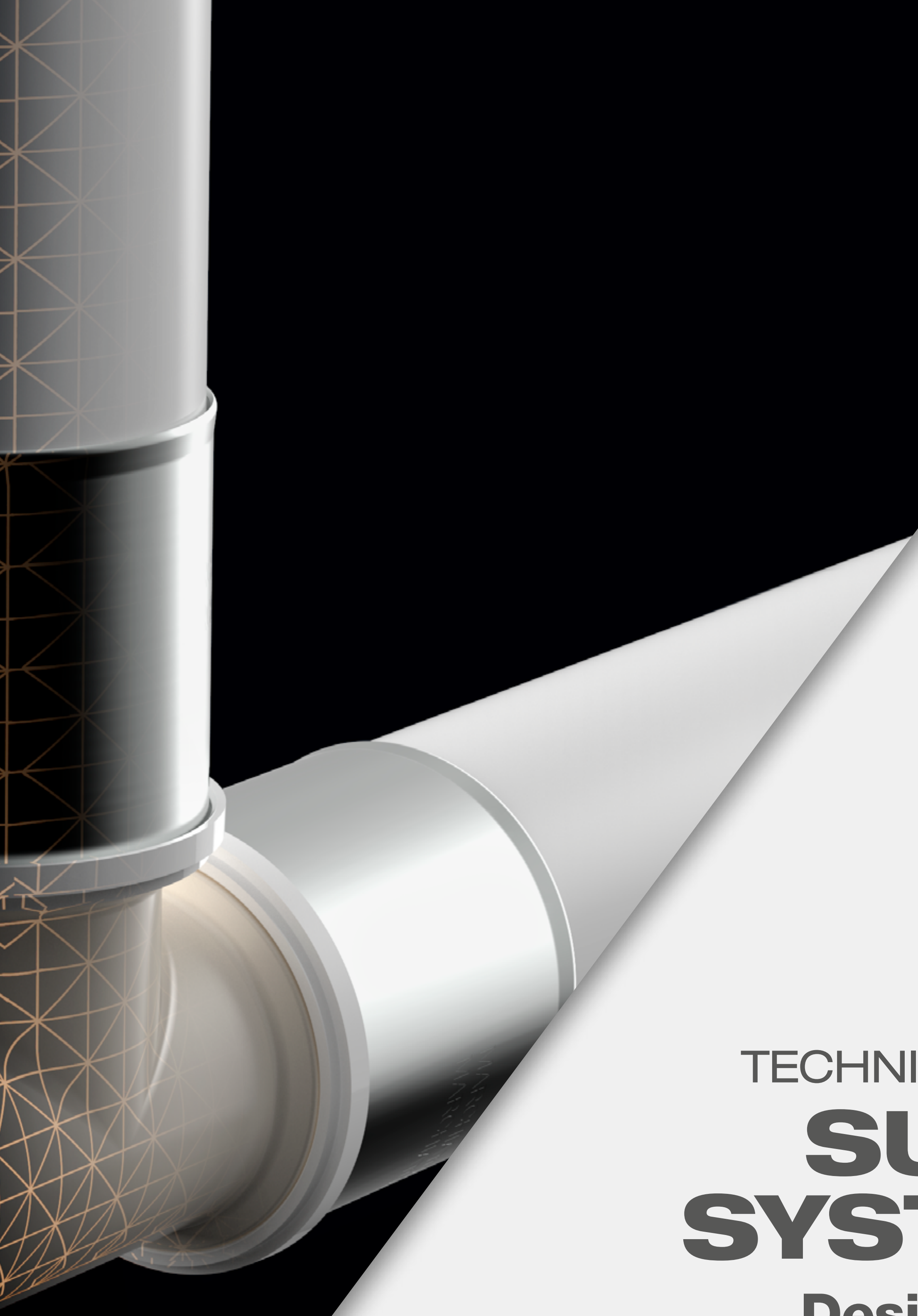

④

TECHNICAL MANUAL

SUPPLY SYSTEMS

Design of water supply systems

MADE IN ITALY

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QUALITY FOR PLUMBING

4

DESIGN OF WATER SUPPLY SYSTEMS

4
DESIGN OF WATER SUPPLY SYSTEMS

4

4.1 Introduction

In Italy, the applicable standards for the design of water supply systems are UNI 9182 as well as EN 806-2 and EN 806-3. The objectives of the design of a water supply system are:

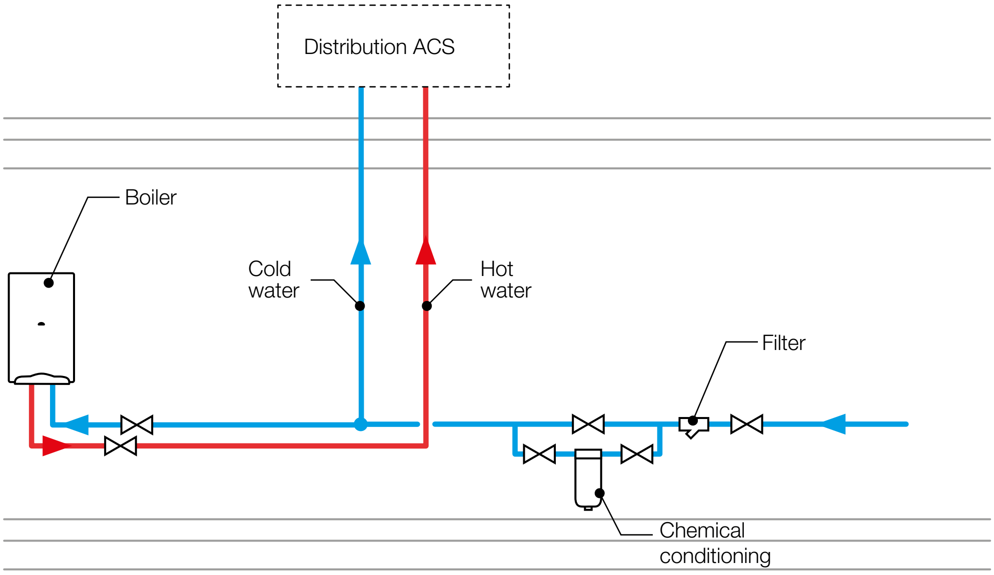
- Reduction of water and energy wastage (for example, when supplying DHW).
- Avoid excessive speed in the pipes (to minimize noise and the risk of water hammer).
- Supply water to each fixture unit at the design pressure and temperature.
- Avoid air entering the pipes.
- Protect the occupants of the building from dangers caused by use of the system.
- Avoid damages to the pipes (corrosion) and the deterioration in the quality of the drinking water.
- Facilitate access to and servicing of the system.

The pipes and fittings used must be chosen and designed to guarantee a system service life of at least 50 years, following a regular maintenance program.

4.2 DHW production systems

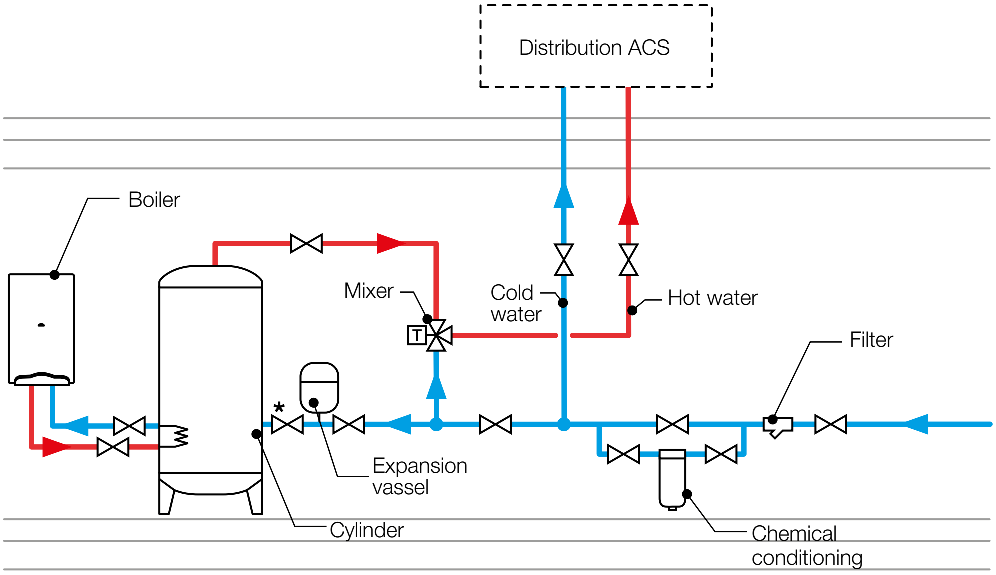
A DHW production system can be instantaneous or with a storage cylinder and the elements that make up the system also depend on whether or not there is a recirculation system.
An instantaneous system produces the necessary hot water “on demand”, starting up when a hot water fixture is turned on. It is the simplest configuration, as shown in Figure 4.1. Before entering the network, the cold water can be suitably filtered and softened. A softener is a device that reduces the hardness of the water, that is, it reduces the concentration of calcium and magnesium, which are the main causes of the formation of limescale on surfaces.

Figure 4.1 Instantaneous DHW production system.



When a DHW production system has been designed both to be instantaneous (or direct) and to use a preheated supply of water from a cylinder tank, it is called a storage system. This technical solution allows a less powerful heater to be used as compared with systems providing instant production only, as the volume of the storage cylinder (the sizing of which is dealt with in paragraph 6.1) is determined according to the consumption of hot water in peak periods.
Systems with storage cylinders also increase the efficiency of the heat producers because frequent switching on and off is avoided, allowing it to operate within the maximum efficiency range. To maintain the correct temperature in the storage cylinder, different sources of heat can be used, such as boilers, solar panels, heat pumps and fireplace stoves, which are often used in combination. Figure 4.2 shows the components that typically make up this system when recirculation is not used. In order to overcome the risks associated with the storage of hot water (such as, for example, the proliferation of the legionella bacterium dealt with in appendix 9.4) the water in the tank is always kept at a temperature above 60°C.
Since the different elements that contribute to heating the volume of water in the cylinder can further increase its temperature, downstream of the point of use of the system, a mixer is installed to guarantee the correct temperature of the water for distribution and for the next usage.
To compensate for variations in the pressure of the heated water, an expansion vessel must be added to the system, the functioning and sizing of which is dealt with in para graph 6.2.

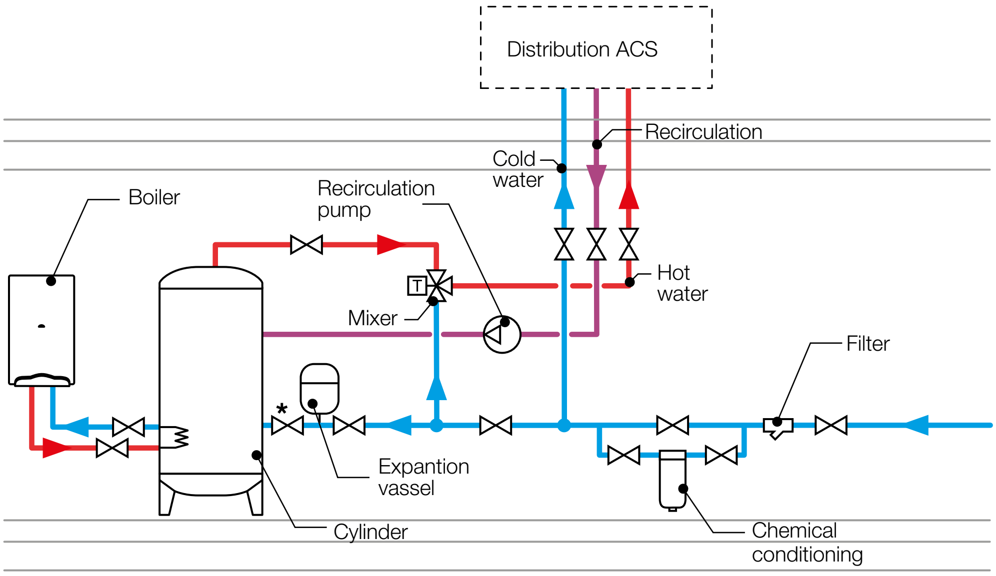
Figure 4.2 DHW production system with cylinder.



*To be used in heating systems over 35 kW (see chapter 6.2)

A production system with a cylinder is always the best choice if it is necessary to create a recirculation system (Figure 4.3). Due to the recirculation system, the hot water is always kept in movement thanks to a pump, therefore making it immediately available at the various fixture units.

Figure 4.3 DHW production system with cylinder and recirculation.



*To be used in heating systems over 35 kW (see chapter 6.2)

4.3 Distribution networks

Systems or distribution networks are a combination of pipes which, starting from the supply, whether it is cold water from the point of connection to the mains or hot water from the DHW generator, distributes water to the various fixture units in the building. There are distribution networks for cold water and for hot water and these differ depending on the location of the source and the supply manifolds.

In cold-water distribution networks, if the water mains is not able to guarantee the correct operating pressure at all points of use, it will be necessary to install a system that increases the pressure (an autoclave) or a cylinder in a raised position. In centralized hot water distribution systems, there is often a recirculation system that guarantees a rapid supply at design temperature and flow conditions (paragraph 4.7).

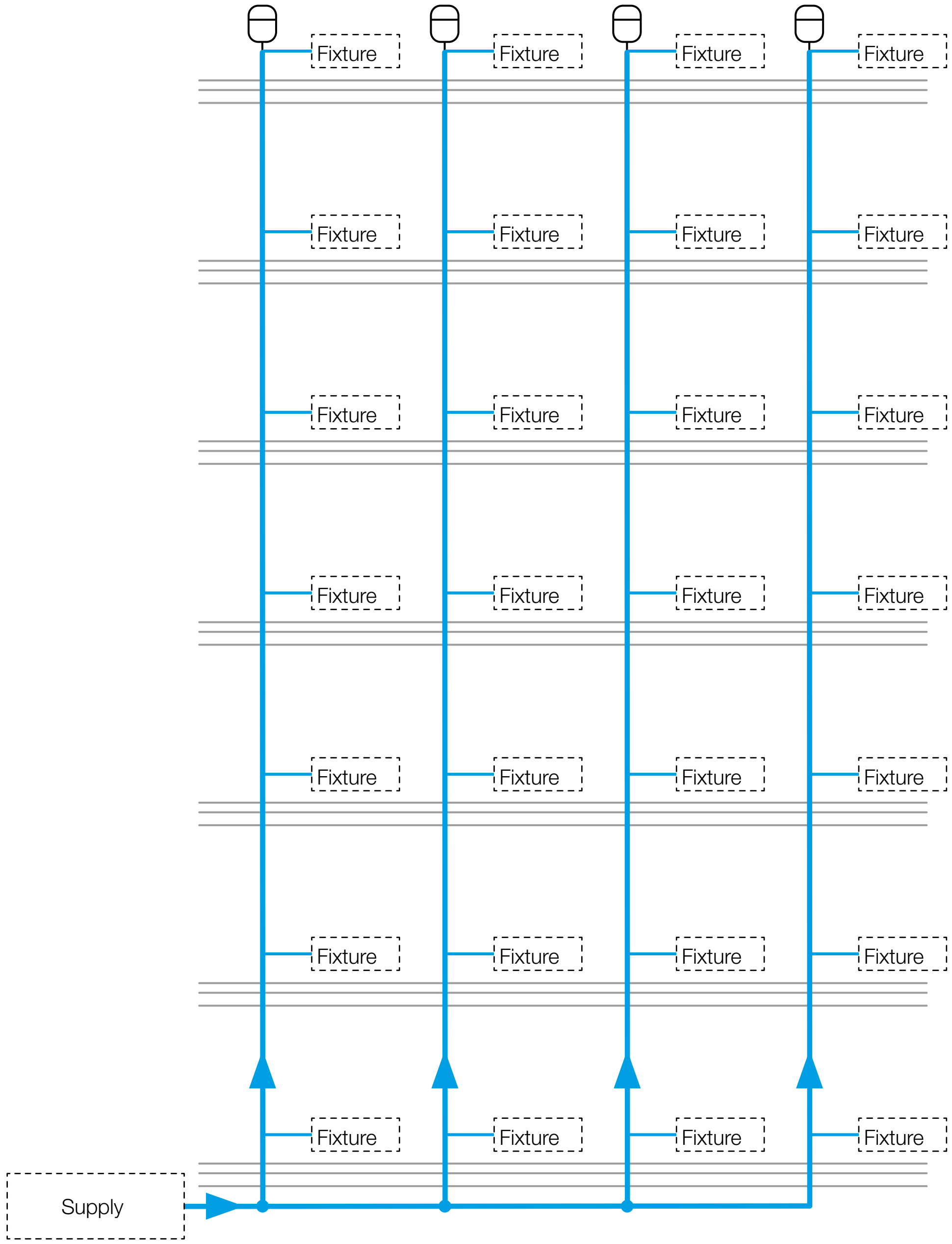
The pressure of hot and cold water at the same fixtures must be identical to ensure that the mixing device functions correctly. To properly design a water supply system, first and foremost, the best distribution system must be chosen, based on the location of the most disadvantaged fixtures, on the available pressure exiting the sources and on the size of the building.

4.3.1 Cold water networks

Distribution from below (at the source)

This is the most widely used system, in which the supply manifold is located below and hence the supply riser pipes providing cold water also start out from below. The branch lines to the individual floors lead off from the supply riser pipes. In the upper part of each riser pipe, a device should be installed to reduce the effect of water hammer, whereas at the bottom it is advisable to fit a stop valve to allow isolation from the rest of the system in the event of malfunction or servicing.

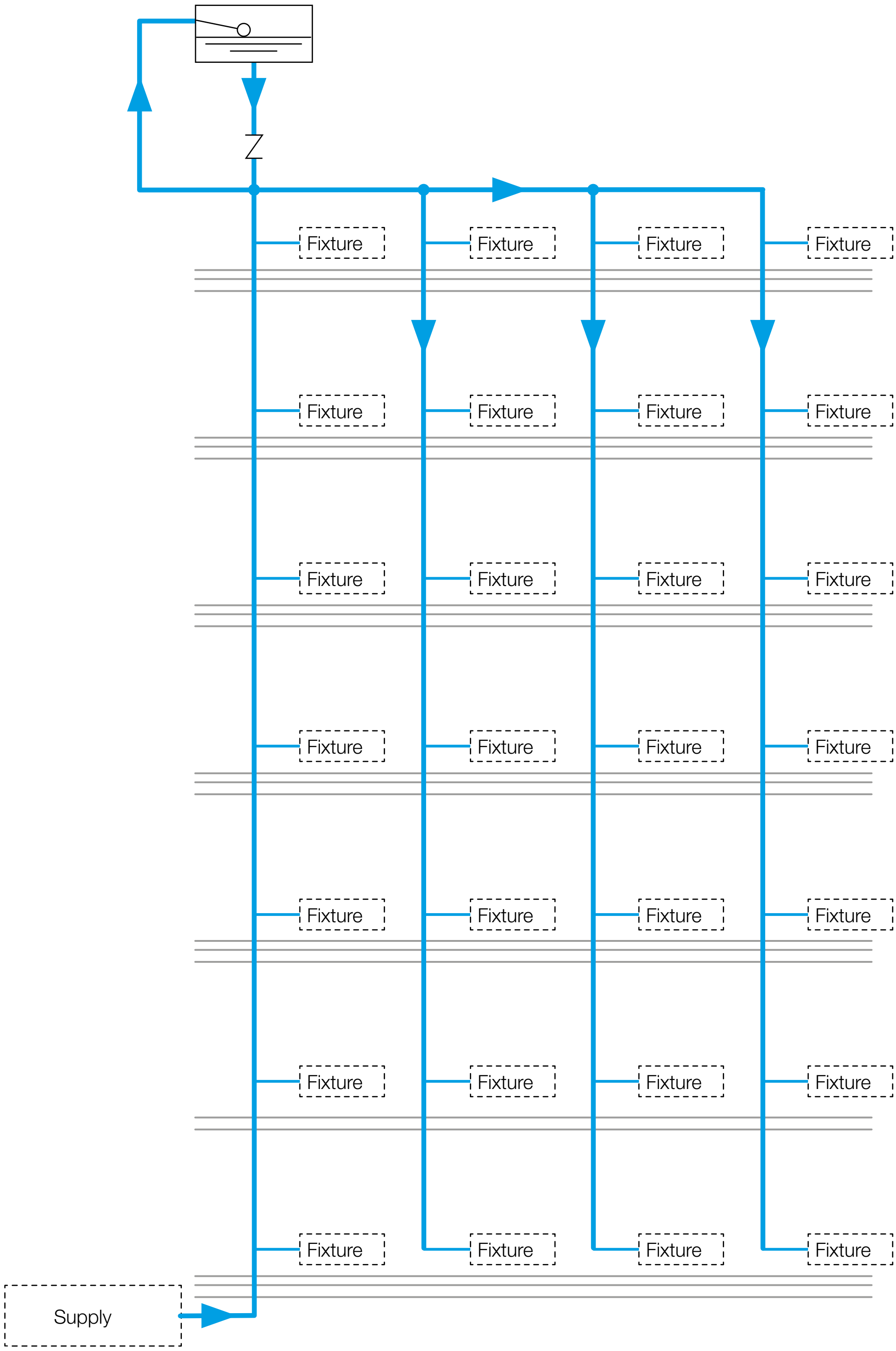
Figure 4.4 Cold water distributed from below (at the source).



Distribution from above

This type of system is generally used when the pressure available at the mains is not constant over time, for example, in large cities where there are significant reductions in pressure at peak times and it is therefore not sufficient to meet the demands of the least favourable fixtures in the building. A cylinder and a distribution manifold are located at a raised level and they supply the supply down pipes and branch lines to each floor. The cylinder only comes into operation when the upper floors do not receive the necessary pressure from the source. The correct direction of the flow from the cylinder is guaranteed by a check valve.

Figure 4.5 Cold water distributed from above.

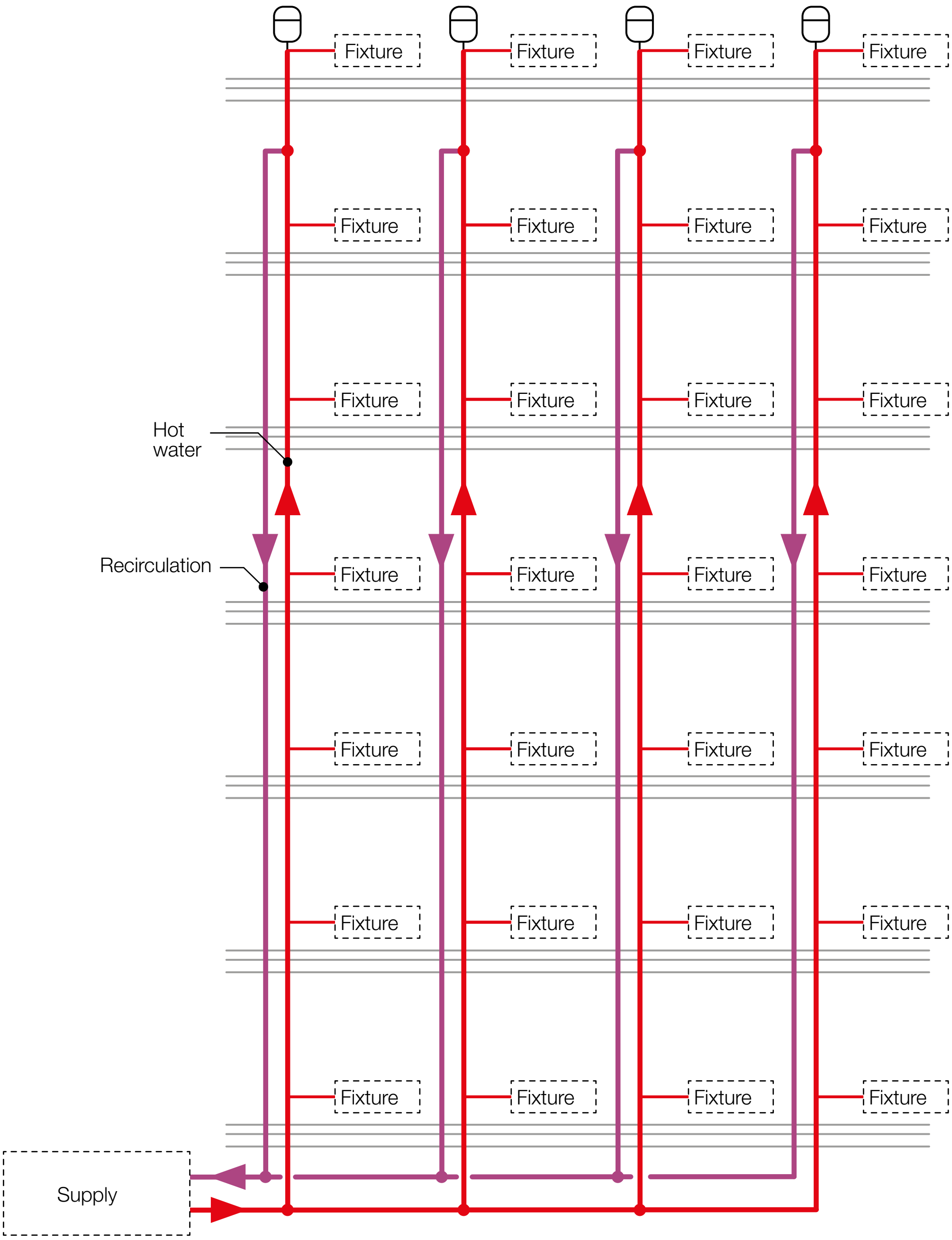


4.3.2 Hot water networks

Supply from below and water heater below

This is the most widely used type of distribution in which both the hot water manifold and the recirculation manifold are located below. The hot water riser pipes (at the top of which water hammer reducers are installed) and the recirculation down pipes (if any) are connected here.

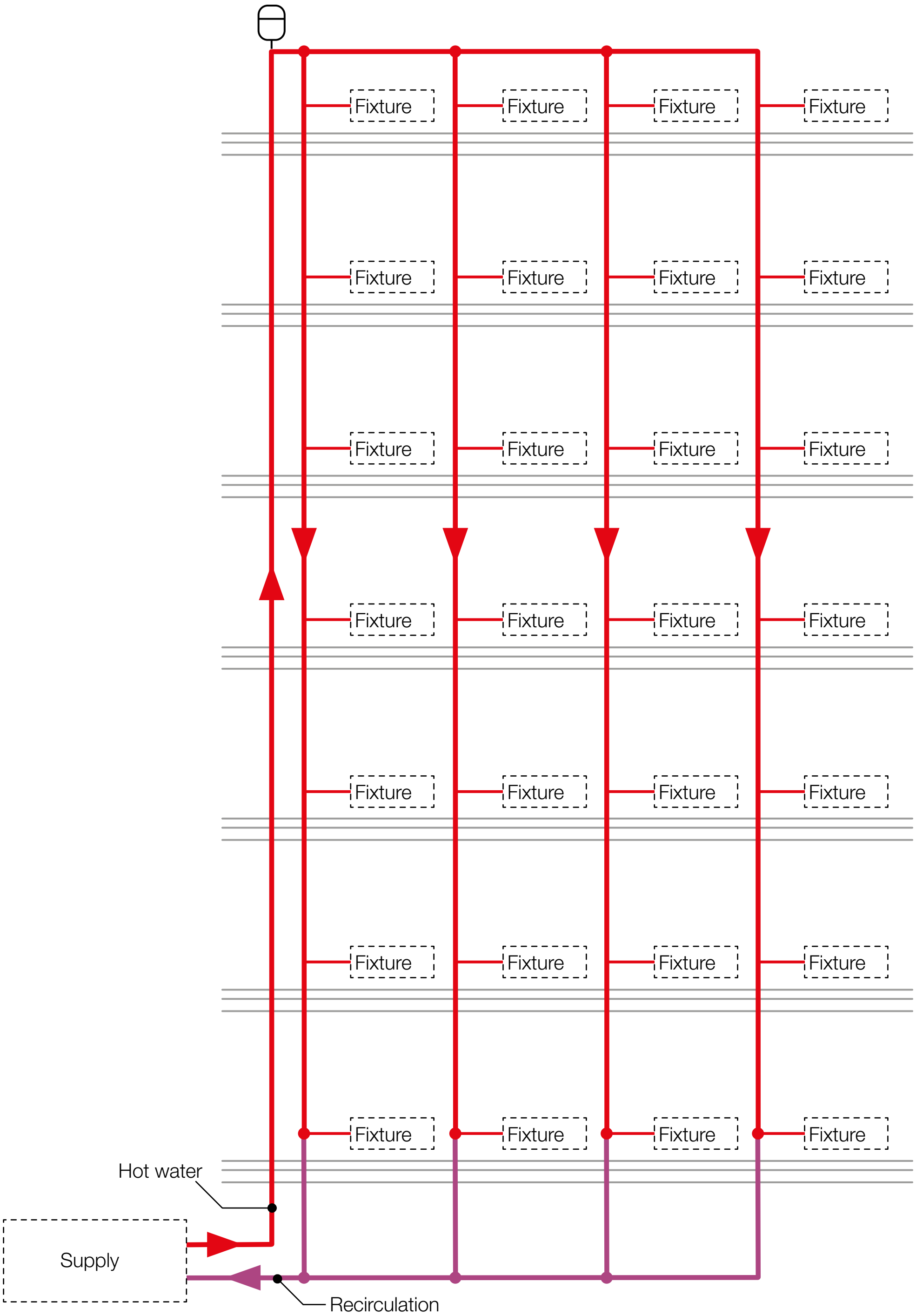
Figure 4.6 Supply from below and water heater below.



Supply from above and water heater below

The advantage of this configuration over the previous one is that fewer pipes are required when otherwise many distribution risers would have been necessary. A riser (at the top of which a water hammer reducer is installed) brings hot water from the source to the manifold at the top that supplies the down pipes, which are connected to the branch lines to each floor. The recirculation manifold is positioned below.

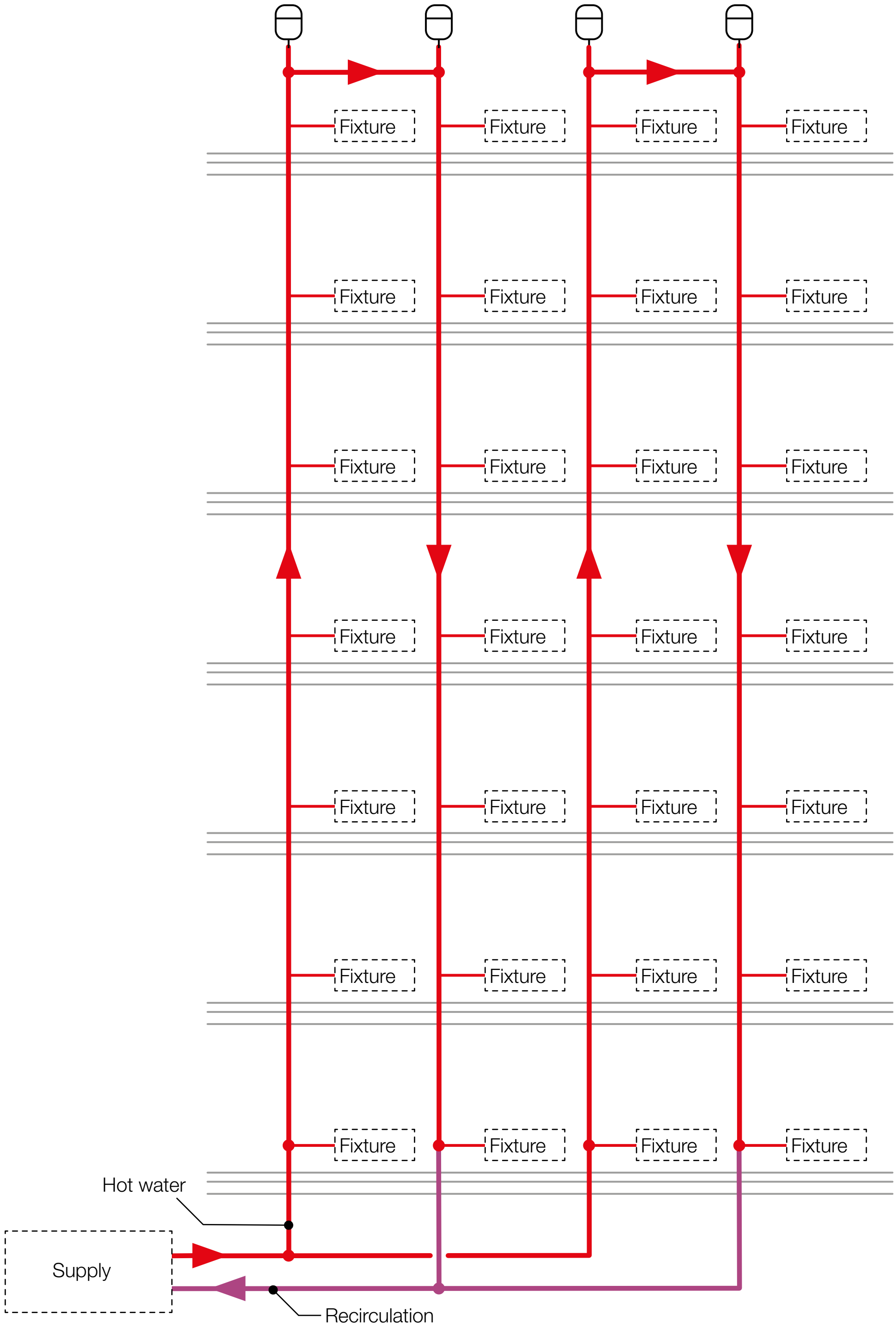
Figure 4.7 Supply from above and water heater below.



Mixed supply from below and from above and water heater below

The supply manifold is placed below for some portions of the system and above for others.
Recirculation pipes are not necessary and the recirculation manifold is positioned below. A water hammer reducer is installed at the top of each supply pipe (riser or down pipe).

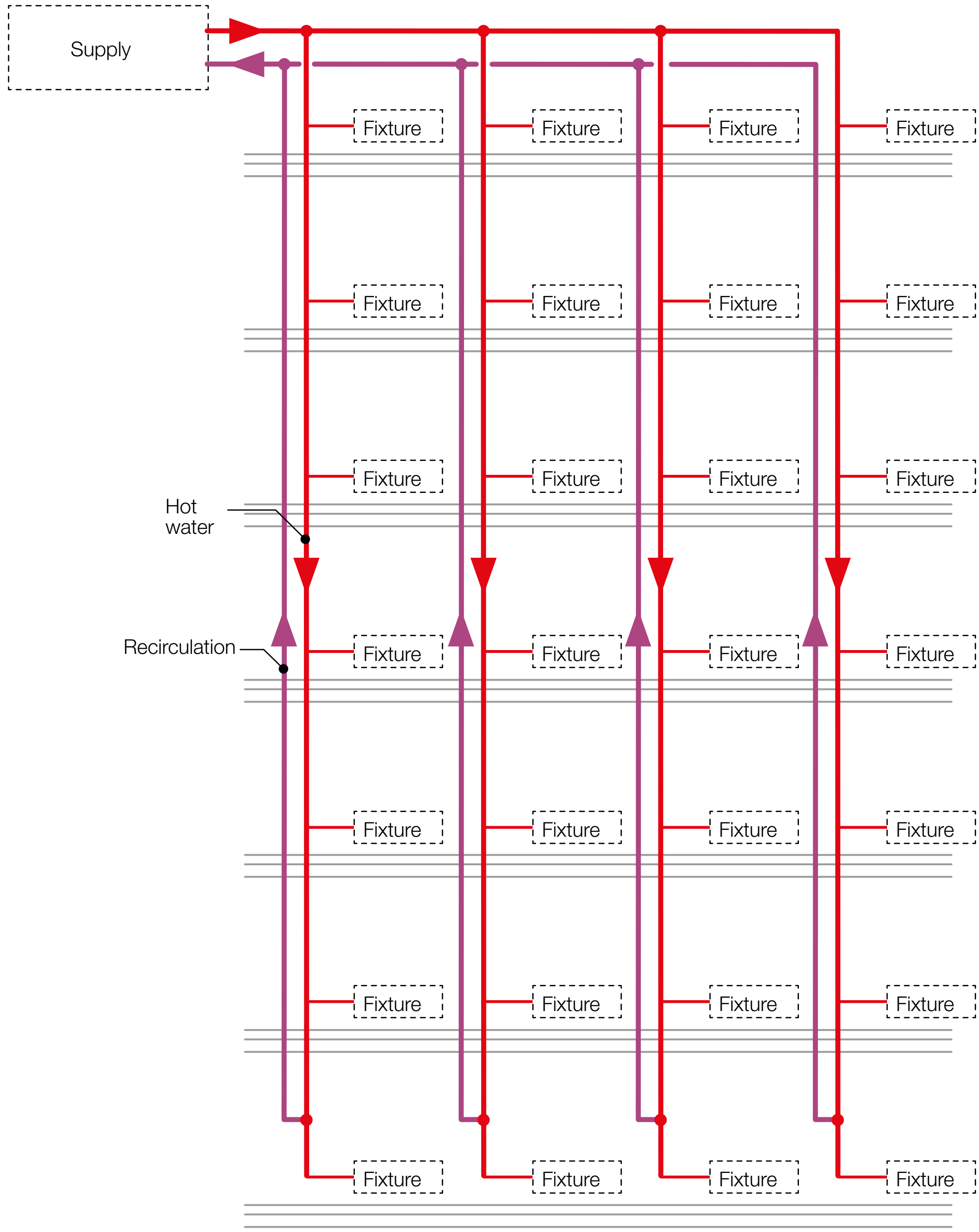
Figure 4.8 Mixed supply from below and from above and water heater below.



Supply from above and water heater above

In this configuration both the hot water manifold and the recirculation manifold are above, with supply down pipes and recirculation riser pipes.

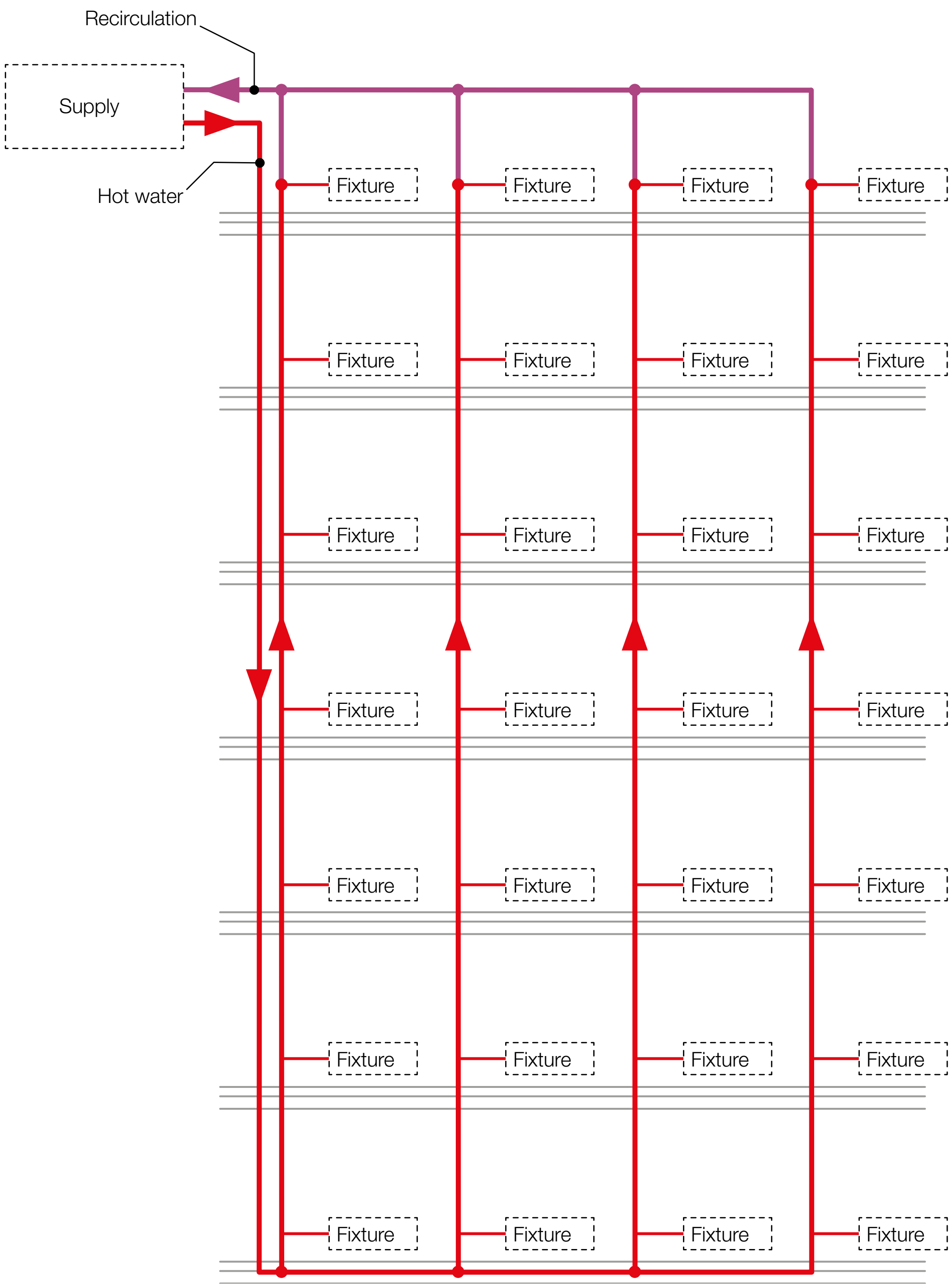
Figure 4.9 Supply from above and water heater above.



Supply from below and water heater above

This type of system is characterised by a supply and recirculation manifold below and by just one supply down pipe, while the others are all risers. Recirculation pipes are not necessary thanks to the recirculation manifold located above.

Figure 4.10 Supply from below and water heater above.



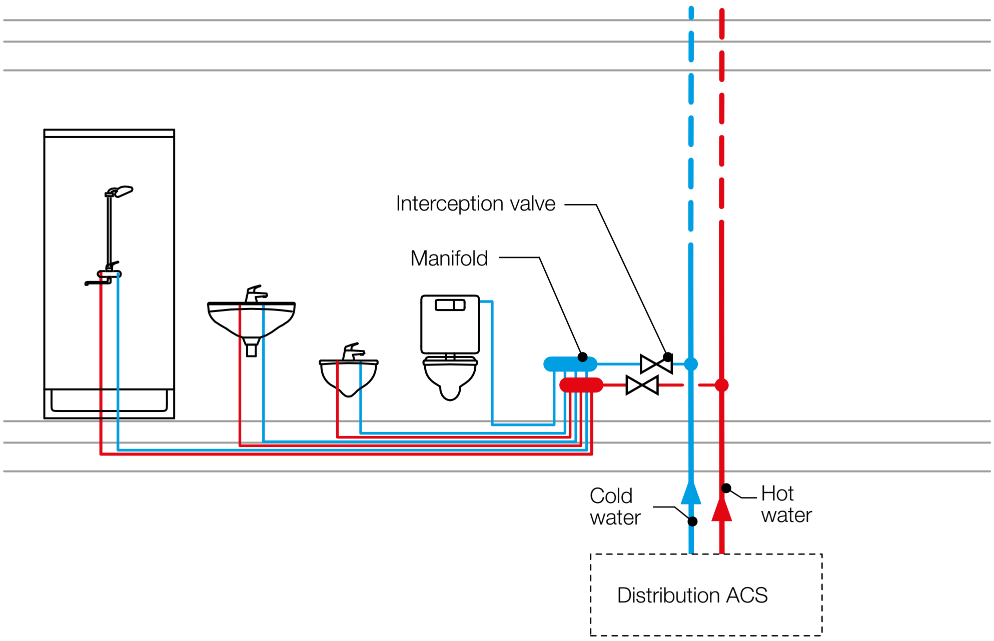
4.3.3 Branch lines and connections to terminal units

The terminal sections of the water supply distribution network, that is, those connecting the supply pipes to the points of use of each fixture, are called branch lines. Every residential unit must have at least one shut-off valve that allows it to be isolated from supply. The pipes of the branch lines can be installed under the floor or in the wall, by choosing different options.

Manifold systems

These are composed of distribution elements installed in pairs, one for cold water and one for hot water with a variable number of outlets depending on the type and quantity of sanitary appliances installed. This is the most widely used type of system in the residential sector, appreciated thanks to the time savings that it ensures during installation and the absence of underground junctions. Each outlet of the manifold can incorporate a stop valve or a flow control valve, so that it is possible to cut off or regulate the flow for each point of use.
The manifolds are generally installed in a concealed cabinet and equipped with stop valves that allow complete isolation from the rest of the system. There may be more than one manifold in the same residential unit, for example, one in the bathroom and one in the kitchen.

Figure 4.11 Manifold system.



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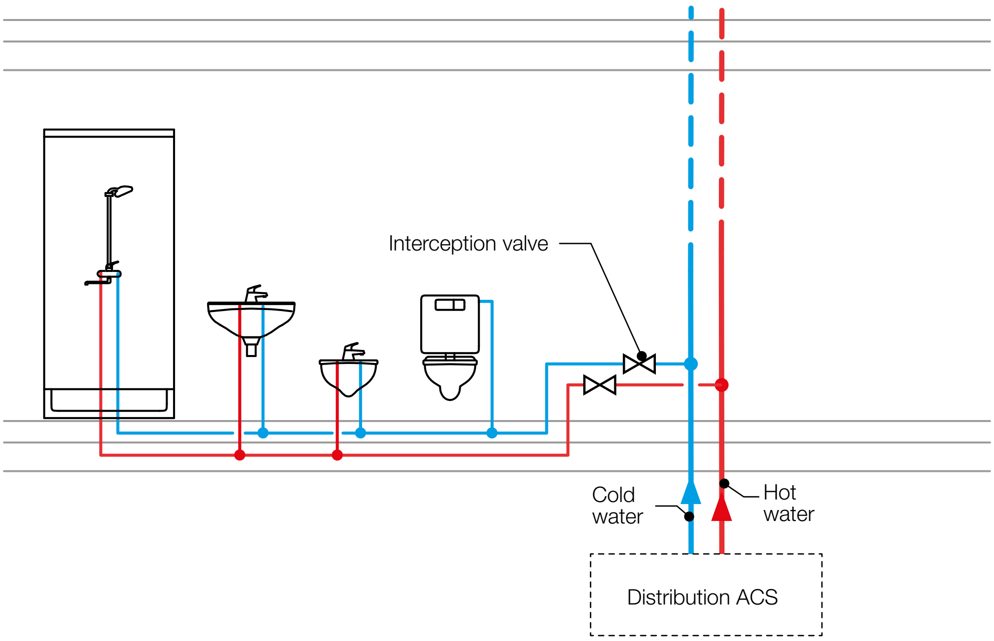
4

Branch systems

In this type of installation, the various fixture units are connected one after the other to the same trunk line, generally using tee fittings. Today this type of system is not used very often since, there are several disadvantages in comparison with manifold systems. Most importantly, the flows and pressures at the fixtures are influenced by each other: when one tap is opened, there is a reduction in the available flow to the other fixtures. Secondly, many joints are in chases and in the event of problems with the system, the walls need to be broken and hence repairs are expensive.

Figure 4.12 Branch systems.

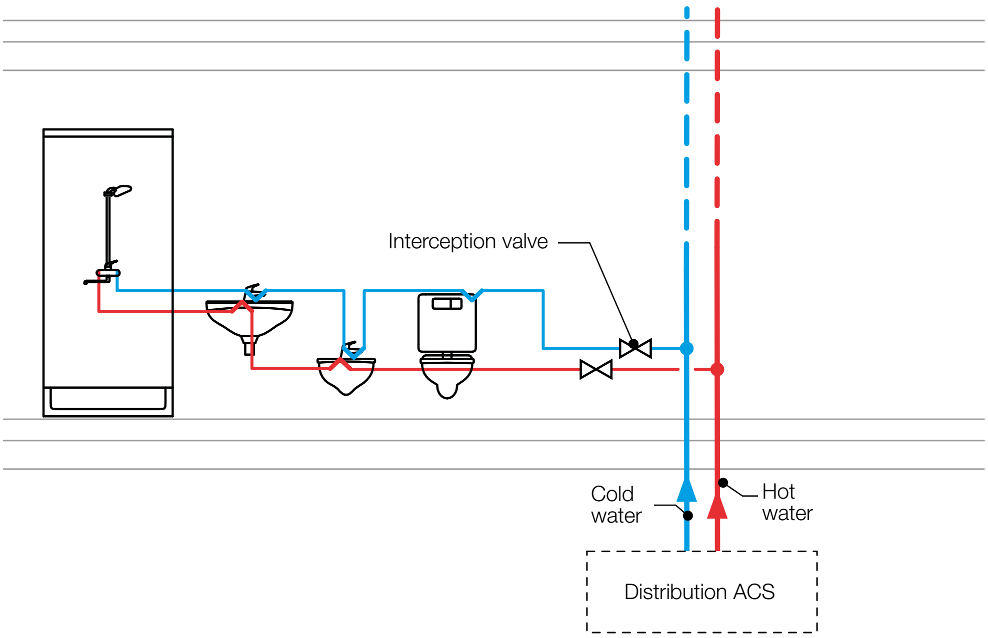


Derivation system with 15° terminal fittings

In this type of system, the various utilities are connected in series through the 15° terminal fitting, except for the last domestic water fitting connected with flanged fittings. The main benefit compared to the installation with the derivation T is the absence of floor junctions; in fact, the system is made on the wall and therefore allows avoiding the T fitting. As in the previous case, the use of a utility affects the flow rate available to the other utilities since they are all connected in series.

Figure 4.13 15° fitting.

Figure 4.14 System in series with 15° fitting.



4.3.4 Derivations and connections to terminal units

Ring systems

Also called closed circuit systems, they are mainly used in sanitary and hotel environments as they reduce water stagnation in the most rarely used utilities. The construction principle is to connect all the utilities to the same pipe (loop) thanks to special U-shaped fittings (Figure 4.15), thus avoiding any dead branches.

Figure 4.15 U- fitting.

In the simple loop distribution (Figure 4.16) the utilities are connected in series with a single pipe that connects to the riser pipe and closes the loop. In the distribution with recirculation (Figure 4.17) instead, the return pipe is no longer connected on the riser pipe but on the recirculation column. Both solutions allow the continuous flow of water contained in the circuit even if only one utility is used, regardless of which one it is.

Figure 4.16 Simple ring circuit.

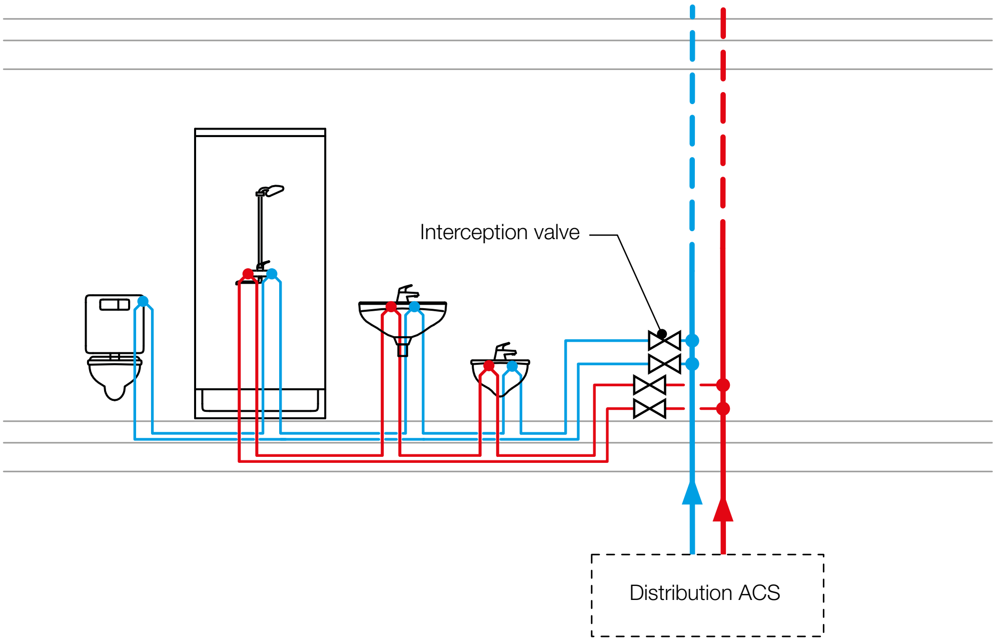
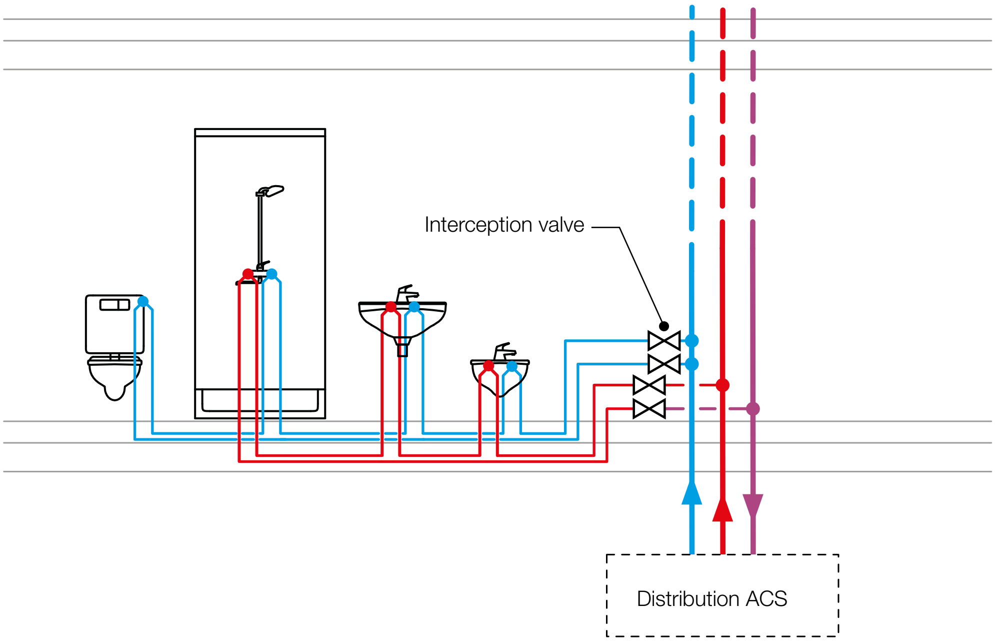


Figure 4.17 Ring with recirculation circuit.



There are several benefits for this type of system. The first is certainly that relating to protection against legionella (described in the appendix of this manual). For protection against legionella, the system must be designed and installed so as to avoid water stagnation; in this regard, according to standard UNI EN 806-5, a domestic water system is considered hygienically managed only if a complete change of water is guaranteed within a period of 7 days. Therefore, the use of a ring solution allows a continuous recirculation of hot and cold water inside each section of pipe, thus eliminating any blind sections.

Another benefit relates to chemical or thermal disinfection treatments; with this type of system, treatments can reach all sections of the system, thus ensuring better results compared to traditional systems. The ring system configuration also allows for an inherent balancing of pressures and temperatures inside the system and, therefore, allows for shorter response times in hot water delivery.

With the same diameter it is possible to connect more utilities, as each section of pipe is not sized according to its maximum flow rate (traditional method) but according to the principle of closed meshes.
Compared to a manifold system, where the diameters used already depend on the individual utility, there is a saving on the amount of pipe used, since it is not necessary to connect the different utilities independently.
For sizing of these systems, as they are closed loops, iterative calculation methods such as Hardy-Cross are used, in addition to compliance with current regulatory constraints.
In simplified form, if the following conditions apply, it is possible to use Table 4.1 and Table 4.2

- Maximum circuit length 20 m.
- Maximum permissible pressure drops in the circuit of 1 bar.
- Utilities with flow rates equal to or lower than those shown in the tables.

Table 4.1 Simplified sizing for individual-use ring circuits.

Individual use (residential, hotels, hospitals)					
Sink, bidet, toilet 0.1 l/s	Washing machine, kitchen sink, dishwasher 0.15 l/s	Shower 0.2 l/s	Tub 0.3 l/s	Total flow rate [l/s]	Pipe diameter [mm]
2	-	-	-	0.2	16
-	2	-	-	0.3	16
2	1	-	-	0.35	16
2	1	1	-	0.55	16
3	-	-	1	0.6	16
3	2	-	-	0.6	16
3	1	1	-	0.65	16
4	2	-	-	0.7	20
3	1	-	1	0.75	20

Table 4.2 Simplified sizing for collective-use ring circuits.

Collective use (schools, gyms, sports facilities)			
Sink, bidet, toilet 0.1 l/s	Shower 0.2 l/s	Total flow rate [l/s]	Pipe diameter [mm]
3	-	0.3	16
4	-	0.4	16
5	-	0.5	16
4	1	0.6	20
4	2	0.8	20

4.4 Prerequisites of a water supply system

4.4.1 Water flow

Paragraphs 4.5 and 4.6 will deal with the dimensioning of the pipes in compliance with EN 806-3 (simplified method) and UNI 9182 (detailed method). The water flows are calculated in a specific way depending on the calculation method used.

4

Water flows according to EN 806

The loading units method is used (LU, Loading Units) with:

$$1\ \text{LU} = 0.1\,\frac{\text{l}}{\text{s}} \qquad [4.1]$$

In some standards, said loading units are abbreviated to UC. This calculation method is used both for hot water and for cold water pipes. Each point of use is given a flow Q_A [l/s], which corresponds to the loading units indicated in Table 4.3.

It should be noted that these values are not related to the product standards of sanitary appliances and are used for dimensioning purposes only. For non-domestic points of use, the flow must be supplied by the producer.

The design flow rate Q_D [l/s], which represents the flow that is effectively used for the dimensioning of the pipes, is obtained from Figure 4.18 once the sum of the loading units ($\sum$LU) is known for a determined section of the system. The part of the graph between $\sum$LU = 2 and $\sum$LU = 300 is made up of six different segments based on the maximum loading unit (LU_{max}) of the sanitary appliances connected to the section of the system under consideration, which is defined according to the values shown in Table 4.3.

For example: having to calculate the design flow rate that is allocated to a section of the system where five sanitary appliances have been installed, each with 2 LU (therefore $\sum$LU = 10), the segment with LU_{max} = 2 is considered. The design flow rate is 0.4 l/s. For the same calculation on a system section where two sanitary appliances are installed, each with 5 LU (therefore $\sum$LU = 10), the segment with LU_{max} = 5 is considered.

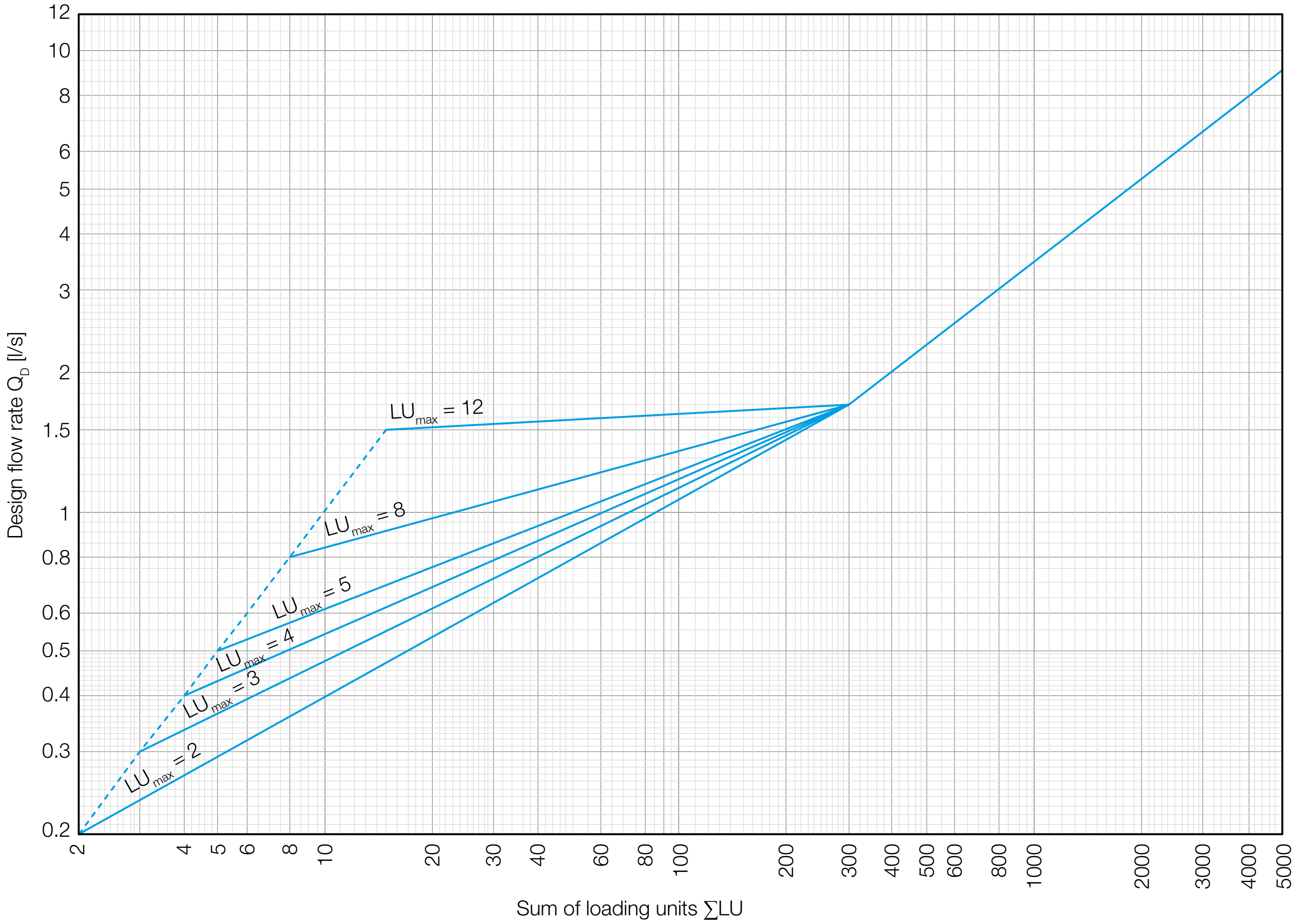
The result is a design flow rate of roughly 0.6 l/s.

The values of the design flow rate Q_D are expressed in relation to the possible contemporaneities but there is no distinction between different types of building.

Table 4.3 Loading units for different points of use (EN 806-3).

Point of use	Flow rate Q_A [l/s]	Loading unit (LU)
Washbasin, bidet, WC	0.1	1
Domestic sink, dishwasher, domestic washing machine, shower	0.2	2
Urinal with outlet valve	0.3	3
Domestic bathtub	0.4	4
Garden or garage taps	0.5	5
Non-domestic sinks and bathtubs DN20	0.8	8
DN20 outlet valve	1.5	15

Figure 4.18 Design flow rate Q_D [l/s] in relation to the ∑LU [l/s].



Water flow rates according to UNI 9182

For the Q_A flow rates to the individual points of use (and therefore for the dimensioning of the terminal sections of the system) please refer to Table 4.4:

Table 4.4 Q_A flow rates for different points of use (UNI 9182).

Point of use	Flow rate Q_A [l/s]
Washbasin, bidet, WC	0.1
Domestic sink, dishwasher, domestic washing machine, shower, urinal	0.15
Domestic bathtub	0.3
Garden hydrant/tap	0.4
WC with direct flush or flowmeter	1.0

For the calculation of the Q_D design flow rates in the sections of the network that supply two or more fixture units, the loading unit (LU) method is used but with a different approach from the one defined in EN 806-3: the loading units of UNI 9182 do not have measurement units [l/s] but are dimensionless values.

In Table 4.5 and Table 4.6 the LUs are indicated for the fixtures for private dwellings and buildings for collective use, which, as can be noted, do not have a direct correlation with the flows Q_A of Table 4.4.

The values indicated in the “Cold water AF” column are to be used to dimension the cold water network, those in the “Hot water AC” column to dimension the hot water network, while those in the “Total AF + AC” column to determine the total loading units upstream of the producer of DHW.

Table 4.5 Loading units for the fixtures of private households.

Appliance	Supply	Loading units		
		Cold water AF	Hot water AC	Total AF + AC
Washbasin	Mixer	0.75	0.75	1.00
Bidet	Mixer	0.75	0.75	1.00
Bathtub	Mixer	1.50	1.50	2.00
Shower	Mixer	1.50	1.50	2.00
Pan	Cistern	3.00	-	3.00
Pan	Direct flush or flowmeter	6.00	-	6.00
Kitchen sink	Mixer	1.50	1.50	2.00
Washing machine	Cold water only	2.00	-	2.00
Dishwasher	Cold water only	2.00	-	2.00
Basin	Mixer	1.50	1.50	2.00
3/8" hydrant	Cold water only	1.00	-	1.00
1/2" hydrant	Cold water only	2.00	-	2.00
3/4" hydrant	Cold water only	3.00	-	3.00
1" hydrant	Cold water only	6.00	-	6.00

Table 4.6 Loading units for buildings for public and collective use.

Appliance	Supply	Loading units		
		Cold water AF	Hot water AC	Total AF + AC
Washbasin	Mixer	1.50	1.50	2.00
Bidet	Mixer	1.50	1.50	2.00
Bathtub	Mixer	3.00	3.00	4.00
Shower	Mixer	3.00	3.00	4.00
Pan	Cistern	5.00	-	5.00
Pan	Direct flush or flowmeter	10.00	-	10.00
Urinal	Valve	0.75	-	0.75
Urinal	Direct flush or flowmeter	10.00	-	10.00
Sink	Mixer	2.00	2.00	3.00
Kitchen sink	Mixer	3.00	3.00	4.00
Basin	Mixer	2.00	2.00	3.00
Slop sink	Cistern	5.00	-	5.00
Slop sink	Direct flush or flowmeter	10.00	-	10.00
Channel washbasin (for each place)	Mixer	1.50	1.50	2.00
Foot washing basins	Mixer	1.50	1.50	2.00
Pan washers	Mixer	2.00	2.00	3.00
Hospital sink	Mixer	1.50	1.50	2.00
Water fountain	Spring tap	0.75	-	0.75
Emergency shower	Pressure control	3.00	-	3.00
3/8" hydrant	Cold water only	2.00	-	2.00
1/2" hydrant	Cold water only	4.00	-	4.00
3/4” hydrant	Cold water only	6.00	-	6.00
1” hydrant	Cold water only	10.00	-	10.00

For each section of the system that supplies a combination of sanitary appliances, the LUs for each appliance in the combination must be summed up. Once known the sum of the loading units (∑LU), the design flow rate Q_D [l/s] is determined for each section of the system thanks to Table 4.7 to Table 4.10, that are defined according to the type of building and the use of pans with direct flush cisterns. Alternatively, the Q_D can be obtained directly from Figure 4.19 and Figure 4.20.

4

Table 4.7 Design flow rates Q_D for systems in private dwellings and buildings for collective use (hotels, hospitals, schools, barracks, sport centres and similar) that have pans with cisterns.

∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]
6	0.30	120	3.65	1,250	15.50
8	0.40	140	3.90	1,500	17.50
10	0.50	160	4.25	1,750	18.80
12	0.60	180	4.60	2,000	20.50
14	0.68	200	4.95	2,250	22.00
16	0.78	225	5.35	2,500	23.50
18	0.85	250	5.75	2,750	24.50
20	0.93	275	6.10	3,000	26.00
25	1.13	300	6.45	3,500	28.00
30	1.30	400	7.80	4,000	30.50
35	1.46	500	9.00	4,500	32.50
40	1.62	600	10.00	5,000	34.50
50	1.90	700	11.00	6,000	38.00
60	2.20	800	11.90	7,000	41.00
70	2.40	900	12.90	8,000	44.00
80	2.65	1,000	13.80	9,000	47.00
90	2.90			10,000	50.00
100	3.15				

Table 4.8 Design flow rates Q_D for systems in private dwellings and buildings for collective use (hotels, hospitals, schools, barracks, sport centres and similar) that have direct flush pans.

∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]
10	1.70	120	7.15	1,250	21.00
12	1.90	140	7.50	1,500	23.00
14	2.10	160	8.00	1,750	24.50
16	2.27	180	8.50	2,000	26.00
18	2.45	200	9.00	2,250	27.50
20	2.60	225	9.50	2,500	28.50
25	2.95	250	10.00	2,750	29.50
30	3.25	275	10.50	3,000	30.50
35	3.55	300	11.00	3,500	33.00
40	3.80	400	12.70	4,000	35.00
50	4.30	500	14.00	4,500	36.50
60	4.80	600	15.10	5,000	37.50
70	5.25	700	16.30	6,000	40.50
80	5.60	800	17.30	7,000	44.00
90	6.00	900	18.20	8,000	46.00
100	6.35	1,000	19.00	9,000	48.00
				10,000	50.00

Figure 4.19 Curve of design flow rates Q_D for systems in private dwellings and buildings for collective use.

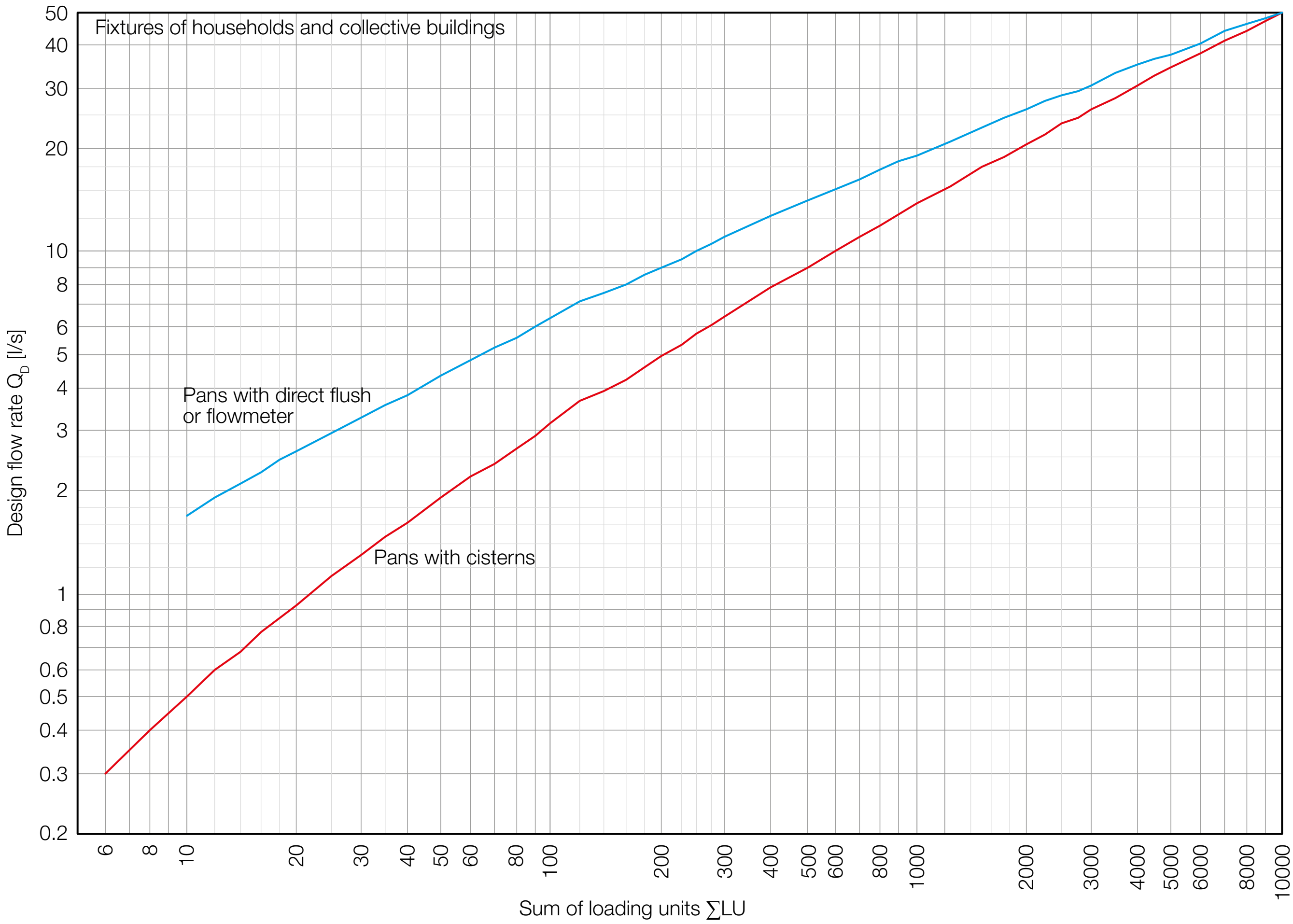


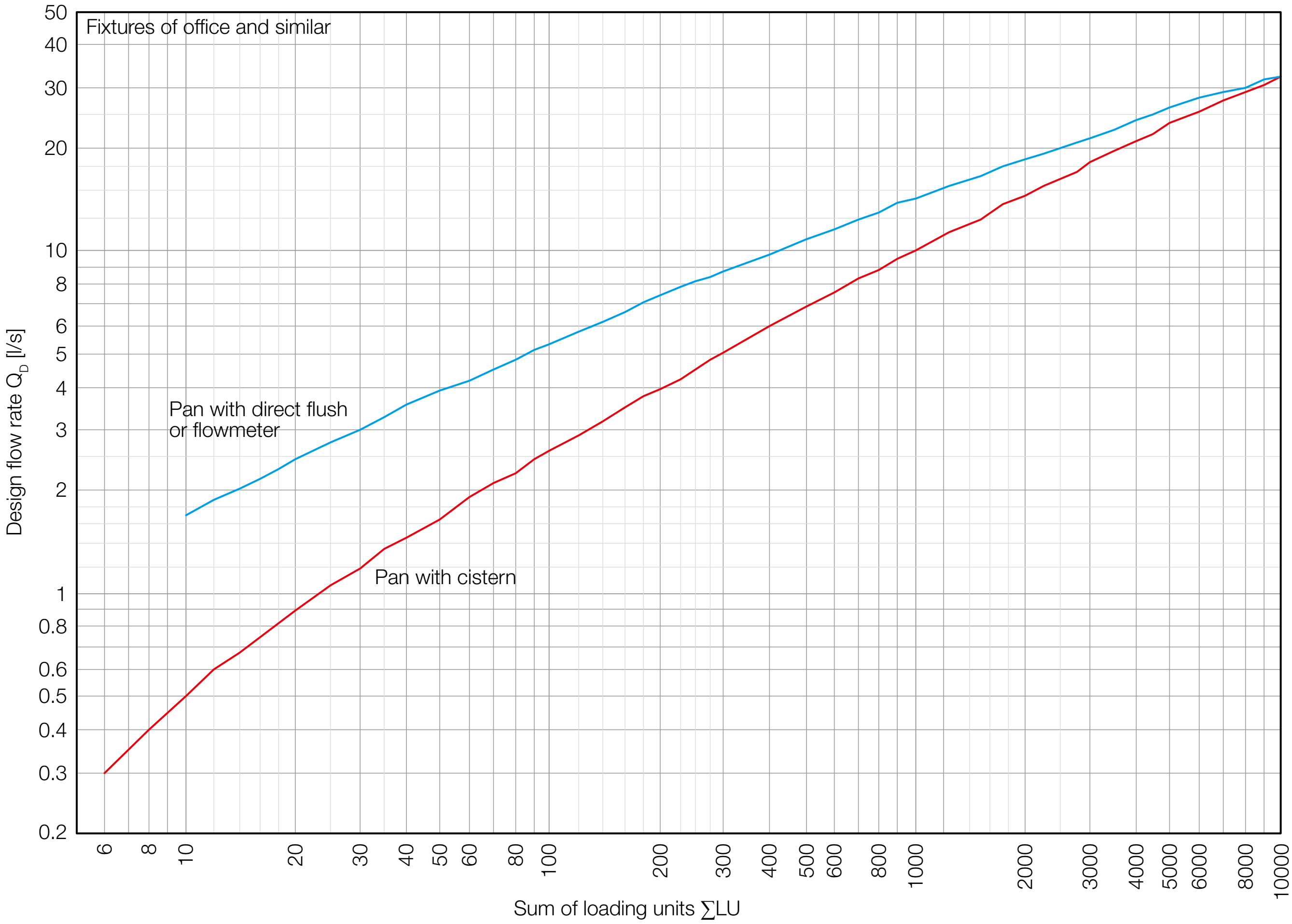
Table 4.9 Design flow rates Q_D for systems in office buildings and similar that have pans with a cistern.

∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]
6	0.30	120	2.90	1,250	11.30
8	0.40	140	3.20	1,500	12.40
10	0.50	160	3.50	1,750	13.60
12	0.60	180	3.75	2,000	14.50
14	0.67	200	3.95	2,250	15.40
16	0.75	225	4.25	2,500	16.20
18	0.82	250	4.50	2,750	17.00
20	0.89	275	4.80	3,000	18.00
25	1.05	300	5.05	3,500	19.50
30	1.18	400	6.00	4,000	21.00
35	1.35	500	6.90	4,500	22.00
40	1.45	600	7.55	5,000	23.50
50	1.65	700	8.30	6,000	25.50
60	1.90	800	8.80	7,000	27.50
70	2.10	900	9.50	8,000	29.00
80	2.25	1,000	10.00	9,000	30.50
90	2.45			10,000	32.00
100	2.60				

Table 4.10 Design flow rates Q_D for systems in office buildings and similar that have direct flush pans.

∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]	∑LU	Flow rate Q_D [l/s]
10	1.70	120	5.80	1,250	15.50
12	1.87	140	6.20	1,500	16.50
14	2.03	160	6.60	1,750	17.50
16	2.17	180	7.10	2,000	18.50
18	2.32	200	7.45	2,250	19.20
20	2.45	225	7.80	2,500	20.00
25	2.75	250	8.10	2,750	20.70
30	3.00	275	8.40	3,000	21.40
35	3.25	300	8.70	3,500	22.50
40	3.55	400	9.80	4,000	24.00
50	3.90	500	10.80	4,500	25.00
60	4.20	600	11.60	5,000	26.20
70	4.50	700	12.40	6,000	28.00
80	4.80	800	13.00	7,000	29.00
90	5.15	900	13.70	8,000	30.00
100	5.35	1,000	14.20	9,000	31.50
				10,000	32.00

Figure 4.20 Curve of design flow rates Q_D for systems in office buildings and similar.



4.4.2 Pressure and temperature allowed at points of use

For each point of use the pressure must be within these limits:

Table 4.11 Pressures allowed at the points of use.

Type	Limit [bar]
Maximum hydrostatic pressure p_R for each point of use excluding taps in the garden or garage	5
Maximum hydrostatic pressure p_R for taps in the garden or garage	10
Minimum hydrodynamic pressure p_{FL}	1

The hydrodynamic pressure at the point of use [bar] is defined as:

$$p_{FL} = p_R - 10^{-4} \cdot \frac{\rho v^2}{2g} \qquad [4.2]$$

where v is the speed at the point of use [m/s], g is the gravity acceleration [m/s²] and ρ is the density of the water [kg/m³]. 30 seconds following the complete aperture of the point of use, the temperature of the water should be:

Table 4.12 Temperature limits at the point of use.

Type of network	Temperature limit [°C]
Cold water	≤ 25
Hot water	≥ 60

These temperatures are adopted to reduce the proliferation of bacteria (in particular, the bacterium legionella) but for hot water networks safety factors such as the risk of scalding should also be considered.
In buildings such as hospitals, schools and playschools, hospices and homes for the elderly, the installation of thermostatic mixers should be considered to limit the temperature of the water at each point of use.
In these cases, a maximum temperature of 43°C (38°C in the case of nurseries and playschools) is recommended.

4.4.3 Maximum speed in pipes

Dimensioning of the system must be performed in observance of the following speed limits:

Table 4.13 Maximum design speed.

Part of the system	Maximum design speed [m/s]
Supply manifold, risers and distribution pipes (branch lines)	2
Terminal connection sections for each point of use	4

National regulations and standards may impose further limits on speed to reduce the risk of noise and water hammer.

4.5 Simplified dimensioning of water supply distribution networks in compliance with EN 806-3

The European Standard EN 806-3 presents a practical method for pipe dimensioning called the “simplified method”, that can be applied to systems that are defined as standardized, that is, that meet the following conditions:

1) The flows to the individual points of use cannot exceed those shown in Table 4.3.
2) The design flow rate Q_D must not exceed 9 l/s (equivalent to the maximum design flow according to Figure 4.18).
3) The system does not envisage the continuous use of water for a period greater than 15 minutes.

If the system does not meet these conditions then it is considered special. For the standard portions of a special system, if they exist, the simplified method, at any rate, can be used. The simplified method can be applied for hot and cold water networks but not for recirculation networks that are not dealt with in the EN 806 standard. With the simplified method:

1) Starting with the last fixture that is connected to the network, the sum of the LUs is calculated for each section of pipe.
2) Based on the type of material used for the pipes and the LUs calculated, the diameter of each section of pipe is determined. Table 4.14 shows the values for multilayer pipes. Note that for ∑LU values equal to 3, 4 and 5, even though it is allowed to use the same pipe diameter, the maximum length of the section cannot exceed the values indicated.

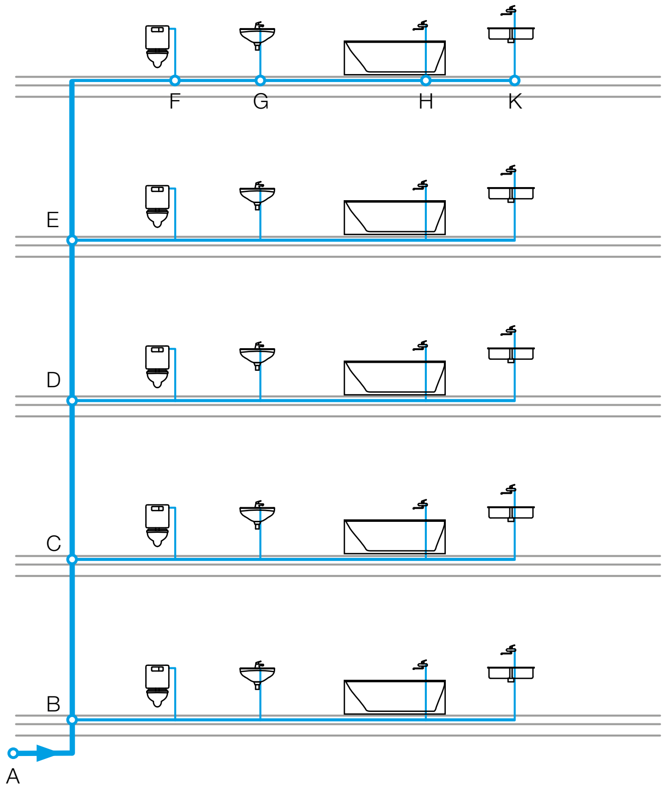
Table 4.14 Diameters of the multilayer pipes in relation to the LUs in compliance with EN 806-3.

∑LU	**LU**	3	4	5	6	10	20	55	180	540	1300	2200*	3400*	5200*
LU_{max}	**LU**			4	5	5	8							
d_e x s	**mm**		16x2.25/16x2		18x2	20x2.5	26x3	32x3	40x3.5	50x4	63x4.5	75x5	90x7	110x10
d_i	**mm**		11.5/12		14	15	20	26	33	42	54	65	76	90
max pipe length	**m**	9	5	4										

*Values not indicated in EN 806 standard, obtained by interpolating.

Example 1.
Dimension the cold water network made with Valsir Pexal® multilayer pipes for the water supply distribution system shown in Figure 4.21. The system is to be installed in a residential five-storey building. On each floor, the following fixtures are connected with branch lines: a WC, a washbasin, a bathtub and a sink.

Figure 4.21 Installation of example 1.



The loading units for the sanitary appliances are obtained from Table 4.3:

Point of use	Loading unit (LU)
WC	1
Washbasin	1
Bathtub	4
Sink	2

The sum of the loading units LU_{TOT} is determined for each section of pipe based on the sanitary appliances connected:

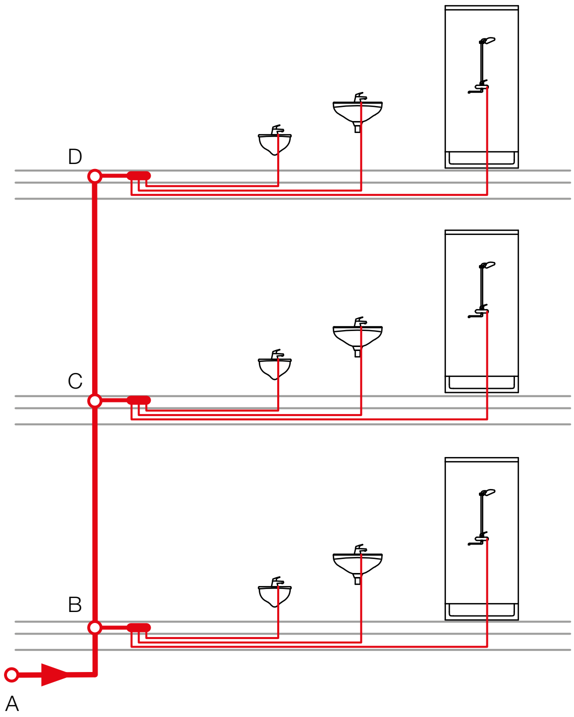
Section	LU_{TOT}	Pexal® diameter [mm]
HK	2	
GH	6	
FG	7	
EF	8	
DE	16	
CD	24	
BC	32	
AB	40	

The required diameter in relation to LU_{TOT} is then identified in Table 4.14:

Section	LU_{TOT}	Pexal® diameter [mm]
HK	2	16x2.25
GH	6	18x2
FG	7	20x2.5
EF	8	20x2.5
DE	16	26x3
CD	24	32x3
BC	32	32x3
AB	40	32x3

Example 2.
Dimension the hot water network made with Valsir Mixal® multilayer pipes for the water supply distribution system shown in Figure 4.22. The system is to be installed in a residential three-storey building. On each floor, the following fixtures are connected with manifold branch lines: a bidet, a washbasin, and a shower.

Figure 4.22 Installation of example 2.



4

The loading units for the sanitary appliances are obtained from Table 4.3:

Point of use	Loading unit (LU)	Mixal® diameter for connection to the manifold [mm]
Bidet	1	
Washbasin	1	
Shower	2	

According to Table 4.14, with a value of up to five LUs the minimum diameter of a Valsir Mixal® multilayer pipe is 16x2 mm. The hot water pipes from the manifold to the bidet, washbasin and shower must therefore have the following diameter:

Point of use	Loading unit (LU)	Mixal® diameter for connection to the manifold [mm]
Bidet	1	16x2
Washbasin	1	16x2
Shower	2	16x2

The system sections from the source, located below, to the manifolds still need to be dimensioned. It easy to calculate that each manifold has a total flow rate equal to 4 LUs, from which the following is obtained:

Section	LU_{TOT}	Mixal® diameter [mm]
CD	4	
BC	8	
AB	12	

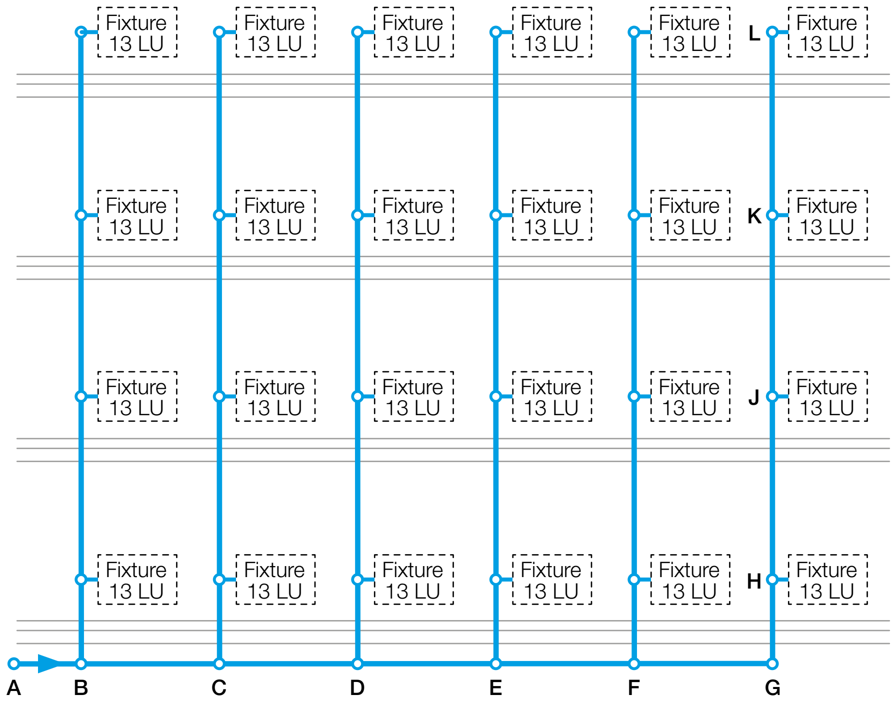
4

The required diameter in relation to LU_{TOT} is then identified in Table 4.14:

Section	LU_{TOT}	Mixal® diameter [mm]
CD	4	16x2
BC	8	20x2
AB	12	26x3

Example 3.
Dimension the distribution manifold and the cold water risers made with Valsir Pexal® multilayer pipes, for the water supply distribution system shown in Figure 4.23. The system is to be installed in a residential four-storey building with supply from below and six risers. For each riser and on each floor consider a combination of fixtures composed of a sink, a dishwasher, a WC, a, bidet, a washbasin, a bathtub and a washing machine.

Figure 4.23 Installation of example 3.



The loading units for the sanitary appliances are obtained from Table 4.3. By summing them the value of 13 LUs is obtained as shown in the drawing:

Point of use	Loading units (LU)
Sink	2
Dishwasher	2
WC	1
Bidet	1
Sink	1
Bathtub	4
Washing machine	2
	∑LU = 13

The relative LU are allocated to each system section:

Section	LU_{TOT}	Pexal® diameter [mm]
KL	13	
JK	26	
HJ	39	
GH = FG	52	
EF	104	
DE	156	
CD	208	
BC	260	
AB	312	

The required diameter in relation to LU_{TOT} is then identified in Table 4.14:

Section	LU_{TOT}	Pexal® diameter [mm]
KL	13	26x3
JK	26	32x3
HJ	39	32x3
GH = FG	52	32x3
EF	104	40x3.5
DE	156	40x3.5
CD	208	50x4
BC	260	50x4
AB	312	50x4

4.6 Detailed dimensioning of water supply distribution networks according to UNI 9182

As opposed to the simplified method indicated in EN 806-3, for a more precise method of calculating the pipe diameters of a hot or cold water supply system, it is possible to refer to the national standards that deal with this aspect. For Italy, Appendix I of UNI 9182 deals with the detailed dimensioning of water supply distribution systems.

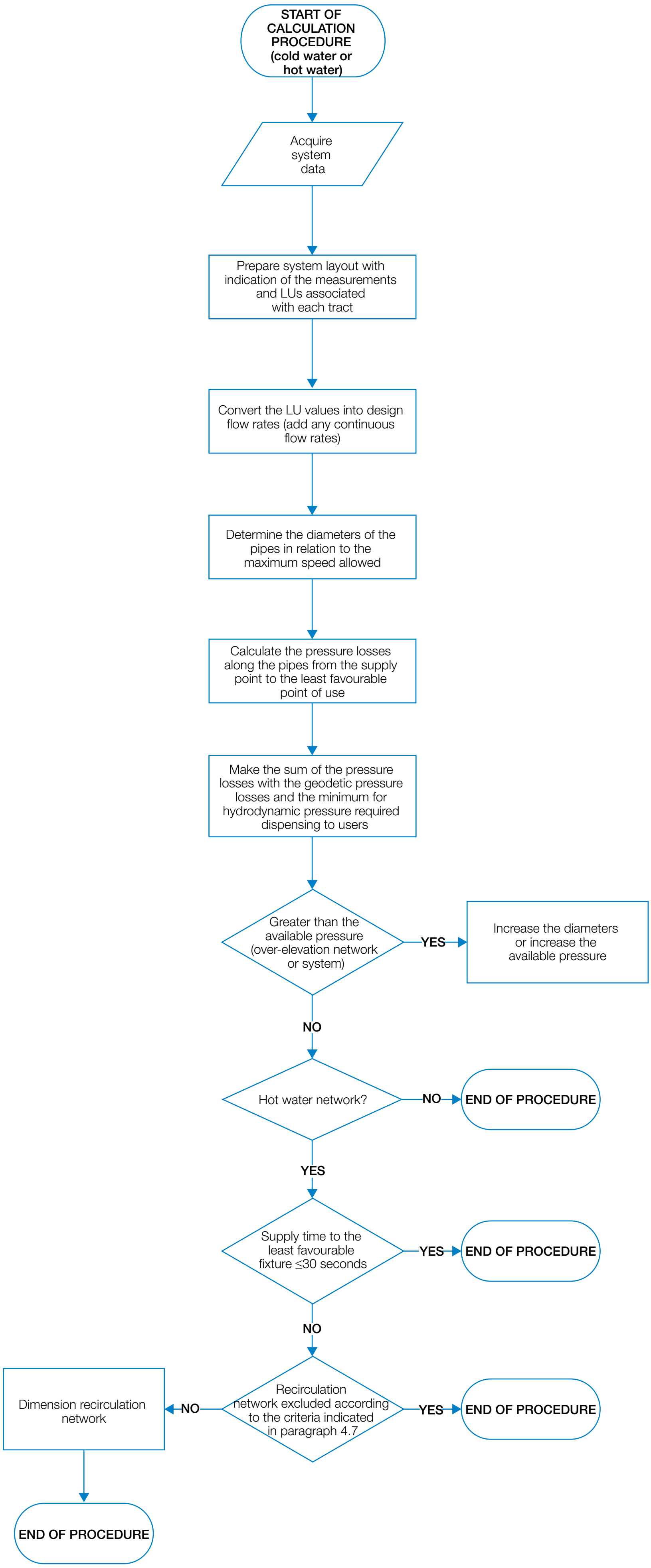
After collecting all the necessary information for dimensioning and having prepared a scheme of the system, the procedure involves the following steps:

1) For each point of use indicate the flow rate expressed in LUs both for cold water and for hot water and the calculate the sum of the LUs, section by section, as far as the supply point.
2) Convert the LUs into design flow rates. To these add any flow rates of the continuous type present in the network (for example, watering, irrigation and similar).
3) Determine the minimum diameter of the pipes based on the maximum speeds allowed (Table 4.13), using the continuity equation:

   $$V = A \cdot c \cdot 10^{-3} \qquad [4.3]$$

   where, V is the flow rate [l/s], A is the internal bore section [mm^2] and c is the speed [m/s].
4) Calculate the pressure losses along the pipe from the supply point as far as the least favourable point of use and verify the sum with the geodetic pressure losses and with the minimum hydrodynamic pressure required at the point of use both less than or equal to the pressure at the point of supply. If the result is positive, and therefore the available pressure is sufficient also for the least favourable fixture, then dimensioning is finished. If the result is negative, continue increasing the diameters of the pipes (in order to reduce pressure losses) and verify once more. Alternatively, it is possible to increase the pressure available at the point of supply with a device that increases the pressure.
5) In the case of a hot water network verify the water supply times at the design conditions for the least favourable fixture unit. This is to verify the necessity of a recirculation system (see paragraph 4.7).

The procedure can be outlined with the following block diagram.


START OF CALCULATION PROCEDURE (cold water or hot water)
Acquire system data
Prepare system layout with indication of the measurements and LUs associated with each tract
Convert the LU values into design flow rates (add any continuous flow rates)
Determine the diameters of the pipes in relation to the maximum speed allowed
Calculate the pressure losses along the pipes from the supply point to the least favourable point of use
Make the sum of the pressure losses with the geodetic pressure losses and the minimum for hydrodynamic pressure required dispensing to users
Greater than the available pressure (over-elevation network or system)
YES
Increase the diameters or increase the available pressure
NO
Hot water network?
NO
END OF PROCEDURE
YES
Supply time to the least favourable fixture ≤30 seconds
YES
END OF PROCEDURE
NO
Recirculation network excluded according to the criteria indicated in paragraph 4.7
YES
END OF PROCEDURE
NO
Dimension recirculation network
END OF PROCEDURE

Example 1.
Dimension the cold water system using Valsir Pexal® multilayer pipes for the water supply distribution system shown in Figure 4.21, already used in the example of simplified dimensioning according to EN 806-3. The following additional information is available:

- Pressure available at the source: 3 bar.
- Relative height of the least favourable fixture: 15 m.
- Temperature of the cold water: 10°C.
- Branch lines (with tee fittings).
- Residential type building (private dwellings).
- Pans with cistern.
- Pexal® Brass type fittings.
- HK = GH = FG = 2 m, EF = 5 m, BC = CD = DE = 3 m, AB = 9 m.

First, it is necessary to identify the loading units for each point of use. As it is a residential building, use the values shown in Table 4.5:

Point of use	Loading units (LU)
Kitchen sink	1.5
Bathtub	1.5
Washbasin	0.75
WC (with cistern)	3
	∑LU = 6.75

Sum the LU of the sanitary appliances connected to each pipe section:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
HK	Kitchen sink	1.5	
GH	sink + tub	3.00	
FG	sink + tub + washbasin	3.75	
EF	1 floor (sink + tub + washbasin + WC)	6.75	
DE	2 floors	13.50	
CD	3 floors	20.25	
BC	4 floors	27.00	
AB	5 floors	33.75	

Table 4.7 is used to calculate the design flow rate Q_D. Where just one sanitary appliance is connected, as with section HK, consider the flow rate for it according to Table 4.4:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
HK	Kitchen sink	1.5	0.15 (from Table 4.4)
GH	sink + tub	3.00	0.30
FG	sink + tub + washbasin	3.75	0.30
EF	1 floor (sink + tub + washbasin + WC)	6.75	0.35
DE	2 floors	13.50	0.65
CD	3 floors	20.25	0.95
BC	4 floors	27.00	1.20
AB	5 floors	33.75	1.40

The minimum internal diameter of the pipes of the system is calculated thanks to the continuity equation [4.3], imposing the maximum speed allowed for each pipe section, according to Table 4.13. The following is obtained:

$$d_{i,min} = 2 \cdot \sqrt{\frac{V \cdot 10^3}{\pi \cdot c}} \qquad [4.4]$$

Where, $d_{i,min}$ is the minimum diameter of the pipe [mm], V is the flow rate [l/s] and c is the maximum speed allowed. Consider the section HK. The flow rate, already calculated, is 0.15 l/s and as it is a terminal section, the maximum speed allowed is 4 m/s. By inserting these values in [4.4] we obtain:

$$d_{i,min}\,(HK) = 2 \cdot \sqrt{\frac{0.15 \cdot 10^3}{\pi \cdot 4}} = 6.91 \text{ mm} \qquad [4.5]$$

Section	$d_{i,min}$ [mm]	Pexal® diameter
HK	6.91	
GH		
FG		
EF		
DE		
CD		
BC		
AB		

Consider section GH. The flow rate, already calculated, is 0.3 l/s but in this case the GH section is used to supply more than one point of use and the maximum speed allowed is therefore 2 m/s. By inserting these values in [4.4] we obtain:

$$d_{i,min}\,(GH) = 2 \cdot \sqrt{\frac{0.3 \cdot 10^3}{\pi \cdot 2}} = 13.82 \text{ mm} \qquad [4.6]$$

The same procedure is used also for the other sections:

Section	$d_{i,min}$ [mm]	Pexal® diameter
HK	6.91	
GH	13.82	
FG	13.82	
EF	14.93	
DE	20.35	
CD	24.60	
BC	27.65	
AB	29.86	

Once the diameter of the minimum cross sectional flow area required is known for each section, the pipe of the Valsir Pexal® range that meets such a requirement is immediately identified:

Section	$d_{i,min}$ [mm]	Pexal® diameter
HK	6.91	14x2
GH	13.82	18x2
FG	13.82	18x2
EF	14.93	20x2
DE	20.35	32x3
CD	24.60	32x3
BC	27.65	40x3.5
AB	29.86	40x3.5

By referring to appendix 9.1, both the continuous and localized pressure losses are calculated from point of supply A to the least favourable fixture. The actual, and not the imposed speed, must be calculated in each section of pipe, in relation to the Pexal® diameter chosen:

Section	Flow rate Q_D [l/s]	Pexal® diameter	Speed [m/s]
HK	0.15	14x2	1.91
GH	0.30	18x2	1.95
FG	0.30	18x2	1.95
EF	0.35	20x2	1.74
DE	0.65	32x3	1.23
CD	0.95	32x3	1.79
BC	1.20	40x3.5	1.40
AB	1.40	40x3.5	1.64

4

Thanks to the diagram in Figure 9.1 the pressure loss is identified for each meter of pipe and therefore the continuous pressure loss for each section of pipe:

Section	L [m]	Linear pressure loss at 10°C [mbar/m]	Continuous pressure losses [mbar]
HK	2	53	106
GH	2	36	72
FG	2	36	72
EF	5	25	125
DE	3	8	24
CD	3	14	42
BC	3	7	21
AB	9	9	81
TOTAL	-	-	**543**

For localized pressure losses, it is necessary to establish which k loss factor is to be used according to the fitting used in the direction of the flow.
It is very easy to calculate the pressure loss in point K [mbar]:

$$Z(K) = k \cdot \frac{\rho v^2}{200} \quad [4.7]$$

Where Z(K) is the pressure loss localized in point K, k is the loss factor for the Pexal® Brass 14 mm elbow in point K, v is the speed of the flow in section HK [m/s], ρ is density of the water [kg/m^3] (at 10°C for this example). From which:

$$Z(K) = 4.6 \cdot \frac{1000 \cdot 1.91^2}{200} = 84 \text{ mbar} \quad [4.8]$$

Point	Localized pressure losses Z [mbar]
K	84
H	
G	
F	
E	
D	
C	
B	
TOTAL	

Calculation of the pressure loss in point H, on the other hand, is more complex. A tee fitting is considered, which in the direction of the flow is reduced from diameter 18 mm (used for section GH) to diameter 14 mm (used for section HK). The tables for the k values given in appendix 9.1 relate to tee fittings of the same diameter (not reduced). It can be assumed, with sufficient approximation, that the localized pressure loss for a reduced tee fitting of this type is the same as a sequence of two fittings made up of an 18 mm tee fitting and a 14 mm straight fitting. Once the k values are known for each of the two fittings, the calculation is made using this formula:

$$Z(H) = k_1 \cdot \frac{\rho v^2}{200} + k_2 \cdot \frac{\rho {v_2}^2}{200} \qquad [4.9]$$

where Z(H) is the localized pressure loss in point H [mbar], k_1 is the coefficient for the 18 mm tee fitting, v_1 is the speed of the flow in section GH [m/s], k_2 is the coefficient for the 14 mm straight fitting, v_2 is the speed in section HK [m/s], ρ is the density of the water [kg/m³] (at 10°C in this example). From which:

$$Z(H) = 1.1 \cdot \frac{1000 \cdot 1.95^2}{200} + 1.3 \cdot \frac{1000 \cdot 1.91^2}{200} = 21 + 24 = 45 \text{ mbar} \qquad [4.10]$$

Proceed in the same way for all the other points, until the table is complete:

Point	Localized pressure losses Z [mbar]
K	84
H	45
G	21
F	29
E	14
D	8
C	10
B	5
TOTAL	**216**

To sum up, the total pressure losses from point of supply A as far as the least favourable fixture, are:

$$R_{tot} = 543 \text{ mbar} + 216 \text{ mbar} = 759 \text{ mbar} = 0.76 \text{ bar} \qquad [4.11]$$

The geodetic pressure loss [bar] is indicated with a H, since the water must travel at the height of 15 m, we have:

$$H = 1.5 \text{ bar} \qquad [4.12]$$

As the minimum hydrodynamic pressure p_{FL} for each point of use is 1 bar and the pressure available for this installation is 5 bar, the following must be verified:

$$R_{TOT} + H + p_{FL} \leq \text{available pressure} \qquad [4.13]$$

That is, the following must apply:

$$76 + 1.5 + 1 \leq 5$$ verification OK ▶ dimensioning complete

Example 2.

Dimension the hot water system with Valsir Mixal® multilayer pipe for the water supply distribution system shown in Figure 4.22, already used for the example with simplified dimensioning according to EN 806-3. The following additional information is also available:

- Pressure available at the source: 4 bar.
- Relative height of the least favourable fixture: 6 m.
- Temperature of the hot water: 60°C.
- Manifold branches (suppose a pressure loss of 0.2 bar between the manifold and the least favourable fixture).
- Residential type building (private dwellings).
- Pans with cistern.
- Pexal® Brass type fittings.
- AB = BC = CD = 3 m.

First of all the loading units of each point of use need to be identified. As it is a residential building, the values shown in Table 4.5 are used:

Point of use	Loading units (LU)
Bidet	0.75
Washbasin	0.75
Shower	1.5
	∑LU = 3

Sum up the LUs of the sanitary appliances connected to each pipe section:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
CD	1 floor	3	
BC	2 floors	6	
AB	3 floors	9	

Table 4.7 is used to calculate the design flow rates Q_D:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
CD	1 floor	3	0.30
BC	2 floors	6	0.30
AB	3 floors	9	0.45

Consider the section CD. The flow rate, already calculated, is 0.3 l/s and the maximum speed allowed is 2 m/s. By inserting these values in [4.4] we obtain:

$$d_{i,min}\,(CD) = 2 \cdot \sqrt{\frac{0.3 \cdot 10^3}{\pi \cdot 2}} = 13.82 \text{ mm} \qquad [4.14]$$

The same procedure is used also for the other sections:

Section	$d_{i,min}$ [mm]	Mixal® diameter
CD	13.82	
BC	13.82	
AB	16.93	

Once the diameter of the minimum cross sectional flow area required is known for each section, the pipe of the Valsir Mixal® range that meets such a requirement is immediately identified:

Section	$d_{i,min}$ [mm]	Mixal® diameter
CD	13.82	18x2
BC	13.82	18x2
AB	16.93	26x3

By referring to appendix 9.1, both the continuous and localized pressure losses are calculated from point of supply A to the least favourable fixture. The actual, and not the imposed speed, must be calculated in each section of pipe, in relation to the Mixal® diameter chosen:

Section	Flow rate Q_D [l/s]	Mixal® diameter	Speed [m/s]
CD	0.30	18x2	1.95
BC	0.30	18x2	1.95
AB	0.45	26x3	1.43

Thanks to the diagram in Figure 9.2 the pressure loss is identified for each meter of pipe and therefore the continuous pressure loss for each section of pipe:

Section	L [m]	Linear pressure loss at 60°C [mbar/m]	Continuous pressure losses [mbar]
CD	3	29.9	89.7
BC	3	29.9	89.7
AB	3	10.9	32.7
TOTAL	**-**	**-**	**212**

For localized pressure losses, it is necessary to establish which k loss factor is to be used according to the fitting used in the direction of the flow. It is very easy to calculate the pressure loss Z(D) in point D [mbar]:

$$Z(D) = k \cdot \frac{\rho v^2}{200} \quad [4.15]$$

Where, k is the loss factor for the Pexal® Brass 18 mm elbow in point D (appendix 9.1), v is the speed of the flow in section CD [m/s], and ρ is the density of the water [kg/m³] (at 60°C for this example). From which:

$$Z(D) = 3.3 \cdot \frac{983 \cdot 1.95^2}{200} = 62 \text{ mbar} \quad [4.16]$$

Point	Localized pressure losses Z [mbar]
D	62
C	
B	
TOTAL	

Proceed also for points C (in which a Pexal® Brass 18 mm tee fitting is considered with k = 1.1 in the direction of flow) and B (where in a similar way to the previous example the pressure loss generated by the sequence of a Pexal® Brass 26 mm tee fitting and a Pexal® Brass 18 mm tee fitting is calculated). We obtain:

Point	Localized pressure losses Z [mbar]
D	62
C	21
B	22
TOTAL	**104**

To sum up, the total pressure losses from the supply point A to the least favourable fixture are obtained from the sum of the localized pressure losses and distributed as far as point D and the pressure loss from the manifold to the least favourable fixture (according to the information supplied equal to 200 mbar):

$$R_{tot} = 212 \text{ mbar} + 104 \text{ mbar} + 200 \text{ mbar} = 516 \text{ mbar} = 0.52 \text{ bar} \quad [4.17]$$

The geodetic pressure loss [bar] is indicated with a H, since the water must travel at the height of 6 m, we have:

$$H = 0.6 \text{ bar} \quad [4.18]$$

As the minimum hydrodynamic pressure p_{FL} for each point of use is 1 bar and the pressure available for this installation is 4 bar, the following must be verified:

$$R_{tot} + H + p_{FL} \leq \text{available pressure} \quad [4.19]$$

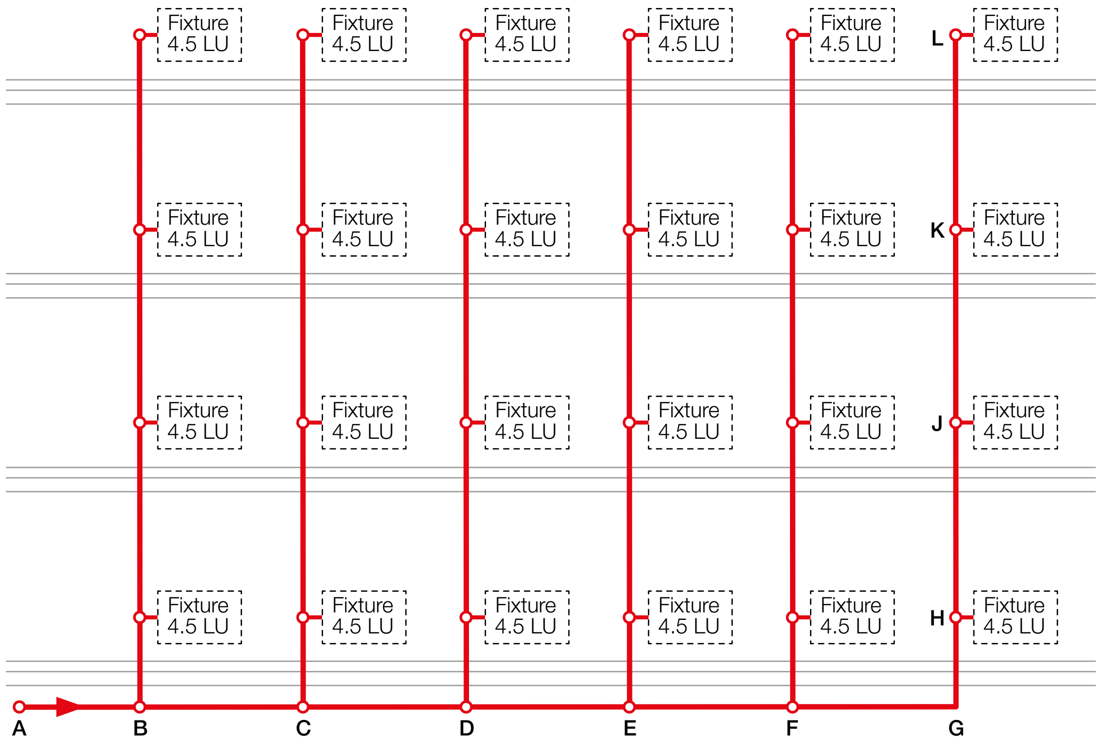
That is, the following must apply:

$0.52 + 0.6 + 1 \leq 4$ verification OK ▶ dimensioning complete

Example 3.
Dimension the supply manifold and the hot water risers created with Valsir Pexal® multilayer pipes, for the water supply distribution system shown in Figure 4.24. It is a four-storey residential building with supply from below and six risers. For each riser and on each floor consider a combination of fixtures composed of sink, bidet, washbasin, and bathtub. The following additional information is available:

- Pressure available at the source: 4 bar.
- Relative height of the least favourable fixture: 10 m.
- Temperature of the hot water: 60°C.
- Pressure loss between the gap from the riser to the least favourable fixture: 0.5 bar.
- Residential type building (private dwellings).
- Pans with cistern.
- Pexal® Brass type fittings.
- AB = BC = CD = DE = EF = FG = 12 m, GH = 1 m, HJ = JK = KL = 3 m.

Figure 4.24 Installation of example 3 according to UNI 9182.



First of all the loading units of each point of use need to be identified. As it is a residential building, the values shown in Table 4.5 are used:

Point of use	Loading unit (LU)
Sink	1.5
Bidet	0.75
Washbasin	0.75
Bathtub	1.5
	∑LU = 4.5

4

Sum up the LUs of the sanitary appliances connected to each pipe section:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
KL	1 storey	4.5	
JK	2 storeys	9	
HJ	3 storeys	13.5	
GH	4 storeys	18	
FG	1 riser (4 storeys)	18	
EF	2 risers	36	
DE	3 risers	54	
CD	4 risers	72	
BC	5 risers	90	
AB	6 risers	108	

Table 4.7 is used to calculate the design flow rate Q_D:

Section	Sanitary appliances connected	∑LU	Flow rate Q_D [l/s]
KL	1 storey	4.5	0.30
JK	2 storeys	9	0.45
HJ	3 storeys	13.5	0.65
GH	4 storeys	18	0.85
FG	1 riser (4 storeys)	18	0.85
EF	2 risers	36	1.50
DE	3 risers	54	2.05
CD	4 risers	72	2.45
BC	5 risers	90	2.90
AB	6 risers	108	3.40

Consider the section KL. The flow rate, already calculated, is 0.3 l/s and the maximum speed allowed is 2 m/s. By inserting these values in [4.4] we obtain:

$$d_{i,min}\,(KL) = 2 \cdot \sqrt{\frac{0.3 \cdot 10^3}{\pi \cdot 2}} = 13.82 \text{ mm} \qquad [4.20]$$

The same procedure is used also for the other sections:

Section	$d_{i,min}$ [mm]	Pexal® diameter
KL	13.82	
JK	16.93	
HJ	20.34	
GH	23.26	
FG	23.26	
EF	30.90	
DE	36.13	
CD	39.49	
BC	42.97	
AB	46.52	

Once the diameter of the minimum cross sectional flow area required is known for each section, the pipe of the Valsir Pexal® range that meets such a requirement is immediately identified:

Section	$d_{i,min}$ [mm]	Pexal® diameter
KL	13.82	18x2
JK	16.93	26x3
HJ	20.34	32x3
GH	23.26	32x3
FG	23.26	32x3
EF	30.90	40x3.5
DE	36.13	50x4
CD	39.49	50x4
BC	42.97	63x4.5
AB	46.52	63x4.5

By referring to appendix 9.1, both the continuous and localized pressure losses are calculated from point of supply A to the least favourable fixture. The actual, and not the imposed speed, must be calculated in each section of pipe, in relation to the Pexal® diameter chosen:

Section	Flow rate Q_D [l/s]	Pexal® diameter	Speed [m/s]
KL	0.30	18x2	1.95
JK	0.45	26x3	1.43
HJ	0.65	32x3	1.22
GH	0.85	32x3	1.60
FG	0.85	32x3	1.60
EF	1.50	40x3.5	1.75
DE	2.05	50x4	1.48
CD	2.45	50x4	1.77
BC	2.90	63x4.5	1.27
AB	3.40	63x4.5	1.48

Thanks to the diagram in Figure 9.2 the pressure loss is identified for each meter of pipe and therefore the continuous pressure loss for each section of pipe:

Section	L [m]	Linear pressure loss at 60°C [mbar/m]	Continuous pressure losses [mbar]
KL	3	29.9	89.7
JK	3	10.9	32.7
HJ	3	6	18
GH	1	9.7	9.7
FG	12	9.7	116.4
EF	12	8.6	103.2
DE	12	4.7	56.4
CD	12	6.5	78
BC	12	2.6	31.2
AB	12	3.5	42
TOTAL	**-**	**-**	**577**

For localized pressure losses, it is necessary to establish which k loss factor is to be used according to the fitting used in the direction of the flow. The pressure loss Z(L) in point L [mbar] is easily calculated:

$$Z(L) = k \cdot \frac{\rho v^2}{200} \qquad [4.21]$$

Where, k is the loss factor for the Pexal® Brass 18 mm elbow in point L (appendix 9.1), v is the speed of the flow in section KL [m/s], and ρ is the density of the water [kg/m³] (at 60°C for this example). From which:

$$Z(L) = 3.3 \cdot \frac{983 \cdot 1.95^2}{200} = 62 \text{ mbar} \qquad [4.22]$$

Point	Localized pressure losses Z [mbar]
L	62
K	
J	
H	
G	
F	
E	
D	
C	
B	
TOTAL	

Proceed also for the other points C, keeping in mind the considerations made in examples 1 and 2. We obtain:

Point	Localized pressure losses Z [mbar]
L	62
K	22
J	9
H	6
G	25
F	11
E	8
D	5
C	7
B	3
TOTAL	**157**

To sum up, the total pressure losses from the supply point A to the least favourable fixture are obtained from the sum of the localized pressure losses that are also distributed as far as point L and the pressure loss from the manifold to the least favourable fixture (according to the information supplied equal to 500 mbar):

$$R_{tot} = 577 \text{ mbar} + 157 \text{ mbar} + 500 \text{ mbar} = 1234 \text{ mbar} = 1.23 \text{ bar} \quad [4.23]$$

The geodetic pressure loss [bar] is indicated with a H, since the water must travel at the height of 10 m, we have:

$$H = 1 \text{ bar} \quad [4.24]$$

As the minimum hydrodynamic pressure p_{FL} for each point of use is 1 bar and the pressure available for this installation is 4 bar, the following must be verified:

$$R_{tot} + H + p_{FL} \leq \text{available pressure} \quad [4.25]$$

That is, the following must apply:

$$1.23 + 1 + 1 \leq 4 \qquad \text{verification OK} \blacktriangleright \text{dimensioning complete}$$

The dimensioning procedure according to UNI 9182 imposes, in the case of a hot water system, the verification of the necessity of recirculation, by estimating the water supply time at the least favourable point of use (for more details see the next paragraph).
In this example, L can be considered as the least favourable point with a flow rate of 0.1 l/s (flow rate of the bidet or washbasin according to Table 4.4, that is the lowest flow rate of all the points of use connected).
Although it is clear that recirculation is required, in order to proceed analytically, it is necessary to first calculate the volume of water in the pipes from the supply point A to point L and then to verify that the delivery time of hot water is less than 30 seconds. The following formula is applied:

$$V = \pi \cdot r_i^2 \cdot L \cdot 1000 \qquad [4.26]$$

Where V is the volume of water in the pipe[l], r_i is the internal radius of the pipe [m] and L is the length of the section of pipe [m]. For section KL:

$$V = \pi \cdot 0.007^2 \cdot 3 \cdot 1000 = 0.46 \text{ l} \qquad [4.27]$$

We proceed in the same way for all the other diameters:

Section	L [m]	Pexal® diameter [mm]	V [l]
KL	3	18x2	0.46
JK	3	26x3	0.94
HJ	3	32x3	1.59
GH	1	32x3	0.53
FG	12	32x3	6.37
EF	12	40x3.5	10.26
DE	12	50x4	16.63
CD	12	50x4	16.63
BC	12	63x4.5	27.48
AB	12	63x4.5	27.48
TOTAL	**-**	**-**	**108**

Delivery time t [s]:

$$t = \frac{V}{\dot{m}} \qquad [4.28]$$

where V is the total volume of water [l] and $\dot{m}$ is the flow rate of the fixture in question [l/s], that is:

$$t = \frac{108}{0.1} = 1080 \text{ s} > 30 \text{ s} \qquad [4.29]$$

As expected, recirculation is required.

4.7 Recirculation systems

Recirculation is meant to keep the hot water in circulation inside the distribution system to avoid it cooling. By means of a recirculation system, it is possible to supply the various points of use with water at a constant temperature, even when they are far away from the source. Recirculation avoids stagnation and therefore it is more hygienic from a safety point of view.
According to the provisions of UNI 9182, recirculation is necessary to guarantee that, at the various fixture units, hot water is available at the design pressure and flow rate within 30 seconds (in compliance with the provisions of 806-2). Recirculation must always be provided, except in the following cases:

- Hot water consumption is continuous or with a predominance of continuous consumption and with interruptions that are no longer than 15 minutes.
- In the case of autonomous systems, for residential use or similar (offices, studios, shops, etc.):
    - with instant production by means of appliances with a total heat output below 35 kW, without a storage cylinder.
    - similar with storage cylinder ≤ 100 l or at any rate with storage cylinder equipped with integrated system for maintenance of the design temperature in the cylinder (for example, electrical resistance).
- In the distribution section to the floor of a centralized system with recirculation, if the total volume of hot water inside the pipes, from the point of detachment of the line in which recirculation is in operation until each point of use, does not exceed 3 litres.

To guarantee the correct flow rate in every section of the network, all the recirculation trunk lines must be equipped with appropriate balancing valves. Furthermore, to prevent areas of water stagnation, unused lines are to be avoided.

4.8 Simplified dimensioning of recirculation networks in compliance with UNI 9182

Simplified dimensioning of the recirculation can be used for modest-sized systems that meet the following conditions:

- Total length of all the hot water pipes of the system (excluding recirculation) less than 30 m.
- Maximum length of each individual recirculation line (from the pump to the meeting point with the hot water pipe) less than 20 m.

In these conditions recirculation can be created as follows:

- Minimum internal diameter of the single recirculation lines and manifold sections equal to 10 mm.
- DN15 recirculation pump with a minimum flow rate of 200 l/h at a pressure of 100 mbar.

4.9 Detailed dimensioning of recirculation systems in compliance with UNI 9182

To correctly calculate the flow rate of a recirculation system we first need to know the heat loss of the hot water pipes. Based on experience the following heat losses can be applied with sufficient approximation:

Table 4.15 Heat loss values per meter of pipe.

Installation position	Symbol	Heat loss value per meter of pipe [W/m]
Central heating plant	$q_{W,K}$	11
Duct	$q_{W,S}$	7

We can also assume that the temperature drop between the outlet of the storage cylinder and the most distant point of use of the recirculation system is:

$$\Delta T_w = 2°C$$

The following relation is therefore applied:

$$\dot{V}_p = \frac{(l_{W,K} \cdot q_{W,K}) + (l_{W,S} \cdot q_{W,S})}{\rho \cdot c \cdot \Delta T_W} \quad [4.30]$$

Where

$\dot{V}_p$ is the flow rate of the recirculation pump [l/h],

$l_{W,K}$ is the length of all the hot water pipes in the central heating system [m],

$q_{W,K}$ is the heat loss per meter for the pipes in the central heating [W/m],

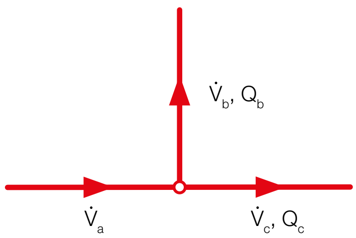
$l_{W,S}$ is the length of all the hot water pipes in the duct [m],

$q_{W,S}$ is the heat loss per meter for the pipes in the duct [W/m],

ρ is the water density at 60°C [kg/l],

c is the heat capacity of the water, equal to 1.2 Wh/kg°C.

In the presence of a branch line in the hot water system, partial flows can be calculated. The flow rates that are calculated with this method for the hot water network correspond, section by section, with the flow rates that must be guaranteed by the recirculation network that runs parallel. For example, for a branch line as shown:



$$\dot{V}_b = \dot{V}_a \cdot \frac{Q_b}{Q_b + Q_c} \quad [4.31]$$

$$\dot{V}_c = \dot{V}_a \cdot \frac{Q_c}{Q_b + Q_c} \quad [4.32]$$

$$\dot{V}_c = \dot{V}_a - \dot{V}_b \quad [4.33]$$

Where
$\dot{V}_a$ is the flow rate on entering the branch line [l/h],
$\dot{V}_b$ is the flow rate on exiting the branch line in the path of the branch line [l/h],
$\dot{V}_c$ is the flow rate on exiting the branch line in the transition path [l/h],
Q_b is the heat loss in all the pipes downstream of the branch line path [W],
Q_c is the heat loss of all the pipes downstream of the transition path [W].

Once the flow rates of the various sections are known, the continuity equation can be applied to dimension the diameters of the pipes in relation to the maximum speeds allowed. The minimum internal diameter of the pipe must at any rate be at least 10 mm. Based on experience, it is advised to respect the following limits:

Table 4.16 Maximum speeds allowed for the recirculation system.

Part of the system	Maximum speed [m/s]
Near the recirculation pumps, manifolds	0.5 ÷ 1
Far from the recirculation pump, risers, branch lines	0.2 ÷ 0.3

To calculate the head of the recirculation pump, it is necessary to consider all the pressure losses generated along the least favourable section of the circuit (generally the longest). Once the flow rate (calculated with equation [4.3]) and the minimum head required is known, it is possible to identify the functioning point of the system.

Example 1.
Dimension the recirculation system (in purple) made using Valsir Pexal® pipes for the system shown in Figure 4.25 (see example 3 of paragraph 4.6). The following additional information is available:

- Position of installation of hot water pipes: duct.
- MN = NO = OP = PQ = QR = RS = 12 m, NT = OU = PV = QW = RZ = SL = 10 m.

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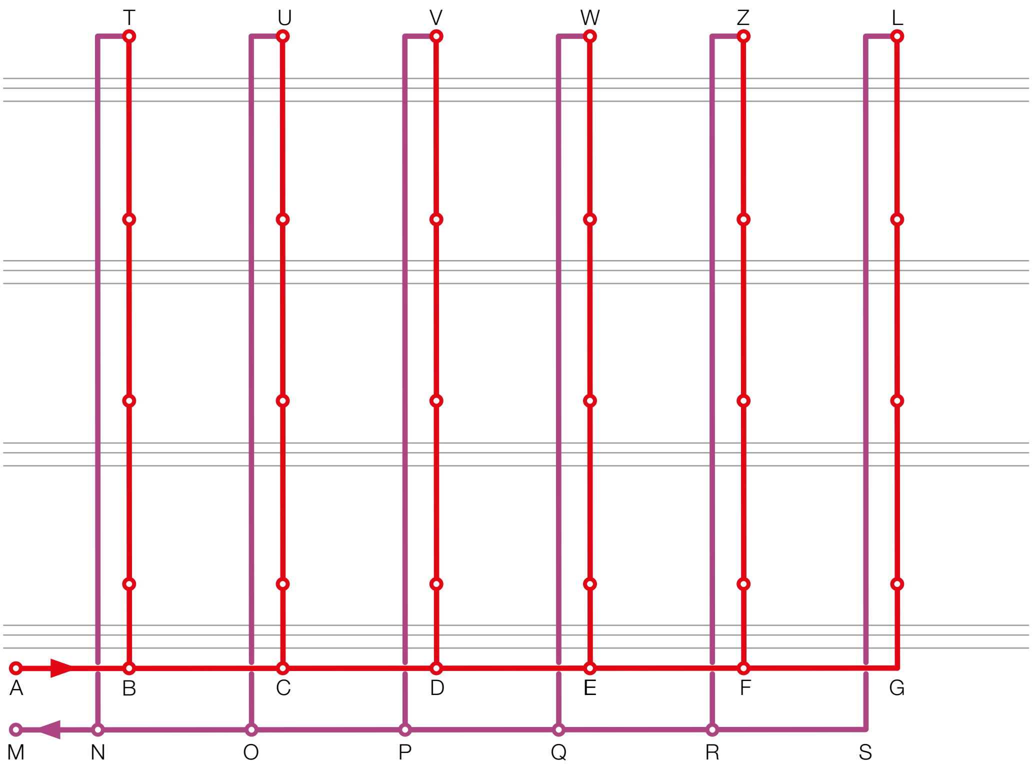
Figure 4.25 Installation of the example for the recirculation systems.



To calculate the flow rate of the various sections of the recirculation system, the hot water network is analysed. A table needs to be prepared with the name of the various branches, the relative length and the heat loss value for the specific type of installation (in this case we presume that all the hot water pipes are installed in a duct). Calculation of the heat losses in each section is therefore immediate, by multiplying the length by $q_{W,s}$:

Section	L [m]	$q_{w,s}$ [W/m]	Heat losses [W]	Flow rate [l/h]
AB	12	7	84	
BT	10	7	70	
BC	12	7	84	
CU	10	7	70	
CD	12	7	84	
DV	10	7	70	
DE	12	7	84	
EW	10	7	70	
EF	12	7	84	
FZ	10	7	70	
FG	12	7	84	
GL	10	7	70	

Equation [4.30] is therefore applied to section AB, to determine the total flow rate of the recirculation pump (remembering that the water density at 60°C obtained from appendix 9.7 is 0.983 kg/l):

$$\dot{V}_p = \frac{(l_{W,K} \cdot q_{W,K}) + (l_{W,S} \cdot q_{W,S})}{\rho \cdot c \cdot \Delta T_W} = \frac{132 \cdot 7}{0.983 \cdot 1.2 \cdot 2} = 391.7 \ \frac{l}{h} \qquad [4.34]$$

The value is entered in the table:

Section	L [m]	$q_{w,s}$ [W/m]	Heat losses [W]	Flow rate [l/h]
AB	12	7	84	391.7
BT	10	7	70	
BC	12	7	84	
CU	10	7	70	
CD	12	7	84	
DV	10	7	70	
DE	12	7	84	
EW	10	7	70	
EF	12	7	84	
FZ	10	7	70	
FG	12	7	84	
GL	10	7	70	

For all the next sections, because there are branch lines, equations [4.31] and [4.32] are applied. For example, for section BT:

$$\dot{V}_{BT} = \dot{V}_{AB} \cdot \frac{Q_{BT}}{Q_{BT} + Q_{TOT\ (A\ VALLE\ DI\ B)}} = 391.7 \cdot \frac{70}{70 + 770} = 32.6 \ \frac{l}{h} \qquad [4.35]$$

For section BC:

$$\dot{V}_{BC} = \dot{V}_{AB} \cdot \frac{Q_{TOT\ (A\ VALLE\ DI\ B)}}{Q_{BT} + Q_{TOT\ (A\ VALLE\ DI\ B)}} = 391.7 \cdot \frac{770}{70 + 770} = 359 \ \frac{l}{h} \qquad [4.36]$$

By applying the same formulas for each branch we obtain:

Section	L [m]	$q_{w,s}$ [W/m]	Heat losses [W]	Flow rate [l/h]
AB	12	7	84	391.7
BT	10	7	70	32.6
BC	12	7	84	359.0
CU	10	7	70	36.6
CD	12	7	84	322.4
DV	10	7	70	42.4
DE	12	7	84	280.0
EW	10	7	70	51.8
EF	12	7	84	228.1
FZ	10	7	70	71.3
FG	12	7	84	156.8
GL	10	7	70	156.8

The flow rates calculated for each section of the hot water system are the same as the flow rates of the recirculation system, parallel to it. For example, the flow rate calculated for AB is the same as MN, the one for BT is the same as NT and so on. This information can be entered in a new table in which the sections of hot water are replaced with the recirculation sections, quoting the relative flow rates and indicating for each element of the network the maximum speed allowed, chosen according to Table 4.16. In this example we can consider a maximum speed in the manifold of 0.5 m/s and in the risers 0.3 m/s:

Section	Flow rate [l/h]	v_{MAX} [m/s]	$d_{i,min}$ [mm]	Pexal® diameter
MN	391.7	0.5		
NT	32.6	0.3		
NO	359.0	0.5		
OU	36.6	0.3		
OP	322.4	0.5		
PV	42.4	0.3		
PQ	280.0	0.5		
QW	51.8	0.3		
QR	228.1	0.5		
RZ	71.3	0.3		
RS	156.8	0.5		
SL	156.8	0.3		

To determine the minimum internal diameter of the recirculation pipe, equation [4.4] is applied, making sure to transform the flow rate in l/s (here it is expressed l/h). We obtain:

Section	Flow rate [l/h]	v_{MAX} [m/s]	$d_{i,min}$ [mm]	Pexal® diameter
MN	391.7	0.5	16.64	
NT	32.6	0.3	6.20	
NO	359.0	0.5	15.94	
OU	36.6	0.3	6.57	
OP	322.4	0.5	15.10	
PV	42.4	0.3	7.07	
PQ	280.0	0.5	14.07	
QW	51.8	0.3	7.82	
QR	228.1	0.5	12.70	
RZ	71.3	0.3	9.17	
RS	156.8	0.5	10.53	
SL	156.8	0.3	13.60	

Lastly, we identify the diameters of the Pexal® pipe that respect the minimum internal diameter found. Note that for section RS it makes sense to modify the diameter of the pipe adapting it to that of the next section SL

Section	Flow rate [l/h]	v_{MAX} [m/s]	$d_{i,min}$ [mm]	Pexal® diameter
MN	391.7	0.5	16.64	26x3
NT	32.6	0.3	6.20	14x2
NO	359.0	0.5	15.94	20x2
OU	36.6	0.3	6.57	14x2
OP	322.4	0.5	15.10	20x2
PV	42.4	0.3	7.07	14x2
PQ	280.0	0.5	14.07	20x2
QW	51.8	0.3	7.82	14x2
QR	228.1	0.5	12.70	18x2
RZ	71.3	0.3	9.17	14x2
RS	156.8	0.5	10.53	~~16x2~~ 18x2
SL	156.8	0.3	13.60	18x2

4

WASTE SYSTEMS

SUPPLY SYSTEMS

GAS SYSTEMS

FLUSHING SYSTEMS

BATHROOM SYSTEMS

TRAPS

RADIANT SYSTEMS

DRAINAGE SYSTEMS

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