (26.8)	81 (25.1)	82 (23.7)	83 (22.5)	83 (21.5)	84 (20.6)	84 (19.8)	85 (19)	85 (18.4)
80	5 (93.4)	39 (59.7)	49 (48.9)	54 (43.4)	57 (40.5)	62 (34.9)	65 (31)	67 (28)	69 (25.7)	71 (23.9)	72 (22.4)	73 (21.1)	73 (20)	74 (19.1)	75 (18.3)	75 (17.6)	75 (16.9)	76 (16.4)
70	4 (81.7)	34 (52.2)	43 (42.8)	47 (38)	50 (35.4)	54 (30.6)	57 (27.1)	59 (24.5)	61 (22.5)	62 (20.9)	63 (19.6)	64 (18.4)	64 (17.5)	65 (16.7)	65 (16)	66 (15.4)	66 (14.8)	66 (14.3)
60	4 (70)	29 (44.7)	37 (36.7)	41 (32.6)	43 (30.4)	46 (26.2)	49 (23.2)	51 (21)	52 (19.3)	53 (17.9)	54 (16.8)	55 (15.8)	55 (15)	56 (14.3)	56 (13.7)	56 (13.2)	57 (12.7)	57 (12.3)
50	3 (58.4)	24 (37.3)	31 (30.6)	34 (27.1)	35 (25.3)	39 (21.8)	41 (19.4)	42 (17.5)	43 (16.1)	44 (14.9)	45 (14)	45 (13.2)	46 (12.5)	46 (11.9)	47 (11.4)	47 (11)	47 (10.6)	47 (10.2)
40	2 (46.7)	19 (29.8)	24 (24.5)	27 (21.7)	28 (20.2)	31 (17.5)	33 (15.5)	34 (14)	35 (12.9)	35 (11.9)	36 (11.2)	36 (10.5)	37 (10)	37 (9.5)	37 (9.1)	38 (8.8)	38 (8.5)	38 (8.2)
30	2 (35)	14 (22.4)	18 (18.3)	20 (16.3)	21 (15.2)	23 (13.1)	24 (11.6)	25 (10.5)	26 (9.6)	27 (8.9)	27 (8.4)	27 (7.9)	28 (7.5)	28 (7.2)	28 (6.9)	28 (6.6)	28 (6.3)	28 (6.1)
25	2 (29.2)	12 (18.6)	15 (15.3)	17 (13.6)	18 (12.7)	19 (10.9)	20 (9.7)	21 (8.8)	22 (8)	22 (7.5)	22 (7)	23 (6.6)	23 (6.3)	23 (6)	23 (5.7)	23 (5.5)	24 (5.3)	24 (5.1)
20	1 (23.3)	10 (14.9)	12 (12.2)	14 (10.9)	14 (10.1)	15 (8.7)	16 (7.7)	17 (7)	17 (6.4)	18 (6)	18 (5.6)	18 (5.3)	18 (5)	19 (4.8)	19 (4.6)	19 (4.4)	19 (4.2)	19 (4.1)
15	1 (17.5)	7 (11.2)	9 (9.2)	10 (8.1)	11 (7.6)	12 (6.5)	12 (5.8)	13 (5.3)	13 (4.8)	13 (4.5)	13 (4.2)	14 (4)	14 (3.8)	14 (3.6)	14 (3.4)	14 (3.3)	14 (3.2)	14 (3.1)
10	1 (11.7)	5 (7.5)	6 (6.1)	7 (5.4)	7 (5.1)	8 (4.4)	8 (3.9)	8 (3.5)	9 (3.2)	9 (3)	9 (2.8)	9 (2.6)	9 (2.5)	9 (2.4)	9 (2.3)	9 (2.2)	9 (2.1)	9 (2)
5	0 (5.8)	2 (3.7)	3 (3.1)	3 (2.7)	4 (2.5)	4 (2.2)	4 (1.9)	4 (1.8)	4 (1.6)	4 (1.5)	4 (1.4)	5 (1.3)	5 (1.3)	5 (1.2)	5 (1.1)	5 (1.1)	5 (1.1)	5 (1)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-5.8)	-2 (-3.7)	-3 (-3.1)	-3 (-2.7)	-4 (-2.5)	-4 (-2.2)	-4 (-1.9)	-4 (-1.8)	-4 (-1.6)	-4 (-1.5)	-4 (-1.4)	-5 (-1.3)	-5 (-1.3)	-5 (-1.2)	-5 (-1.1)	-5 (-1.1)	-5 (-1.1)	-5 (-1)
-10	-1 (-11.7)	-5 (-7.5)	-6 (-6.1)	-7 (-5.4)	-7 (-5.1)	-8 (-4.4)	-8 (-3.9)	-8 (-3.5)	-9 (-3.2)	-9 (-3)	-9 (-2.8)	-9 (-2.6)	-9 (-2.5)	-9 (-2.4)	-9 (-2.3)	-9 (-2.2)	-9 (-2.1)	-9 (-2)
-15	-1 (-17.5)	-7 (-11.2)	-9 (-9.2)	-10 (-8.1)	-11 (-7.6)	-12 (-6.5)	-12 (-5.8)	-13 (-5.3)	-13 (-4.8)	-13 (-4.5)	-13 (-4.2)	-14 (-4)	-14 (-3.8)	-14 (-3.6)	-14 (-3.4)	-14 (-3.3)	-14 (-3.2)	-14 (-3.1)
-20	-1 (-23.3)	-10 (-14.9)	-12 (-12.2)	-14 (-10.9)	-14 (-10.1)	-15 (-8.7)	-16 (-7.7)	-17 (-7)	-17 (-6.4)	-18 (-6)	-18 (-5.6)	-18 (-5.3)	-18 (-5)	-19 (-4.8)	-19 (-4.6)	-19 (-4.4)	-19 (-4.2)	-19 (-4.1)
-25	-2 (-29.2)	-12 (-18.6)	-15 (-15.3)	-17 (-13.6)	-18 (-12.7)	-19 (-10.9)	-20 (-9.7)	-21 (-8.8)	-22 (-8)	-22 (-7.5)	-22 (-7)	-23 (-6.6)	-23 (-6.3)	-23 (-6)	-23 (-5.7)	-23 (-5.5)	-24 (-5.3)	-24 (-5.1)
-30	-2 (-35)	-14 (-22.4)	-18 (-18.3)	-20 (-16.3)	-21 (-15.2)	-23 (-13.1)	-24 (-11.6)	-25 (-10.5)	-26 (-9.6)	-27 (-8.9)	-27 (-8.4)	-27 (-7.9)	-28 (-7.5)	-28 (-7.2)	-28 (-6.9)	-28 (-6.6)	-28 (-6.3)	-28 (-6.1)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.27 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 90 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	9 (136.5)	49 (86.6)	61 (70.7)	68 (62.5)	71 (58.2)	77 (50)	81 (44.2)	84 (39.8)	86 (36.4)	88 (33.7)	89 (31.5)	91 (29.6)	92 (28)	92 (26.7)	93 (25.5)	94 (24.5)	94 (23.6)	95 (22.7)
90	8 (122.9)	44 (77.9)	55 (63.6)	61 (56.3)	64 (52.4)	69 (45)	73 (39.7)	76 (35.8)	78 (32.8)	79 (30.3)	81 (28.3)	82 (26.7)	82 (25.2)	83 (24)	84 (23)	84 (22)	85 (21.2)	85 (20.5)
80	7 (109.2)	39 (69.2)	49 (56.5)	54 (50)	57 (46.6)	61 (40)	65 (35.3)	67 (31.8)	69 (29.1)	70 (27)	72 (25.2)	72 (23.7)	73 (22.4)	74 (21.4)	74 (20.4)	75 (19.6)	75 (18.8)	76 (18.2)
70	6 (95.6)	34 (60.6)	43 (49.5)	47 (43.8)	50 (40.7)	54 (35)	57 (30.9)	59 (27.9)	60 (25.5)	62 (23.6)	63 (22)	63 (20.7)	64 (19.6)	65 (18.7)	65 (17.9)	66 (17.1)	66 (16.5)	66 (15.9)
60	5 (81.9)	29 (51.9)	37 (42.4)	41 (37.5)	42 (34.9)	46 (30)	49 (26.5)	50 (23.9)	52 (21.9)	53 (20.2)	54 (18.9)	54 (17.8)	55 (16.8)	55 (16)	56 (15.3)	56 (14.7)	56 (14.1)	57 (13.6)
50	4 (68.3)	24 (43.3)	31 (35.3)	34 (31.3)	35 (29.1)	38 (25)	40 (22.1)	42 (19.9)	43 (18.2)	44 (16.9)	45 (15.7)	45 (14.8)	46 (14)	46 (13.3)	47 (12.8)	47 (12.2)	47 (11.8)	47 (11.4)
40	3 (54.6)	20 (34.6)	25 (28.3)	27 (25)	28 (23.3)	31 (20)	32 (17.7)	34 (15.9)	35 (14.6)	35 (13.5)	36 (12.6)	36 (11.9)	37 (11.2)	37 (10.7)	37 (10.2)	37 (9.8)	38 (9.4)	38 (9.1)
30	3 (41)	15 (26)	18 (21.2)	20 (18.8)	21 (17.5)	23 (15)	24 (13.2)	25 (11.9)	26 (10.9)	26 (10.1)	27 (9.4)	27 (8.9)	27 (8.4)	28 (8)	28 (7.7)	28 (7.3)	28 (7.1)	28 (6.8)
25	2 (34.1)	12 (21.6)	15 (17.7)	17 (15.6)	18 (14.5)	19 (12.5)	20 (11)	21 (10)	22 (9.1)	22 (8.4)	22 (7.9)	23 (7.4)	23 (7)	23 (6.7)	23 (6.4)	23 (6.1)	24 (5.9)	24 (5.7)
20	2 (27.3)	10 (17.3)	12 (14.1)	14 (12.5)	14 (11.6)	15 (10)	16 (8.8)	17 (8)	17 (7.3)	18 (6.7)	18 (6.3)	18 (5.9)	18 (5.6)	18 (5.3)	19 (5.1)	19 (4.9)	19 (4.7)	19 (4.5)
15	1 (20.5)	7 (13)	9 (10.6)	10 (9.4)	11 (8.7)	12 (7.5)	12 (6.6)	13 (6)	13 (5.5)	13 (5.1)	13 (4.7)	14 (4.4)	14 (4.2)	14 (4)	14 (3.8)	14 (3.7)	14 (3.5)	14 (3.4)
10	1 (13.7)	5 (8.7)	6 (7.1)	7 (6.3)	7 (5.8)	8 (5)	8 (4.4)	8 (4)	9 (3.6)	9 (3.4)	9 (3.1)	9 (3)	9 (2.8)	9 (2.7)	9 (2.6)	9 (2.4)	9 (2.4)	9 (2.3)
5	0 (6.8)	2 (4.3)	3 (3.5)	3 (3.1)	4 (2.9)	4 (2.5)	4 (2.2)	4 (2)	4 (1.8)	4 (1.7)	4 (1.6)	5 (1.5)	5 (1.4)	5 (1.3)	5 (1.3)	5 (1.2)	5 (1.2)	5 (1.1)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-6.8)	-2 (-4.3)	-3 (-3.5)	-3 (-3.1)	-4 (-2.9)	-4 (-2.5)	-4 (-2.2)	-4 (-2)	-4 (-1.8)	-4 (-1.7)	-4 (-1.6)	-5 (-1.5)	-5 (-1.4)	-5 (-1.3)	-5 (-1.3)	-5 (-1.2)	-5 (-1.2)	-5 (-1.1)
-10	-1 (-13.7)	-5 (-8.7)	-6 (-7.1)	-7 (-6.3)	-7 (-5.8)	-8 (-5)	-8 (-4.4)	-8 (-4)	-9 (-3.6)	-9 (-3.4)	-9 (-3.1)	-9 (-3)	-9 (-2.8)	-9 (-2.7)	-9 (-2.6)	-9 (-2.4)	-9 (-2.4)	-9 (-2.3)
-15	-1 (-20.5)	-7 (-13)	-9 (-10.6)	-10 (-9.4)	-11 (-8.7)	-12 (-7.5)	-12 (-6.6)	-13 (-6)	-13 (-5.5)	-13 (-5.1)	-13 (-4.7)	-14 (-4.4)	-14 (-4.2)	-14 (-4)	-14 (-3.8)	-14 (-3.7)	-14 (-3.5)	-14 (-3.4)
-20	-2 (-27.3)	-10 (-17.3)	-12 (-14.1)	-14 (-12.5)	-14 (-11.6)	-15 (-10)	-16 (-8.8)	-17 (-8)	-17 (-7.3)	-18 (-6.7)	-18 (-6.3)	-18 (-5.9)	-18 (-5.6)	-18 (-5.3)	-19 (-5.1)	-19 (-4.9)	-19 (-4.7)	-19 (-4.5)
-25	-2 (-34.1)	-12 (-21.6)	-15 (-17.7)	-17 (-15.6)	-18 (-14.5)	-19 (-12.5)	-20 (-11)	-21 (-10)	-22 (-9.1)	-22 (-8.4)	-22 (-7.9)	-23 (-7.4)	-23 (-7)	-23 (-6.7)	-23 (-6.4)	-23 (-6.1)	-24 (-5.9)	-24 (-5.7)
-30	-3 (-41)	-15 (-26)	-18 (-21.2)	-20 (-18.8)	-21 (-17.5)	-23 (-15)	-24 (-13.2)	-25 (-11.9)	-26 (-10.9)	-26 (-10.1)	-27 (-9.4)	-27 (-8.9)	-27 (-8.4)	-28 (-8)	-28 (-7.7)	-28 (-7.3)	-28 (-7.1)	-28 (-6.8)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.28 Energy losses in pipes without and with insulation - Pexal®/Mixal® - Diameter 110 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	12 (160.7)	50 (101.7)	62 (82.8)	68 (73.1)	71 (67.9)	77 (58.2)	81 (51.2)	84 (46)	86 (42)	88 (38.7)	89 (36.1)	90 (33.9)	91 (32)	92 (30.4)	93 (29)	93 (27.7)	94 (26.6)	94 (25.7)
90	11 (144.6)	45 (91.5)	55 (74.5)	61 (65.8)	64 (61.2)	69 (52.3)	73 (46.1)	75 (41.4)	77 (37.8)	79 (34.8)	80 (32.5)	81 (30.5)	82 (28.8)	83 (27.3)	83 (26.1)	84 (25)	84 (24)	85 (23.1)
80	10 (128.5)	40 (81.3)	49 (66.2)	54 (58.5)	57 (54.4)	61 (46.5)	65 (41)	67 (36.8)	69 (33.6)	70 (31)	71 (28.9)	72 (27.1)	73 (25.6)	74 (24.3)	74 (23.2)	75 (22.2)	75 (21.3)	75 (20.5)
70	8 (112.5)	35 (71.2)	43 (58)	47 (51.2)	50 (47.6)	54 (40.7)	56 (35.8)	59 (32.2)	60 (29.4)	61 (27.1)	62 (25.2)	63 (23.7)	64 (22.4)	64 (21.3)	65 (20.3)	65 (19.4)	66 (18.6)	66 (18)
60	7 (96.4)	30 (61)	37 (49.7)	41 (43.9)	42 (40.8)	46 (34.9)	48 (30.7)	50 (27.6)	52 (25.2)	53 (23.2)	53 (21.6)	54 (20.3)	55 (19.2)	55 (18.2)	56 (17.4)	56 (16.6)	56 (16)	57 (15.4)
50	6 (80.3)	25 (50.8)	31 (41.4)	34 (36.5)	35 (34)	38 (29.1)	40 (25.6)	42 (23)	43 (21)	44 (19.4)	45 (18)	45 (16.9)	46 (16)	46 (15.2)	46 (14.5)	47 (13.9)	47 (13.3)	47 (12.8)
40	5 (64.3)	20 (40.7)	25 (33.1)	27 (29.2)	28 (27.2)	31 (23.3)	32 (20.5)	33 (18.4)	34 (16.8)	35 (15.5)	36 (14.4)	36 (13.5)	36 (12.8)	37 (12.1)	37 (11.6)	37 (11.1)	38 (10.7)	38 (10.3)
30	4 (48.2)	15 (30.5)	18 (24.8)	20 (21.9)	21 (20.4)	23 (17.4)	24 (15.4)	25 (13.8)	26 (12.6)	26 (11.6)	27 (10.8)	27 (10.2)	27 (9.6)	28 (9.1)	28 (8.7)	28 (8.3)	28 (8)	28 (7.7)
25	3 (40.2)	12 (25.4)	15 (20.7)	17 (18.3)	18 (17)	19 (14.5)	20 (12.8)	21 (11.5)	21 (10.5)	22 (9.7)	22 (9)	23 (8.5)	23 (8)	23 (7.6)	23 (7.2)	23 (6.9)	23 (6.7)	24 (6.4)
20	2 (32.1)	10 (20.3)	12 (16.6)	14 (14.6)	14 (13.6)	15 (11.6)	16 (10.2)	17 (9.2)	17 (8.4)	18 (7.7)	18 (7.2)	18 (6.8)	18 (6.4)	18 (6.1)	19 (5.8)	19 (5.5)	19 (5.3)	19 (5.1)
15	2 (24.1)	7 (15.3)	9 (12.4)	10 (11)	11 (10.2)	11 (8.7)	12 (7.7)	13 (6.9)	13 (6.3)	13 (5.8)	13 (5.4)	14 (5.1)	14 (4.8)	14 (4.6)	14 (4.3)	14 (4.2)	14 (4)	14 (3.8)
10	1 (16.1)	5 (10.2)	6 (8.3)	7 (7.3)	7 (6.8)	8 (5.8)	8 (5.1)	8 (4.6)	9 (4.2)	9 (3.9)	9 (3.6)	9 (3.4)	9 (3.2)	9 (3)	9 (2.9)	9 (2.8)	9 (2.7)	9 (2.6)
5	1 (8)	2 (5.1)	3 (4.1)	3 (3.7)	4 (3.4)	4 (2.9)	4 (2.6)	4 (2.3)	4 (2.1)	4 (1.9)	4 (1.8)	5 (1.7)	5 (1.6)	5 (1.5)	5 (1.4)	5 (1.4)	5 (1.3)	5 (1.3)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	-1 (-8)	-2 (-5.1)	-3 (-4.1)	-3 (-3.7)	-4 (-3.4)	-4 (-2.9)	-4 (-2.6)	-4 (-2.3)	-4 (-2.1)	-4 (-1.9)	-4 (-1.8)	-5 (-1.7)	-5 (-1.6)	-5 (-1.5)	-5 (-1.4)	-5 (-1.4)	-5 (-1.3)	-5 (-1.3)
-10	-1 (-16.1)	-5 (-10.2)	-6 (-8.3)	-7 (-7.3)	-7 (-6.8)	-8 (-5.8)	-8 (-5.1)	-8 (-4.6)	-9 (-4.2)	-9 (-3.9)	-9 (-3.6)	-9 (-3.4)	-9 (-3.2)	-9 (-3)	-9 (-2.9)	-9 (-2.8)	-9 (-2.7)	-9 (-2.6)
-15	-2 (-24.1)	-7 (-15.3)	-9 (-12.4)	-10 (-11)	-11 (-10.2)	-11 (-8.7)	-12 (-7.7)	-13 (-6.9)	-13 (-6.3)	-13 (-5.8)	-13 (-5.4)	-14 (-5.1)	-14 (-4.8)	-14 (-4.6)	-14 (-4.3)	-14 (-4.2)	-14 (-4)	-14 (-3.8)
-20	-2 (-32.1)	-10 (-20.3)	-12 (-16.6)	-14 (-14.6)	-14 (-13.6)	-15 (-11.6)	-16 (-10.2)	-17 (-9.2)	-17 (-8.4)	-18 (-7.7)	-18 (-7.2)	-18 (-6.8)	-18 (-6.4)	-18 (-6.1)	-19 (-5.8)	-19 (-5.5)	-19 (-5.3)	-19 (-5.1)
-25	-3 (-40.2)	-12 (-25.4)	-15 (-20.7)	-17 (-18.3)	-18 (-17)	-19 (-14.5)	-20 (-12.8)	-21 (-11.5)	-21 (-10.5)	-22 (-9.7)	-22 (-9)	-23 (-8.5)	-23 (-8)	-23 (-7.6)	-23 (-7.2)	-23 (-6.9)	-23 (-6.7)	-24 (-6.4)
-30	-4 (-48.2)	-15 (-30.5)	-18 (-24.8)	-20 (-21.9)	-21 (-20.4)	-23 (-17.4)	-24 (-15.4)	-25 (-13.8)	-26 (-12.6)	-26 (-11.6)	-27 (-10.8)	-27 (-10.2)	-27 (-9.6)	-28 (-9.1)	-28 (-8.7)	-28 (-8.3)	-28 (-8)	-28 (-7.7)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.29 Energy losses in pipes without and with insulation - Thermoline® - Diameter 12 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i – T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (19.3)	54 (18.3)	69 (16.7)	75 (15.7)	78 (15.1)	84 (13.9)	87 (12.9)	90 (12.2)	91 (11.6)	93 (11.1)	94 (10.7)	94 (10.3)	95 (10)	96 (9.8)	96 (9.5)	96 (9.3)	97 (9.1)	97 (8.9)
90	3 (17.3)	49 (16.5)	62 (15)	68 (14.1)	71 (13.6)	76 (12.5)	79 (11.6)	81 (11)	82 (10.5)	83 (10)	84 (9.6)	85 (9.3)	86 (9)	86 (8.8)	86 (8.6)	87 (8.4)	87 (8.2)	87 (8)
80	3 (15.4)	43 (14.7)	55 (13.4)	60 (12.5)	63 (12.1)	67 (11.1)	70 (10.4)	72 (9.8)	73 (9.3)	74 (8.9)	75 (8.6)	76 (8.3)	76 (8)	76 (7.8)	77 (7.6)	77 (7.4)	77 (7.3)	77 (7.1)
70	2 (13.5)	38 (12.8)	48 (11.7)	53 (11)	55 (10.6)	59 (9.7)	61 (9.1)	63 (8.5)	64 (8.1)	65 (7.8)	66 (7.5)	66 (7.2)	67 (7)	67 (6.8)	67 (6.7)	67 (6.5)	68 (6.4)	68 (6.3)
60	2 (11.6)	32 (11)	41 (10)	45 (9.4)	47 (9.1)	50 (8.3)	52 (7.8)	54 (7.3)	55 (7)	56 (6.7)	56 (6.4)	57 (6.2)	57 (6)	57 (5.9)	58 (5.7)	58 (5.6)	58 (5.5)	58 (5.4)
50	2 (9.6)	27 (9.2)	34 (8.4)	38 (7.8)	39 (7.5)	42 (6.9)	44 (6.5)	45 (6.1)	46 (5.8)	46 (5.6)	47 (5.4)	47 (5.2)	48 (5)	48 (4.9)	48 (4.8)	48 (4.7)	48 (4.6)	48 (4.5)
40	1 (7.7)	22 (7.3)	27 (6.7)	30 (6.3)	31 (6)	34 (5.5)	35 (5.2)	36 (4.9)	37 (4.6)	37 (4.4)	37 (4.3)	38 (4.1)	38 (4)	38 (3.9)	38 (3.8)	39 (3.7)	39 (3.6)	39 (3.6)
30	1 (5.8)	16 (5.5)	21 (5)	23 (4.7)	24 (4.5)	25 (4.2)	26 (3.9)	27 (3.7)	27 (3.5)	28 (3.3)	28 (3.2)	28 (3.1)	29 (3)	29 (2.9)	29 (2.9)	29 (2.8)	29 (2.7)	29 (2.7)
25	1 (4.8)	13 (4.6)	17 (4.2)	19 (3.9)	20 (3.8)	21 (3.5)	22 (3.2)	22 (3.1)	23 (2.9)	23 (2.8)	23 (2.7)	24 (2.6)	24 (2.5)	24 (2.4)	24 (2.4)	24 (2.3)	24 (2.3)	24 (2.2)
20	1 (3.9)	11 (3.7)	14 (3.3)	15 (3.1)	16 (3)	17 (2.8)	17 (2.6)	18 (2.4)	18 (2.3)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)	19 (2)	19 (1.9)	19 (1.9)	19 (1.8)	19 (1.8)
15	0 (2.9)	8 (2.7)	10 (2.5)	11 (2.4)	12 (2.3)	13 (2.1)	13 (1.9)	13 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.5)	14 (1.5)	14 (1.4)	14 (1.4)	14 (1.4)	15 (1.3)
10	0 (1.9)	5 (1.8)	7 (1.7)	8 (1.6)	8 (1.5)	8 (1.4)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.1)	9 (1.1)	9 (1)	10 (1)	10 (1)	10 (1)	10 (0.9)	10 (0.9)	10 (0.9)
5	0 (1)	3 (0.9)	3 (0.8)	4 (0.8)	4 (0.8)	4 (0.7)	4 (0.6)	4 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.4)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1)	-3 (-0.9)	-3 (-0.8)	-4 (-0.8)	-4 (-0.8)	-4 (-0.7)	-4 (-0.6)	-4 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.4)
-10	0 (-1.9)	-5 (-1.8)	-7 (-1.7)	-8 (-1.6)	-8 (-1.5)	-8 (-1.4)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.1)	-9 (-1.1)	-9 (-1)	-10 (-1)	-10 (-1)	-10 (-1)	-10 (-0.9)	-10 (-0.9)	-10 (-0.9)
-15	0 (-2.9)	-8 (-2.7)	-10 (-2.5)	-11 (-2.4)	-12 (-2.3)	-13 (-2.1)	-13 (-1.9)	-13 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)	-14 (-1.5)	-14 (-1.4)	-14 (-1.4)	-14 (-1.4)	-15 (-1.3)
-20	-1 (-3.9)	-11 (-3.7)	-14 (-3.3)	-15 (-3.1)	-16 (-3)	-17 (-2.8)	-17 (-2.6)	-18 (-2.4)	-18 (-2.3)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)	-19 (-2)	-19 (-1.9)	-19 (-1.9)	-19 (-1.8)	-19 (-1.8)
-25	-1 (-4.8)	-13 (-4.6)	-17 (-4.2)	-19 (-3.9)	-20 (-3.8)	-21 (-3.5)	-22 (-3.2)	-22 (-3.1)	-23 (-2.9)	-23 (-2.8)	-23 (-2.7)	-24 (-2.6)	-24 (-2.5)	-24 (-2.4)	-24 (-2.4)	-24 (-2.3)	-24 (-2.3)	-24 (-2.2)
-30	-1 (-5.8)	-16 (-5.5)	-21 (-5)	-23 (-4.7)	-24 (-4.5)	-25 (-4.2)	-26 (-3.9)	-27 (-3.7)	-27 (-3.5)	-28 (-3.3)	-28 (-3.2)	-28 (-3.1)	-29 (-3)	-29 (-2.9)	-29 (-2.9)	-29 (-2.8)	-29 (-2.7)	-29 (-2.7)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.30 Energy losses in pipes without and with insulation - Thermoline® - Diameter 14 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (22.5)	53 (20.2)	68 (18.3)	74 (17.1)	78 (16.4)	83 (15)	87 (13.9)	89 (13.1)	91 (12.4)	92 (11.9)	93 (11.4)	94 (11)	95 (10.7)	95 (10.4)	96 (10.1)	96 (9.9)	96 (9.6)	97 (9.4)
90	3 (20.2)	48 (18.2)	61 (16.4)	67 (15.4)	70 (14.7)	75 (13.5)	78 (12.5)	80 (11.8)	82 (11.2)	83 (10.7)	84 (10.3)	85 (9.9)	85 (9.6)	86 (9.3)	86 (9.1)	87 (8.9)	87 (8.7)	87 (8.5)
80	3 (18)	42 (16.2)	54 (14.6)	59 (13.7)	62 (13.1)	67 (12)	69 (11.1)	71 (10.5)	73 (9.9)	74 (9.5)	75 (9.1)	75 (8.8)	76 (8.5)	76 (8.3)	77 (8.1)	77 (7.9)	77 (7.7)	77 (7.6)
70	2 (15.7)	37 (14.2)	47 (12.8)	52 (12)	54 (11.5)	58 (10.5)	61 (9.8)	63 (9.2)	64 (8.7)	65 (8.3)	65 (8)	66 (7.7)	66 (7.5)	67 (7.3)	67 (7.1)	67 (6.9)	68 (6.7)	68 (6.6)
60	2 (13.5)	32 (12.1)	41 (11)	45 (10.2)	47 (9.8)	50 (9)	52 (8.4)	54 (7.9)	55 (7.5)	55 (7.1)	56 (6.8)	57 (6.6)	57 (6.4)	57 (6.2)	57 (6.1)	58 (5.9)	58 (5.8)	58 (5.7)
50	2 (11.2)	27 (10.1)	34 (9.1)	37 (8.5)	39 (8.2)	42 (7.5)	43 (7)	45 (6.6)	46 (6.2)	46 (5.9)	47 (5.7)	47 (5.5)	47 (5.3)	48 (5.2)	48 (5)	48 (4.9)	48 (4.8)	48 (4.7)
40	1 (9)	21 (8.1)	27 (7.3)	30 (6.8)	31 (6.6)	33 (6)	35 (5.6)	36 (5.2)	36 (5)	37 (4.8)	37 (4.6)	38 (4.4)	38 (4.3)	38 (4.1)	38 (4)	38 (3.9)	39 (3.9)	39 (3.8)
30	1 (6.7)	16 (6.1)	20 (5.5)	22 (5.1)	23 (4.9)	25 (4.5)	26 (4.2)	27 (3.9)	27 (3.7)	28 (3.6)	28 (3.4)	28 (3.3)	28 (3.2)	29 (3.1)	29 (3)	29 (3)	29 (2.9)	29 (2.8)
25	1 (5.6)	13 (5.1)	17 (4.6)	19 (4.3)	19 (4.1)	21 (3.7)	22 (3.5)	22 (3.3)	23 (3.1)	23 (3)	23 (2.9)	24 (2.8)	24 (2.7)	24 (2.6)	24 (2.5)	24 (2.5)	24 (2.4)	24 (2.4)
20	1 (4.5)	11 (4)	14 (3.7)	15 (3.4)	16 (3.3)	17 (3)	17 (2.8)	18 (2.6)	18 (2.5)	18 (2.4)	19 (2.3)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)	19 (2)	19 (1.9)	19 (1.9)
15	0 (3.4)	8 (3)	10 (2.7)	11 (2.6)	12 (2.5)	12 (2.2)	13 (2.1)	13 (2)	14 (1.9)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.5)	14 (1.5)	14 (1.4)	15 (1.4)
10	0 (2.2)	5 (2)	7 (1.8)	7 (1.7)	8 (1.6)	8 (1.5)	9 (1.4)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.1)	9 (1.1)	9 (1.1)	10 (1)	10 (1)	10 (1)	10 (1)	10 (0.9)
5	0 (1.1)	3 (1)	3 (0.9)	4 (0.9)	4 (0.8)	4 (0.7)	4 (0.7)	4 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.1)	-3 (-1)	-3 (-0.9)	-4 (-0.9)	-4 (-0.8)	-4 (-0.7)	-4 (-0.7)	-4 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.2)	-5 (-2)	-7 (-1.8)	-7 (-1.7)	-8 (-1.6)	-8 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.1)	-9 (-1.1)	-9 (-1.1)	-10 (-1)	-10 (-1)	-10 (-1)	-10 (-1)	-10 (-0.9)
-15	0 (-3.4)	-8 (-3)	-10 (-2.7)	-11 (-2.6)	-12 (-2.5)	-12 (-2.2)	-13 (-2.1)	-13 (-2)	-14 (-1.9)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)	-14 (-1.5)	-14 (-1.4)	-15 (-1.4)
-20	-1 (-4.5)	-11 (-4)	-14 (-3.7)	-15 (-3.4)	-16 (-3.3)	-17 (-3)	-17 (-2.8)	-18 (-2.6)	-18 (-2.5)	-18 (-2.4)	-19 (-2.3)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)	-19 (-2)	-19 (-1.9)	-19 (-1.9)
-25	-1 (-5.6)	-13 (-5.1)	-17 (-4.6)	-19 (-4.3)	-19 (-4.1)	-21 (-3.7)	-22 (-3.5)	-22 (-3.3)	-23 (-3.1)	-23 (-3)	-23 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.6)	-24 (-2.5)	-24 (-2.5)	-24 (-2.4)	-24 (-2.4)
-30	-1 (-6.7)	-16 (-6.1)	-20 (-5.5)	-22 (-5.1)	-23 (-4.9)	-25 (-4.5)	-26 (-4.2)	-27 (-3.9)	-27 (-3.7)	-28 (-3.6)	-28 (-3.4)	-28 (-3.3)	-28 (-3.2)	-29 (-3.1)	-29 (-3)	-29 (-3)	-29 (-2.9)	-29 (-2.8)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

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Table 8.31 Energy losses in pipes without and with insulation - Thermoline® - Diameter 16 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (25.7)	52 (22.1)	67 (19.8)	74 (18.4)	77 (17.7)	83 (16.1)	86 (14.9)	89 (14)	91 (13.2)	92 (12.6)	93 (12.1)	94 (11.7)	95 (11.3)	95 (10.9)	96 (10.6)	96 (10.4)	96 (10.1)	97 (9.9)
90	3 (23.1)	47 (19.9)	60 (17.8)	66 (16.6)	69 (15.9)	74 (14.5)	78 (13.4)	80 (12.6)	82 (11.9)	83 (11.3)	84 (10.9)	85 (10.5)	85 (10.1)	86 (9.8)	86 (9.6)	86 (9.3)	87 (9.1)	87 (8.9)
80	2 (20.6)	42 (17.7)	53 (15.9)	59 (14.7)	61 (14.1)	66 (12.9)	69 (11.9)	71 (11.2)	73 (10.6)	74 (10.1)	74 (9.7)	75 (9.3)	76 (9)	76 (8.7)	76 (8.5)	77 (8.3)	77 (8.1)	77 (7.9)
70	2 (18)	37 (15.5)	47 (13.9)	51 (12.9)	54 (12.4)	58 (11.3)	60 (10.4)	62 (9.8)	64 (9.3)	64 (8.8)	65 (8.5)	66 (8.2)	66 (7.9)	67 (7.7)	67 (7.4)	67 (7.3)	67 (7.1)	68 (6.9)
60	2 (15.4)	31 (13.3)	40 (11.9)	44 (11.1)	46 (10.6)	50 (9.6)	52 (8.9)	53 (8.4)	54 (7.9)	55 (7.6)	56 (7.3)	56 (7)	57 (6.8)	57 (6.6)	57 (6.4)	58 (6.2)	58 (6.1)	58 (6)
50	2 (12.9)	26 (11.1)	33 (9.9)	37 (9.2)	38 (8.8)	41 (8)	43 (7.4)	44 (7)	45 (6.6)	46 (6.3)	47 (6)	47 (5.8)	47 (5.6)	48 (5.5)	48 (5.3)	48 (5.2)	48 (5.1)	48 (5)
40	1 (10.3)	21 (8.9)	27 (7.9)	29 (7.4)	31 (7.1)	33 (6.4)	35 (6)	36 (5.6)	36 (5.3)	37 (5)	37 (4.8)	38 (4.7)	38 (4.5)	38 (4.4)	38 (4.3)	38 (4.2)	39 (4.1)	39 (4)
30	1 (7.7)	16 (6.6)	20 (5.9)	22 (5.5)	23 (5.3)	25 (4.8)	26 (4.5)	27 (4.2)	27 (4)	28 (3.8)	28 (3.6)	28 (3.5)	28 (3.4)	29 (3.3)	29 (3.2)	29 (3.1)	29 (3)	29 (3)
25	1 (6.4)	13 (5.5)	17 (5)	18 (4.6)	19 (4.4)	21 (4)	22 (3.7)	22 (3.5)	23 (3.3)	23 (3.2)	23 (3)	23 (2.9)	24 (2.8)	24 (2.7)	24 (2.7)	24 (2.6)	24 (2.5)	24 (2.5)
20	1 (5.1)	10 (4.4)	13 (4)	15 (3.7)	15 (3.5)	17 (3.2)	17 (3)	18 (2.8)	18 (2.6)	18 (2.5)	19 (2.4)	19 (2.3)	19 (2.3)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)	19 (2)
15	0 (3.9)	8 (3.3)	10 (3)	11 (2.8)	12 (2.6)	12 (2.4)	13 (2.2)	13 (2.1)	14 (2)	14 (1.9)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.6)	14 (1.5)	14 (1.5)
10	0 (2.6)	5 (2.2)	7 (2)	7 (1.8)	8 (1.8)	8 (1.6)	9 (1.5)	9 (1.4)	9 (1.3)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.1)	10 (1.1)	10 (1.1)	10 (1)	10 (1)	10 (1)
5	0 (1.3)	3 (1.1)	3 (1)	4 (0.9)	4 (0.9)	4 (0.8)	4 (0.7)	4 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.3)	-3 (-1.1)	-3 (-1)	-4 (-0.9)	-4 (-0.9)	-4 (-0.8)	-4 (-0.7)	-4 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.6)	-5 (-2.2)	-7 (-2)	-7 (-1.8)	-8 (-1.8)	-8 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.1)	-10 (-1.1)	-10 (-1.1)	-10 (-1)	-10 (-1)	-10 (-1)
-15	0 (-3.9)	-8 (-3.3)	-10 (-3)	-11 (-2.8)	-12 (-2.6)	-12 (-2.4)	-13 (-2.2)	-13 (-2.1)	-14 (-2)	-14 (-1.9)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)	-14 (-1.5)
-20	-1 (-5.1)	-10 (-4.4)	-13 (-4)	-15 (-3.7)	-15 (-3.5)	-17 (-3.2)	-17 (-3)	-18 (-2.8)	-18 (-2.6)	-18 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.3)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)	-19 (-2)
-25	-1 (-6.4)	-13 (-5.5)	-17 (-5)	-18 (-4.6)	-19 (-4.4)	-21 (-4)	-22 (-3.7)	-22 (-3.5)	-23 (-3.3)	-23 (-3.2)	-23 (-3)	-23 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.7)	-24 (-2.6)	-24 (-2.5)	-24 (-2.5)
-30	-1 (-7.7)	-16 (-6.6)	-20 (-5.9)	-22 (-5.5)	-23 (-5.3)	-25 (-4.8)	-26 (-4.5)	-27 (-4.2)	-27 (-4)	-28 (-3.8)	-28 (-3.6)	-28 (-3.5)	-28 (-3.4)	-29 (-3.3)	-29 (-3.2)	-29 (-3.1)	-29 (-3)	-29 (-3)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.32 Energy losses in pipes without and with insulation - Thermoline® - Diameter 17 mm.

$T_i - T_e$ [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference $T_i - T_{isol}$ [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}/L$ [W/m])																	
100	3 (27.3)	52 (23.1)	66 (20.6)	73 (19.1)	77 (18.3)	82 (16.6)	86 (15.4)	89 (14.4)	91 (13.6)	92 (13)	93 (12.4)	94 (12)	95 (11.6)	95 (11.2)	96 (10.9)	96 (10.6)	96 (10.4)	97 (10.2)
90	3 (24.6)	47 (20.8)	60 (18.5)	66 (17.2)	69 (16.4)	74 (14.9)	78 (13.8)	80 (12.9)	82 (12.2)	83 (11.7)	84 (11.2)	84 (10.8)	85 (10.4)	86 (10.1)	86 (9.8)	86 (9.6)	87 (9.3)	87 (9.1)
80	2 (21.9)	42 (18.5)	53 (16.5)	59 (15.3)	61 (14.6)	66 (13.3)	69 (12.3)	71 (11.5)	72 (10.9)	74 (10.4)	74 (9.9)	75 (9.6)	76 (9.2)	76 (9)	76 (8.7)	77 (8.5)	77 (8.3)	77 (8.1)
70	2 (19.1)	36 (16.2)	47 (14.4)	51 (13.4)	54 (12.8)	58 (11.6)	60 (10.8)	62 (10.1)	63 (9.5)	64 (9.1)	65 (8.7)	66 (8.4)	66 (8.1)	67 (7.8)	67 (7.6)	67 (7.4)	67 (7.3)	68 (7.1)
60	2 (16.4)	31 (13.8)	40 (12.3)	44 (11.5)	46 (11)	49 (10)	52 (9.2)	53 (8.6)	54 (8.2)	55 (7.8)	56 (7.5)	56 (7.2)	57 (6.9)	57 (6.7)	57 (6.5)	58 (6.4)	58 (6.2)	58 (6.1)
50	2 (13.7)	26 (11.5)	33 (10.3)	37 (9.6)	38 (9.1)	41 (8.3)	43 (7.7)	44 (7.2)	45 (6.8)	46 (6.5)	47 (6.2)	47 (6)	47 (5.8)	48 (5.6)	48 (5.5)	48 (5.3)	48 (5.2)	48 (5.1)
40	1 (10.9)	21 (9.2)	27 (8.2)	29 (7.6)	31 (7.3)	33 (6.6)	34 (6.1)	35 (5.8)	36 (5.4)	37 (5.2)	37 (5)	38 (4.8)	38 (4.6)	38 (4.5)	38 (4.4)	38 (4.3)	39 (4.2)	39 (4.1)
30	1 (8.2)	16 (6.9)	20 (6.2)	22 (5.7)	23 (5.5)	25 (5)	26 (4.6)	27 (4.3)	27 (4.1)	28 (3.9)	28 (3.7)	28 (3.6)	28 (3.5)	29 (3.4)	29 (3.3)	29 (3.2)	29 (3.1)	29 (3)
25	1 (6.8)	13 (5.8)	17 (5.1)	18 (4.8)	19 (4.6)	21 (4.2)	22 (3.8)	22 (3.6)	23 (3.4)	23 (3.2)	23 (3.1)	23 (3)	24 (2.9)	24 (2.8)	24 (2.7)	24 (2.7)	24 (2.6)	24 (2.5)
20	1 (5.5)	10 (4.6)	13 (4.1)	15 (3.8)	15 (3.7)	16 (3.3)	17 (3.1)	18 (2.9)	18 (2.7)	18 (2.6)	19 (2.5)	19 (2.4)	19 (2.3)	19 (2.2)	19 (2.2)	19 (2.1)	19 (2.1)	19 (2)
15	0 (4.1)	8 (3.5)	10 (3.1)	11 (2.9)	11 (2.7)	12 (2.5)	13 (2.3)	13 (2.2)	14 (2)	14 (1.9)	14 (1.9)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.6)	14 (1.6)	14 (1.6)	14 (1.5)
10	0 (2.7)	5 (2.3)	7 (2.1)	7 (1.9)	8 (1.8)	8 (1.7)	9 (1.5)	9 (1.4)	9 (1.4)	9 (1.3)	9 (1.2)	9 (1.2)	9 (1.2)	10 (1.1)	10 (1.1)	10 (1.1)	10 (1)	10 (1)
5	0 (1.4)	3 (1.2)	3 (1)	4 (1)	4 (0.9)	4 (0.8)	4 (0.8)	4 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)	5 (0.5)	5 (0.5)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.4)	-3 (-1.2)	-3 (-1)	-4 (-1)	-4 (-0.9)	-4 (-0.8)	-4 (-0.8)	-4 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)	-5 (-0.5)
-10	0 (-2.7)	-5 (-2.3)	-7 (-2.1)	-7 (-1.9)	-8 (-1.8)	-8 (-1.7)	-9 (-1.5)	-9 (-1.4)	-9 (-1.4)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-9 (-1.2)	-10 (-1.1)	-10 (-1.1)	-10 (-1.1)	-10 (-1)	-10 (-1)
-15	0 (-4.1)	-8 (-3.5)	-10 (-3.1)	-11 (-2.9)	-11 (-2.7)	-12 (-2.5)	-13 (-2.3)	-13 (-2.2)	-14 (-2)	-14 (-1.9)	-14 (-1.9)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)	-14 (-1.6)	-14 (-1.6)	-14 (-1.5)
-20	-1 (-5.5)	-10 (-4.6)	-13 (-4.1)	-15 (-3.8)	-15 (-3.7)	-16 (-3.3)	-17 (-3.1)	-18 (-2.9)	-18 (-2.7)	-18 (-2.6)	-19 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.2)	-19 (-2.2)	-19 (-2.1)	-19 (-2.1)	-19 (-2)
-25	-1 (-6.8)	-13 (-5.8)	-17 (-5.1)	-18 (-4.8)	-19 (-4.6)	-21 (-4.2)	-22 (-3.8)	-22 (-3.6)	-23 (-3.4)	-23 (-3.2)	-23 (-3.1)	-23 (-3)	-24 (-2.9)	-24 (-2.8)	-24 (-2.7)	-24 (-2.7)	-24 (-2.6)	-24 (-2.5)
-30	-1 (-8.2)	-16 (-6.9)	-20 (-6.2)	-22 (-5.7)	-23 (-5.5)	-25 (-5)	-26 (-4.6)	-27 (-4.3)	-27 (-4.1)	-28 (-3.9)	-28 (-3.7)	-28 (-3.6)	-28 (-3.5)	-29 (-3.4)	-29 (-3.3)	-29 (-3.2)	-29 (-3.1)	-29 (-3)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Table 8.33 Energy losses in pipes without and with insulation - Thermoline® - Diameter 20 mm.

T_i - T_e [°C]	Thickness of insulation s_{isol} [mm]																	
	0	6	10	13	15	20	25	30	35	40	45	50	55	60	65	70	75	80
	Temperature difference T_i – T_{isol} [°C] (Energy lost/accumulated in one meter of pipe $\dot{Q}$/L [W/m])																	
100	3 (32.2)	51 (25.9)	66 (22.8)	72 (21.1)	76 (20.1)	82 (18.2)	86 (16.7)	88 (15.6)	90 (14.7)	92 (14)	93 (13.4)	94 (12.9)	94 (12.4)	95 (12)	95 (11.7)	96 (11.4)	96 (11.1)	96 (10.8)
90	3 (29)	46 (23.3)	59 (20.6)	65 (19)	68 (18.1)	74 (16.4)	77 (15.1)	79 (14.1)	81 (13.2)	82 (12.6)	83 (12)	84 (11.6)	85 (11.2)	85 (10.8)	86 (10.5)	86 (10.2)	86 (10)	87 (9.7)
80	2 (25.7)	41 (20.7)	52 (18.3)	58 (16.9)	61 (16.1)	65 (14.5)	68 (13.4)	71 (12.5)	72 (11.8)	73 (11.2)	74 (10.7)	75 (10.3)	75 (9.9)	76 (9.6)	76 (9.3)	77 (9.1)	77 (8.9)	77 (8.7)
70	2 (22.5)	36 (18.1)	46 (16)	51 (14.8)	53 (14.1)	57 (12.7)	60 (11.7)	62 (10.9)	63 (10.3)	64 (9.8)	65 (9.4)	65 (9)	66 (8.7)	66 (8.4)	67 (8.2)	67 (7.9)	67 (7.8)	67 (7.6)
60	2 (19.3)	31 (15.5)	39 (13.7)	43 (12.6)	45 (12.1)	49 (10.9)	51 (10)	53 (9.4)	54 (8.8)	55 (8.4)	56 (8)	56 (7.7)	57 (7.4)	57 (7.2)	57 (7)	57 (6.8)	58 (6.6)	58 (6.5)
50	2 (16.1)	26 (12.9)	33 (11.4)	36 (10.5)	38 (10.1)	41 (9.1)	43 (8.4)	44 (7.8)	45 (7.4)	46 (7)	46 (6.7)	47 (6.4)	47 (6.2)	47 (6)	48 (5.8)	48 (5.7)	48 (5.5)	48 (5.4)
40	1 (12.9)	20 (10.4)	26 (9.1)	29 (8.4)	30 (8)	33 (7.3)	34 (6.7)	35 (6.2)	36 (5.9)	37 (5.6)	37 (5.4)	37 (5.1)	38 (5)	38 (4.8)	38 (4.7)	38 (4.5)	38 (4.4)	39 (4.3)
30	1 (9.7)	15 (7.8)	20 (6.9)	22 (6.3)	23 (6)	25 (5.5)	26 (5)	26 (4.7)	27 (4.4)	27 (4.2)	28 (4)	28 (3.9)	28 (3.7)	28 (3.6)	29 (3.5)	29 (3.4)	29 (3.3)	29 (3.2)
25	1 (8)	13 (6.5)	16 (5.7)	18 (5.3)	19 (5)	20 (4.5)	21 (4.2)	22 (3.9)	23 (3.7)	23 (3.5)	23 (3.3)	23 (3.2)	24 (3.1)	24 (3)	24 (2.9)	24 (2.8)	24 (2.8)	24 (2.7)
20	1 (6.4)	10 (5.2)	13 (4.6)	14 (4.2)	15 (4)	16 (3.6)	17 (3.3)	18 (3.1)	18 (2.9)	18 (2.8)	19 (2.7)	19 (2.6)	19 (2.5)	19 (2.4)	19 (2.3)	19 (2.3)	19 (2.2)	19 (2.2)
15	0 (4.8)	8 (3.9)	10 (3.4)	11 (3.2)	11 (3)	12 (2.7)	13 (2.5)	13 (2.3)	14 (2.2)	14 (2.1)	14 (2)	14 (1.9)	14 (1.9)	14 (1.8)	14 (1.7)	14 (1.7)	14 (1.7)	14 (1.6)
10	0 (3.2)	5 (2.6)	7 (2.3)	7 (2.1)	8 (2)	8 (1.8)	9 (1.7)	9 (1.6)	9 (1.5)	9 (1.4)	9 (1.3)	9 (1.3)	9 (1.2)	9 (1.2)	10 (1.2)	10 (1.1)	10 (1.1)	10 (1.1)
5	0 (1.6)	3 (1.3)	3 (1.1)	4 (1.1)	4 (1)	4 (0.9)	4 (0.8)	4 (0.8)	5 (0.7)	5 (0.7)	5 (0.7)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.6)	5 (0.5)
0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-5	0 (-1.6)	-3 (-1.3)	-3 (-1.1)	-4 (-1.1)	-4 (-1)	-4 (-0.9)	-4 (-0.8)	-4 (-0.8)	-5 (-0.7)	-5 (-0.7)	-5 (-0.7)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.6)	-5 (-0.5)
-10	0 (-3.2)	-5 (-2.6)	-7 (-2.3)	-7 (-2.1)	-8 (-2)	-8 (-1.8)	-9 (-1.7)	-9 (-1.6)	-9 (-1.5)	-9 (-1.4)	-9 (-1.3)	-9 (-1.3)	-9 (-1.2)	-9 (-1.2)	-10 (-1.2)	-10 (-1.1)	-10 (-1.1)	-10 (-1.1)
-15	0 (-4.8)	-8 (-3.9)	-10 (-3.4)	-11 (-3.2)	-11 (-3)	-12 (-2.7)	-13 (-2.5)	-13 (-2.3)	-14 (-2.2)	-14 (-2.1)	-14 (-2)	-14 (-1.9)	-14 (-1.9)	-14 (-1.8)	-14 (-1.7)	-14 (-1.7)	-14 (-1.7)	-14 (-1.6)
-20	-1 (-6.4)	-10 (-5.2)	-13 (-4.6)	-14 (-4.2)	-15 (-4)	-16 (-3.6)	-17 (-3.3)	-18 (-3.1)	-18 (-2.9)	-18 (-2.8)	-19 (-2.7)	-19 (-2.6)	-19 (-2.5)	-19 (-2.4)	-19 (-2.3)	-19 (-2.3)	-19 (-2.2)	-19 (-2.2)
-25	-1 (-8)	-13 (-6.5)	-16 (-5.7)	-18 (-5.3)	-19 (-5)	-20 (-4.5)	-21 (-4.2)	-22 (-3.9)	-23 (-3.7)	-23 (-3.5)	-23 (-3.3)	-23 (-3.2)	-24 (-3.1)	-24 (-3)	-24 (-2.9)	-24 (-2.8)	-24 (-2.8)	-24 (-2.7)
-30	-1 (-9.7)	-15 (-7.8)	-20 (-6.9)	-22 (-6.3)	-23 (-6)	-25 (-5.5)	-26 (-5)	-26 (-4.7)	-27 (-4.4)	-27 (-4.2)	-28 (-4)	-28 (-3.9)	-28 (-3.7)	-28 (-3.6)	-29 (-3.5)	-29 (-3.4)	-29 (-3.3)	-29 (-3.2)

Note 1. T_i = Temperature of the water, T_e = Temperature of the air, T_{isol} = Temperature of the outside layer of the insulation.
Note 2. Minimum thickness is calculated taking a thermal conductivity of the insulation of 0.0397 W/m·K into consideration.

Example 1.

Calculate the energy lost in one year from a 150 m section of a 90 mm diameter Pexal® pipe that transports water at 65°C and is laid at a temperature of 15°C. Then assess the energy saved should the pipe be covered with a 30 mm insulation made of closed cell polyethylene foam (0.0397 W/m·K). Keep in mind that the system operates 2000 hours a year.

Table 8.27 indicates that the energy loss from 1 meter of 90 mm diameter Pexal® pipe without insulation (s_{isol} = 0 mm) for a temperature difference of T_i - T_e = 65°C - 15°C = 50°C is about 68 W/m.
The energy loss from 150 m of pipe is therefore equal to 68 W/m · 150 m = 10,200 W which corresponds to a yearly power of 10,200 W · 2000 h/year = 20.4 MWh/year.

If the pipe is covered with a 30 mm insulation then the power lost from 1 meter of pipe is reduced to approximately 20 W/m, which, in one year corresponds to 6 MWh/year, which is the equivalent of a saving of 14.4 MWh/year.

8

8.6.2.1 Pipe insulation according to Italian Law 10/1991

The Italian Law 10/1991, implemented for plants by the Italian Presidential Decree 412/93, indicate the insulation thickness required for limitation of energy losses of thermal systems.

In other countries it may be used as an indication, but reference should always be made to local regulations in force. The minimum requirement is that all heat distribution pipes, including those mounted in the ground or placed in the cavities of the infills, are insulated with the minimum thickness shown in the table below.

Table 8.34 Minimum thickness according to Annex B of Italian Presidential Decree 412/93.

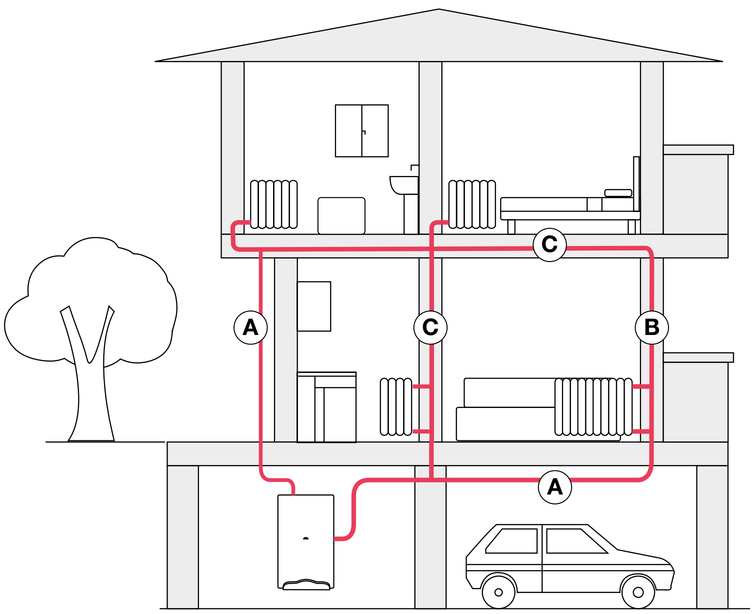
λ(1) [W/m°C]	External pipe diameter [mm]					
	<20	From 20 to 39	From 40 to 59	From 60 to 79	From 80 to 99	>100
0.030	13	19	26	33	37	40
0.032	14	21	29	36	40	44
0.034	15	23	31	39	44	48
0.036	17	25	34	43	47	52
0.038	18	28	37	46	51	56
0.040	20	30	40	50	55	60
0.042	22	32	43	54	59	64
0.044	24	35	46	58	63	69
0.046	26	38	50	62	68	74
0.048	28	41	54	66	72	79
0.050	30	44	58	71	77	84

(1) Useful thermal conductivity of insulation material at a temperature of 40°C.

There are exceptions, depending on the area (Figure 8.39) where the above pipes are installed, that reduce the minimum thickness values required:

- **Area A**: outdoor installation or in non-habitable spaces (e.g. garages or basements, etc.), the values are the same as those shown in Table 8.34.
- **Area B:** underground installation in exterior walls but within the thermal insulation, the values in Table 8.34 must be multiplied by the coefficient 0.5.
- **Area C**: underground installation in interior building walls, the values in Table 8.34 must be multiplied by the coefficient 0.3.

Figure 8.39 Diagram of the different application areas.

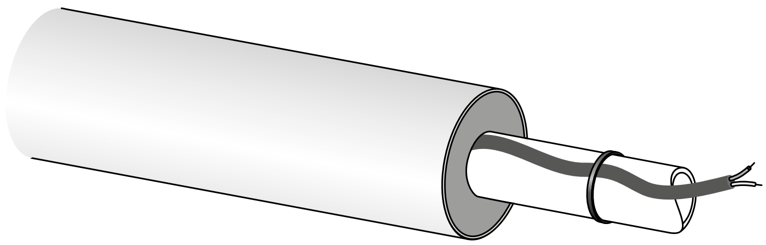


8.6.3 Antifreeze protection

When there is the risk of freezing temperatures, necessary steps must be taken so that the liquid contained in the water supply system does not freeze, causing the pipes to burst and the devices connected to them to break. The risk of freezing, if present, must be taken into account when the system is being designed.
The route for the pipes must be chosen appropriately, avoiding areas that could be risky such as outdoor and above ground areas, unheated attics, unheated basements, garages, ducts in external walls that are not insulated, etc.
The pipes must be suitably insulated, in compliance with any local or national regulations or standards and fitted securely to the building structures that are in turn equipped with an insulating material. When the methods of protection adopted for the water supply systems are not sufficient, for example, in attics of houses located in mountain areas with no insulation and which are not heated for long periods, systems must be provided for maintaining the temperature of the pipes, such as trace heating, a method consisting in attaching a self-regulating heating cable to the pipe to prevent the water inside the pipe from freezing.
The self-regulating heating cables must not exceed a temperature of 80°C, they must be securely attached to the pipe (for example, with heat resistant plastic hose clamps) and protected with a protective insulating sleeve. When the heating cable is attached to a multilayer pipe, the middle layer in aluminium guarantees a uniform distribution of the heat around the entire circumference.
If, however, trace heating is not feasible and, despite the presence of an insulating layer, there is still a risk of freezing, then it should be drained when not in use.

8

Figure 8.40 Pipe with heating cable.



In heating or cooling systems, if the pipes risk freezing, it is recommended to add an antifreeze liquid such as ethylene glycol and propylene glycol in proportions that depend on the minimum temperature reached.
Since antifreeze liquids have a greater density and viscosity than water, the pressure losses inside the circuits are higher and therefore the circulating pump needs to push harder.
The following tables indicate the typical concentrations of the most well-known antifreeze liquids, please refer, however, to the manufacturers' data sheets for further details. Do not use antifreeze liquids in water supply systems for transporting drinking water.

Table 8.35 Concentrations of ethylene glycol based antifreeze.

Temperature	Concentration by volume
-4°C	10%
-9°C	20%
-17°C	30%
-26°C	40%
-37°C	50%

Table 8.36 Concentrations of propylene glycol based antifreeze.

Temperature	Concentration by volume
-10°C	25%
-15°C	33%
-32°C	50%

8.7 Noise reduction techniques

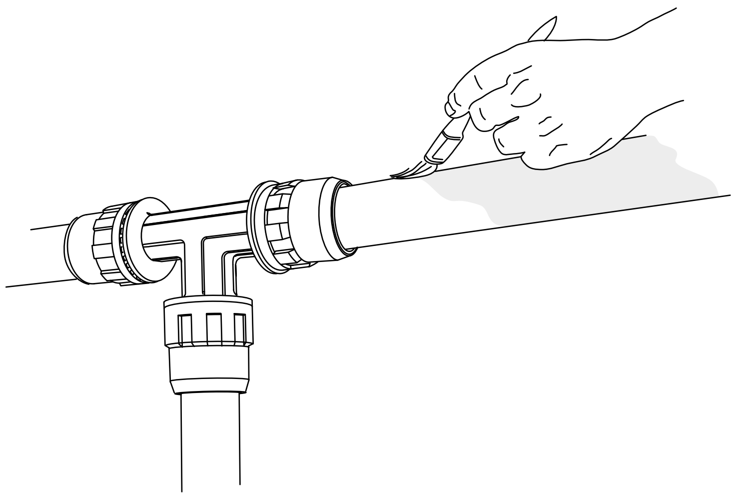
Water supply systems inside buildings must be designed and installed in such a way as to reduce the noise caused by the systems to a minimum, in compliance with any local or national regulations or standards.
Pexal®, Mixal® and Thermoline® pipes are characterised by an excellent flexibility and this guarantees excellent soundproofing properties as compared with metal pipes.
To keep noise to a minimum:
- Bracket the pipes with clips with anti-vibration rubber inserts.
- Insulate the pipes in the walls to avoid the transmission of vibrations.
- Decouple the sanitary fixtures using anti-vibration rubber placed between the sanitary fixture and the wall.

8.8 Protection against UV rays

Crosslinked polyethylene has a reduced resistance to the action of UV rays and a prolonged exposure can influence performance. The technopolymer fittings (Pexal® Easy and Bravopress®) may be subject to colour variation (yellowing) without, however, undergoing significant variations in the mechanical characteristics.
For the reasons mentioned above, for outdoor installations, it is recommended to adopt suitable methods for protecting against UV rays, such as using plastic or metal ducts or covering the pipes and fittings with a special paint that Valsir has studied specifically for such situations. To guarantee the correct level of protection, the paint must be touched-up periodically. For further details on the characteristics of the paint and relative thinner please refer to the data sheet in the appendix.

8

Figure 8.41 Application of the anti-UV paint.



8.9 Fire protection

Systems must always be installed in compliance with local or national regulations or standards, respecting any fire protection provisions that may vary from country to country.

8.9.1 Protection by means of heat insulating conduits

In some countries, pipes with rather high fire reaction classes are required, which would compromise the use of multilayer systems. In these cases, however, it is possible to adopt protection techniques by combining the pipes with suitable heat insulating conduits that increase the fire reaction class of the water system. These techniques must in any case be tested in a laboratory and verified by an appropriate approval institute.

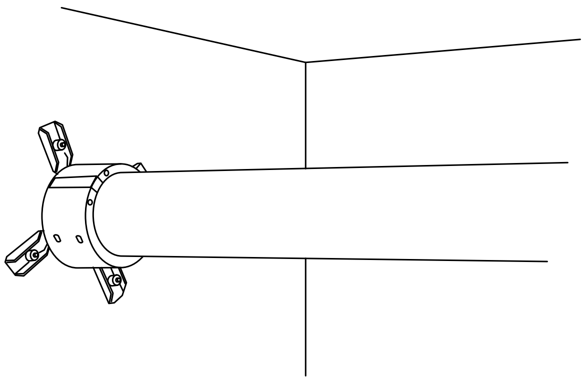
Valsir carried out these tests on its multilayer pipes at the LNE Approval Institute, obtaining **test report P126686** which shows that the system, combined with special insulating elastomer conduits, achieves fire reaction class B-s2,d0.

8.9.2 Fire-stop sleeves

The most commonly used system involves the use of fire-stop sleeves (passive fire resistance devices), which are devices composed of an intumescent material that in the presence of high temperatures expands and blocks the passage of flames, gas and heat through the hole that is left open from the melting pipe.
Fire-stop sleeves are used in wall penetrations using two sleeves, one on each side, and in floor penetrations with one sleeve, one on the soffit side of the floor.

8

Figure 8.42 Fire-stop sleeves.



The installation of these devices must be carried out in compliance with the installation rules as defined by the producer. It is recommended, however, to consider also the following indications:

- The hole in the wall or floor must be made using a core-drilling machine and a suitably sized tool.
- If the space between the pipe and the hole is wide, then it must be sealed with fire mortar or alternatively, a fire-stop intumescent sealant can be used.
- Clean the surface of the plastic pipes where the fire-stop sleeves are to be fitted since any mortar residue will delay the action of the sleeve in the event of a fire.
- For in-wall installations make sure that the hole is sufficiently large to accommodate the outside diameter of the fire-stop sleeve. For floor applications, the fire-stop sleeve must be installed flush with the lower surface.

8.10 System commissioning

The commissioning of a water supply system is composed of three main phases:
- System testing with the purpose of verifying the compliance of the work with the project specifications, the standards on safety and good workmanship.
- Flushing of the water supply system.
- Disinfection of the water supply system.

These operations must be performed in compliance with local or national regulations and standards; in the section, reference is made to the provisions of European standard EN 806-4:2010.

8.10.1 Testing

System testing can be carried out with drinking water or (if allowed by local regulations) with clean air at a low pressure. Pressure gauges for reading must be positioned in the lowest point of the system with reading intervals of 0 to 16 bar and an accuracy of 0.2 bar. Before testing, the entire system must be purged and filled with drinking water (or, if allowed by local regulations, with clean air). The test involves the application of a test pressure TP equal to:

$$TP = 1.1 \cdot MDP \qquad [8.25]$$

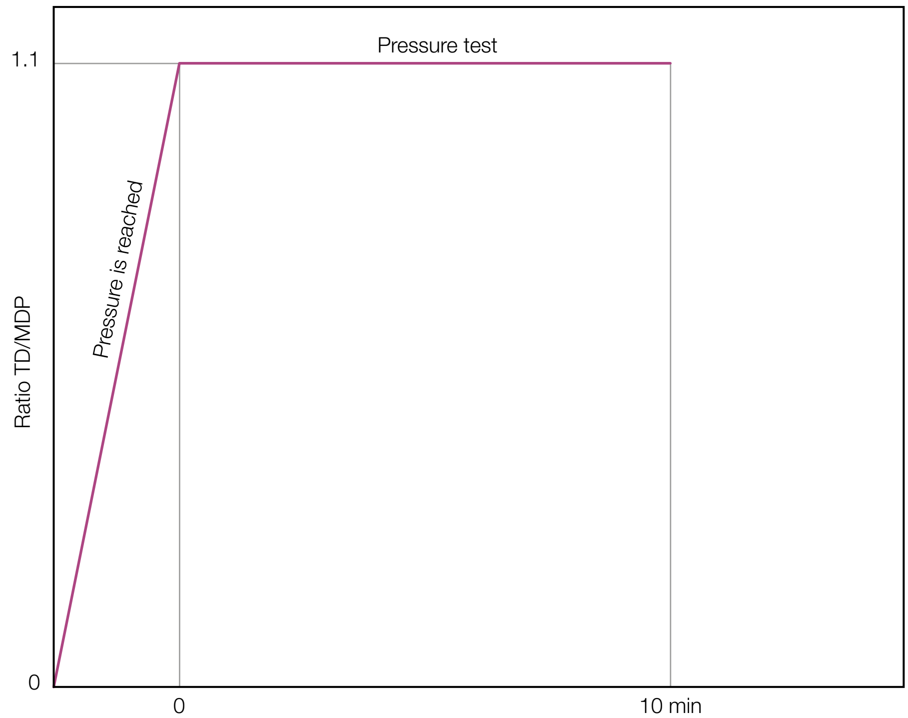
where
MDP is the maximum design pressure.

The speed of pressure application [bar/s] must not exceed the speed calculated with the following formula:

$$v = \frac{4}{60} \cdot TP \qquad [8.26]$$

The test pressure must be maintained for a period of 10 min, during which there must be no leakages.
For further details, please refer to EN 806-4.

Figure 8.43 System testing in compliance with EN 806-4 (A test procedure).



8.10.1.1 Leak test (for Bravopress® and Pexal® Brass D 16-32 fittings only)

As mentioned above, Valsir Bravopress® and Pexal® Brass fittings up to D 32 show a leak, if they are not pressed, when subjected to a pressure range up to 2 bar.
This is ensured by the fact that, for these ranges of fittings, the O-rings are below the fitting profile and therefore, if they are not pressed, there is no hydraulic seal between the O-ring and the inner surface of the pipe, a situation that causes a leak when the system is subjected to even low pressure.
The test can be carried out before placing the pipe underground using water or air (if permitted by local regulations); the test consists in applying to the whole system a test pressure of approx. 1 bar, in **any case it must not exceed 2 bar** for a time of approx. 10’ and using the same instruments provided for by standard EN 806-4 for the standard test.
In case of no pressing, the pressure drop will occur quickly. Leak detection can be done by placing soapy water on each joint, or by observing that each metal sleeve in each tested joint is deformed by the pressing operation.

8.10.1.2 System testing check list

Check of leaks in non-pressed fittings with water (Bravopress® and Pexal® Brass D 16-32):

1) Connect a pressure gauge with 0.2 bar steps to the lowest part of the system.
2) Fill the system with filtered water.
3) Completely vent the air in the system.
4) Set system pressure from 0.5 to 2 bar.
5) Check that the pressure remains stable at the value set in point 4 for at least 10 minutes.
6) Check all system fittings for leaks.
7) The test is passed if the pressure drop is lower than 0.2 bar.
8) Keep the system under pressure for 8 more hours.
9) The test is passed if the pressure drop is lower than 0.2 bar.

Check of leaks in non-pressed fittings with air (Bravopress® and Pexal® Brass D 16-32):

1) Connect a pressure gauge with 1 mbar steps to the lowest part of the system.
2) Calculate the system volume.
3) Depending on the volume calculated in point 2, the test time is 30 minutes if Vol.>100 litres, add 10 minutes for every additional 100 litres Vol.
4) Fill the system with air at a pressure of 150 mbar.
5) Check that the pressure remains stable at the value set in point 4 for the time calculated in point 3.
6) Check all system fittings for leaks.
7) The test is passed if the pressure drop is lower than 0.2 bar.
8) Keep the system under pressure for 8 more hours.
9) The test is passed if the pressure drop is lower than 0.2 bar.

Load test with water according to EN 806-4 procedure A:

1) Set system pressure to 1.1 times the maximum design pressure (max 15 bar).
2) Wait 30 minutes and check if the pressure has dropped, if so, restore the value from point 1.
3) Wait 10 minutes.
4) The test is passed if the pressure drop is lower than 0.2 bar.

Load test with air according to EN 806-4 procedure A:

1) Bring the system pressure to 3 bar if the maximum diameter of the system is 50 mm, to 1 bar if the maximum diameter is 90 mm.
2) Wait 30 minutes and check if the pressure has dropped, if so, restore the value from point 1.
3) Wait 10 minutes.
4) The test is passed if the pressure drop is lower than 0.1 bar.

8.10.2 Flushing

Immediately after testing, the water supply system must be flushed with drinking water.
The hot and cold water pipes must be flushed out separately with filtered drinking water (no particle ≥ 150 µm) and all necessary precautions must be taken to protect any sensitive fixtures such as WC valves, thermostatic mixers, etc. The filters of the fixtures must be removed to increase the flow, whereas those upstream of the system must be washed or replaced after flushing. For further details, please refer to EN 806-4.

8.10.3 Disinfection

Disinfection is not generally required for a detached house or small modifications/extensions.
If required, disinfection can be carried out for sections of the system in the following order: service pipes, supply pipes, storage tanks, distribution pipes.
During the process, it is necessary to ensure that no water is drawn off and the disinfectants used must comply with the requirements for the treatment of water as indicated in the standards or regulations in force.
The disinfectants must also be compatible with the components of the water supply system (pipes, fittings, seals, etc.). For anti-bacterial and anti-legionella treatments, refer to chapter 9.4.

PRESSURISED TEST REPORT WITH WATER FROM DOMESTIC WATER SYSTEM

Project: ....

Address: ....

Customer: ....

Installing company: ....

Test performer name: ....

Test date: ....

Wholesaler where the products have been purchased: ....

Type of pipes used

	14x2	16x2	16x2.25	18x2	20x2	20x2.25	20x2.5	25x2.5	26x3	32x3	40x3.5	50x4	63x4.5	75x5	90x7	110x10
Pexal	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	☐	☐	☐
Mixal	☐	☐		☐	☐			☐	☐	☐						

Type of fittings used

Pexal Brass ☐ Bravopress ☐ Pexal XL ☐ Pexal Easy ☐ Pexal Twist ☐ Connex-T ☐

Total installed pipe length (m): .... m

Check of leaks in non-pressed fittings

OPERATIONS TO BE PERFORMED	CHECK YES	CHECK NO
1. Connect a pressure gauge (with 0.2 bar steps) to the lowest part of the system	☐	☐
2. Fill the system with filtered water	☐	☐
3. The air in the system has been completely vented	☐	☐
4. Set system pressure from 0.5 to 2 bar	☐	☐
5. Set pressure value (between 0.5 and 2 bar)	.... bar	
6. Check if the pressure is stable at the set value (wait 10 minutes, if the pressure has dropped, restore it to the value in point 5 above)	☐	☐
7. Check all system fittings for leaks	☐	☐
8. Has the test been passed? (pressure drop must not be more than 0.2 bar)	☐	☐
9. Keep the system under pressure for 8 more hours	☐	☐
10. Has the test been passed? (pressure drop must not be more than 0.2 bar)	☐	☐

Load test (EN 806-4 procedure A)

OPERATIONS TO BE PERFORMED	CHECK YES	CHECK NO
1. Set system pressure to 1.1 times the design pressure (max 15 bar)	☐	☐
2. Set pressure value (max 15 bar)	.... bar	
3. Wait 30 minutes and check if the pressure has dropped (if the pressure has dropped, restore it to the value in point 2 above)	☐	☐
4. Load test start time	hours	
5. Wait 10 min	☐	☐
6. Load test end time	hours	
7. Has the test been passed? (pressure drop must not be more than 0.2 bar)	☐	☐

Customer signature

and stamp of the installing company

....

QUALITY FOR PLUMBING

PRESSURISED TEST REPORT WITH AIR FROM DOMESTIC WATER SYSTEM

Project: ....

Address: ....

Customer: ....

Installing company: ....

Test performer name: ....

Test date: ....

Wholesaler where the products have been purchased: ....

Type of pipes used

	14x2	16x2	16x2.25	18x2	20x2	20x2.25	20x2.5	25x2.5	26x3	32x3	40x3.5	50x4	63x4.5	75x5	90x7	110x10
Pexal	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	☐	☐	☐
Mixal	☐	☐		☐	☐			☐	☐	☐						

Type of fittings used

Pexal Brass ☐ Bravopress ☐ Pexal XL ☐ Pexal Easy ☐ Pexal Twist ☐ Connex-T ☐

Total installed pipe length (m): .... m

Check of leaks in non-pressed fittings

OPERATIONS TO BE PERFORMED		CHECK YES	CHECK NO
1. Connect a pressure gauge (with 1 mbar steps) to the lowest part of the system		☐	☐
2. The volume of the system is:		.... litres	
3. Based on the system volume in step 2, the test time is **(30 min. if VOL <100 litres. Add 10 minutes for every additional 100 l of system volume)**		.... minutes	
4. Fill the system with air at a pressure of 150 mbar		☐	☐
5. Set pressure value		.... bar	
6. Check if the pressure is stable at the set value		☐	☐
7. Visually check all system fittings for leaks		☐	☐
8. Has the test been passed?	(pressure drop must not be more than 1 mbar)	☐	☐
9. Keep the system under pressure for 8 more hours			
10. Has the test been passed?	(pressure drop must not be more than 1 mbar)	☐	☐

Load test (EN 806-4 procedure A)

OPERATIONS TO BE PERFORMED		CHECK YES	CHECK NO
1. Bring the system pressure to 3 bar if the maximum diameter is 50 mm, to 1 bar if the maximum diameter is 90 mm.		☐	☐
2. Set pressure value		.... bar	
3. Wait 30 minutes and check if the pressure has dropped (if the pressure has dropped, restore it to the value in point 2 above)		☐	☐
4. Load test start time		hours	
5. Wait 10 min		☐	☐
6. Load test end time		hours	
7. Has the test been passed?	(pressure drop must not be more than 0.1 bar)	☐	☐

Customer signature ....

and stamp of the installing company ....

valsir®

QUALITY FOR PLUMBING

8

WASTE SYSTEMS

SUPPLY SYSTEMS

GAS SYSTEMS

FLUSHING SYSTEMS

BATHROOM SYSTEMS

TRAPS

RADIANT SYSTEMS

DRAINAGE SYSTEMS

HRV SYSTEM

ACADEMY

SEWER SYSTEMS

WATER TREATMENT

SILMAR GROUP

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