Hydronic systems - circuits

Heating, Ventilation and Air Conditioning Systems
A.A. 2024/25

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Bernoulli's principle

For incompressible fluids with steady flow:

$$\mathrm{p} + \rho g h + \frac{\rho u^2}{2} = cost.$$

The pressure drops of a closed circuit should be equal to the head of the pump:

$$\Delta \mathrm{p} = \sum_j \rho \left(f_j \frac{L_j}{D_j} + \beta_j \right) \frac{u^2}{2}$$

The volumetric flow rate is:

$$Q_v = u\, S$$

Bernoulli's principle

The pressure loss can be calculated with:

$$\Delta p = \sum_j \rho \left(f_j \frac{L_j}{D_j} + \beta_j \right) \frac{{Q_{v,j}}^2}{2\, S^2}$$

Therefore:

$$\Delta p = \sum_j \underbrace{\frac{\rho}{2{S_j}^2} \left(f_j \frac{L_j}{D_j} + \beta_j \right)}_{R_j = hydraulic\ resistance} {Q_{v,j}}^2$$

Bernoulli's principle

The pressure loss can be calculated with:

$$\Delta \mathrm{p} = \sum_j R_j \, {Q_{v,j}}^2$$

Over a single j-th element:

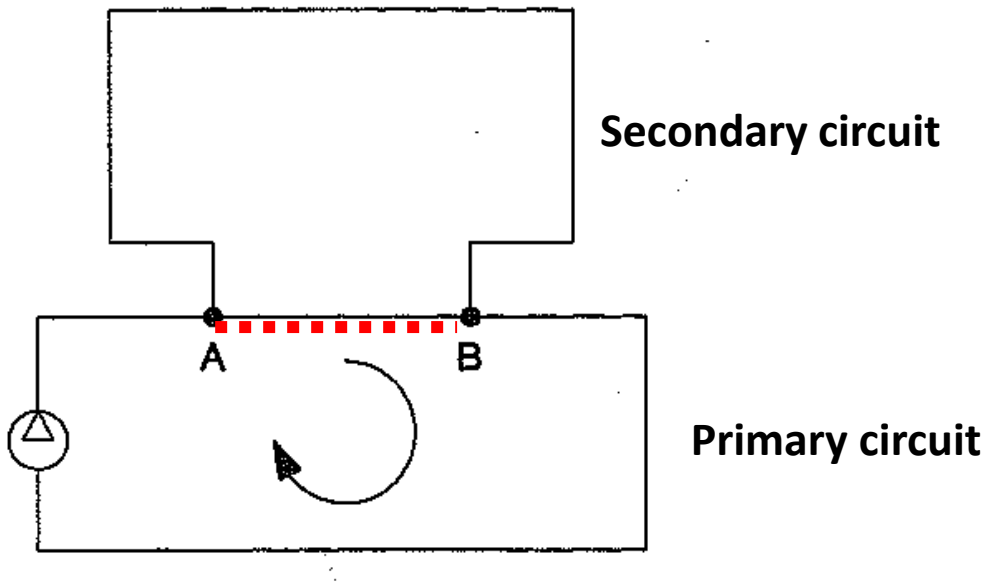
$$\Delta \mathrm{p} = R \, {Q_v}^2$$

Electrical analogy:

$$\Delta V = R_{el} I$$

Hydronic circuits

When there are two circuits, the primary and secundary flow rates depend on the pressure drop in the common section (e.g. AB)



Hydronic circuits

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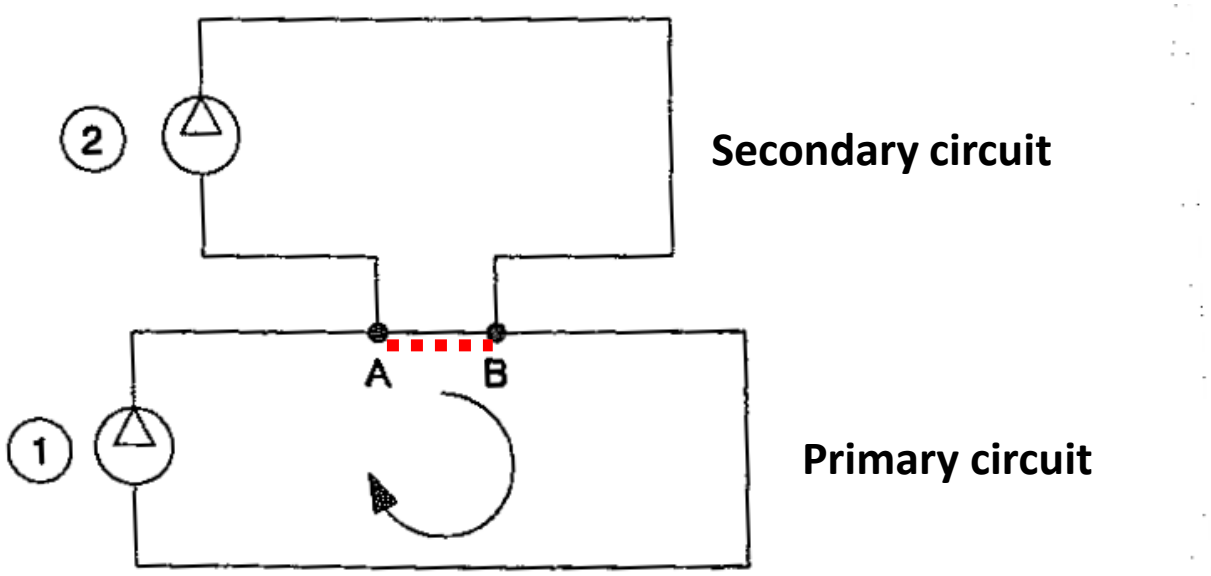
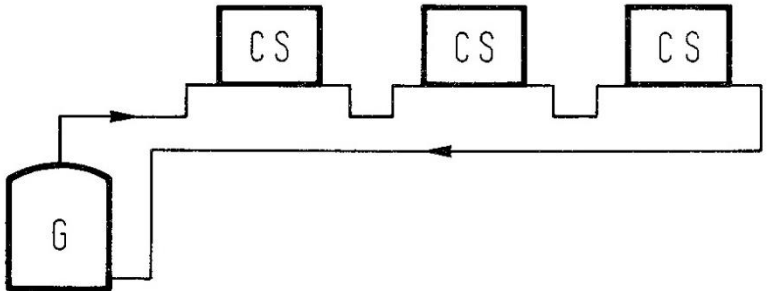


One-pipe circuit with in-series connection

The terminal units are connected **in series**.



Pros

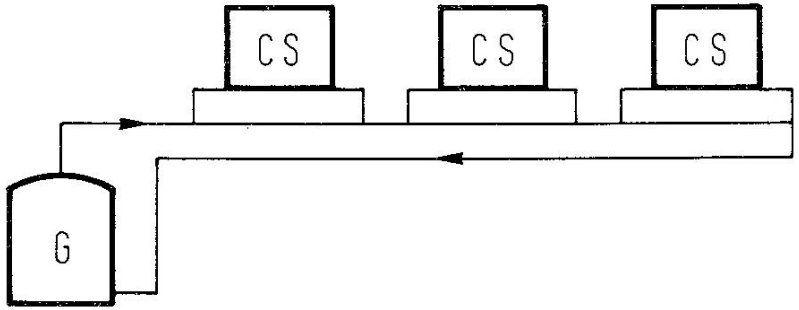
- Limited installation costs
- Simple sizing

Cons

- Supply temperature decreasing with distance from generator → last units need to be oversized to compensate for lower average temperature
- Heat emitters with high flow resistance limit the total heat output
- No individual flow control, which is limited to control features on heat emitters (e.g. blower speed in fan-coils)
- Noise due to excessive flow velocity through small tubes / valves in heat emitters

One-pipe circuit with in-parallel connection

The terminal units are connected **in parallel**.



Pros

- Limited installation costs
- Lower pressure drop
- Individual flow control

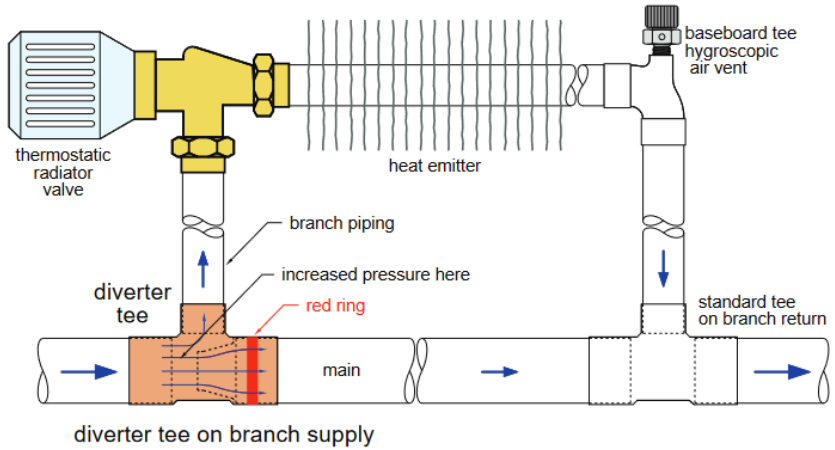
Cons

- Supply temperature decreasing with distance from generator → last units need to be oversized to compensate for lower average temperature

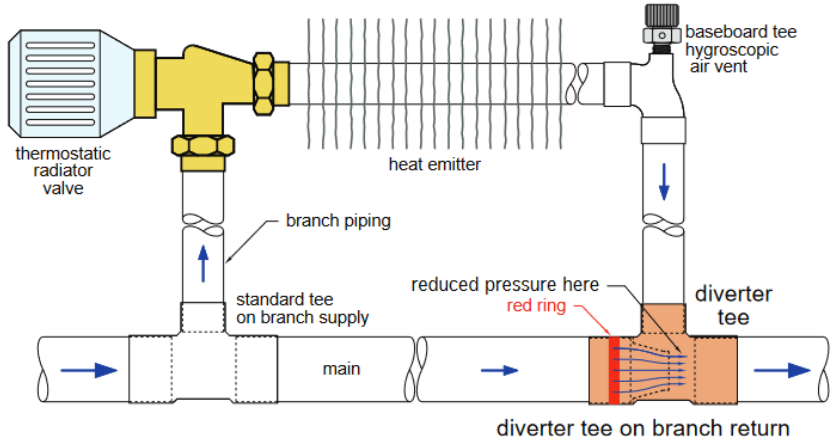
One-pipe circuit with in-parallel connection

Diverter tees are fittings specially designed to divert a portion of the water flowing in the main piping circuit through a branch circuit that includes at least one heat emitter.

- They can be installed on the supply, on the return, or on both branches.
- Each branch includes a thermostatic radiator valve that can modulate flow through that branch based on the set room temperature. Flow through a given branch can be completely stopped if necessary.



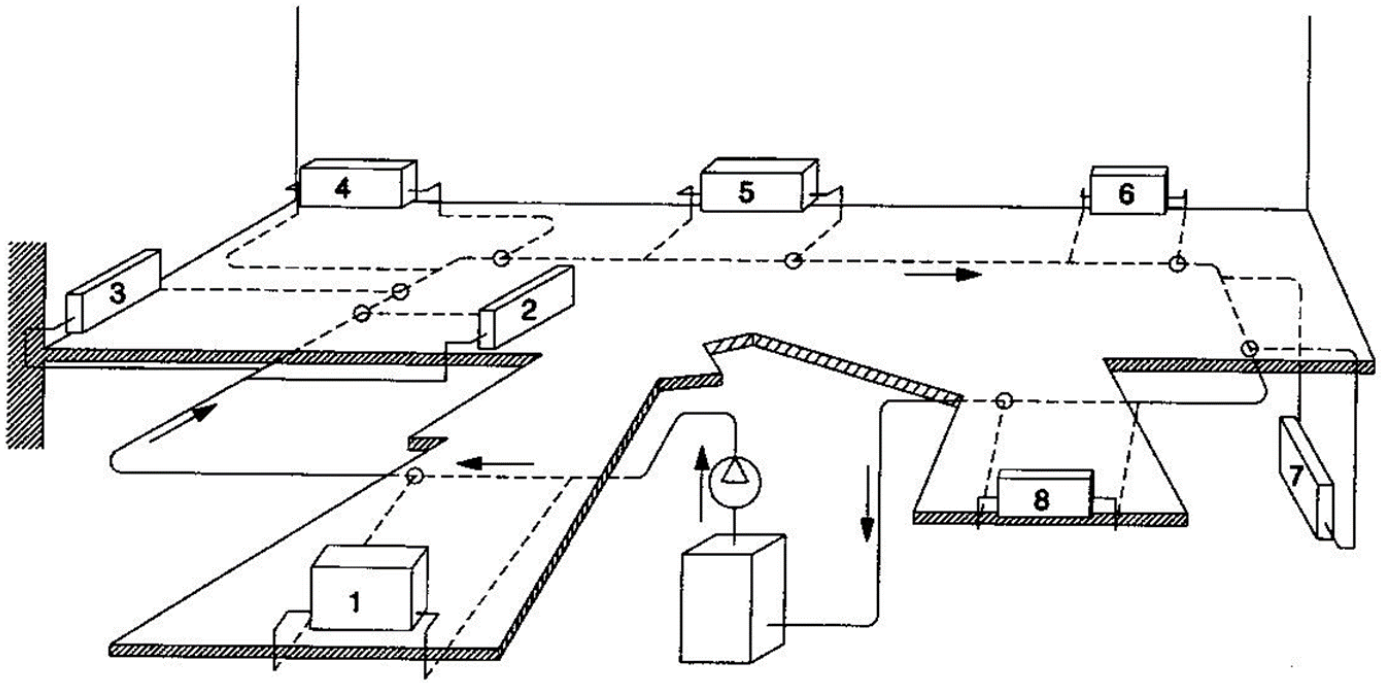
diverter tee on branch supply



diverter tee on branch return

One-pipe circuit with in-parallel connection

The terminal units are connected **in parallel**.



Two-pipe circuit with direct return

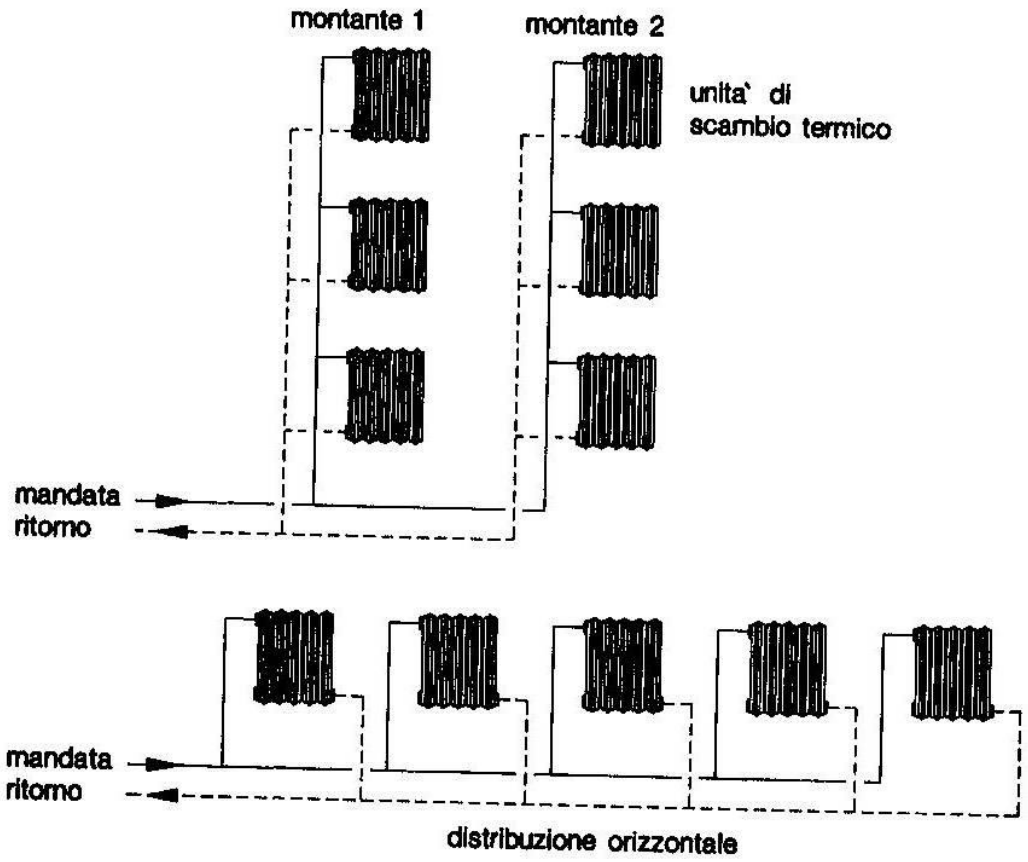
Double-pipe distribution with **direct return**

Pros

- Same supply temperature to all units (in contrast to single-pipe systems)

Cons

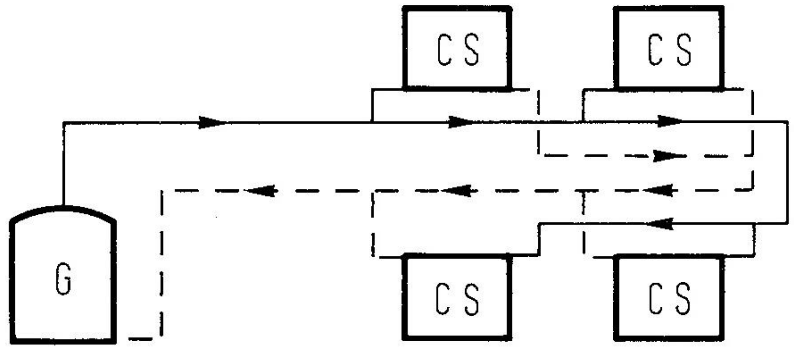
- Distribution system costs more than equivalent single-pipe due to longer piping
- Balancing needed to supply the design flow to all units because pressure differential decreases with distance from the pump(s)



Two-pipe circuit with reverse return

Double-pipe distribution with **reverse return**

(Tichelmann loop)



Pros

- Same supply temperature to all units (in contrast to single-pipe systems)
- Self-balanced system because the last terminal unit is «hydraulically» the closest to the pump on the return line

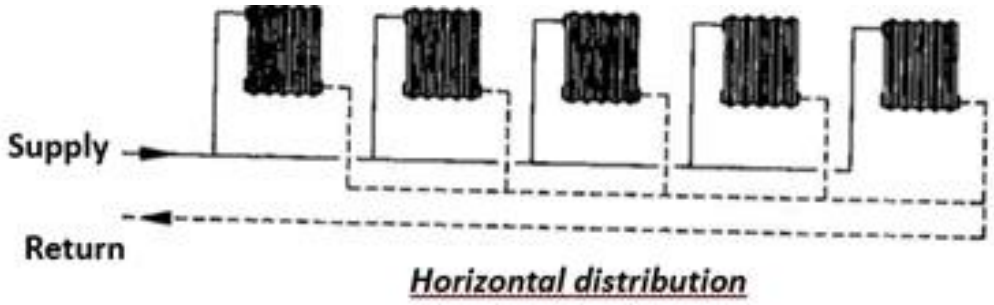
Cons

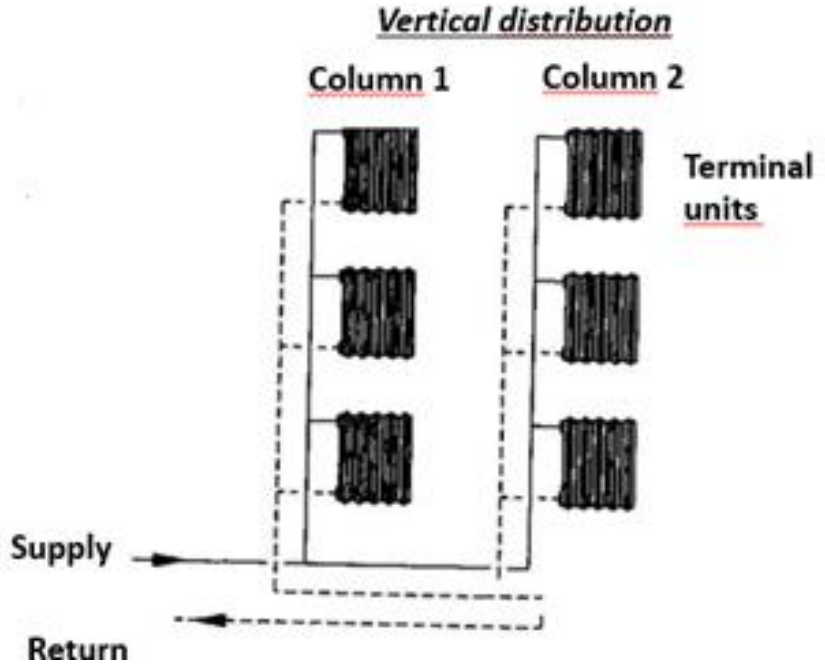
- Distribution system costs more than equivalent double-pipe system with direct return due to longer piping needed for the return line (installation of 3 pipes in parallel for part of the circuit).

Two-pipe circuit with reverse return

Double-pipe distribution with **reverse return**

(Tichelmann loop)

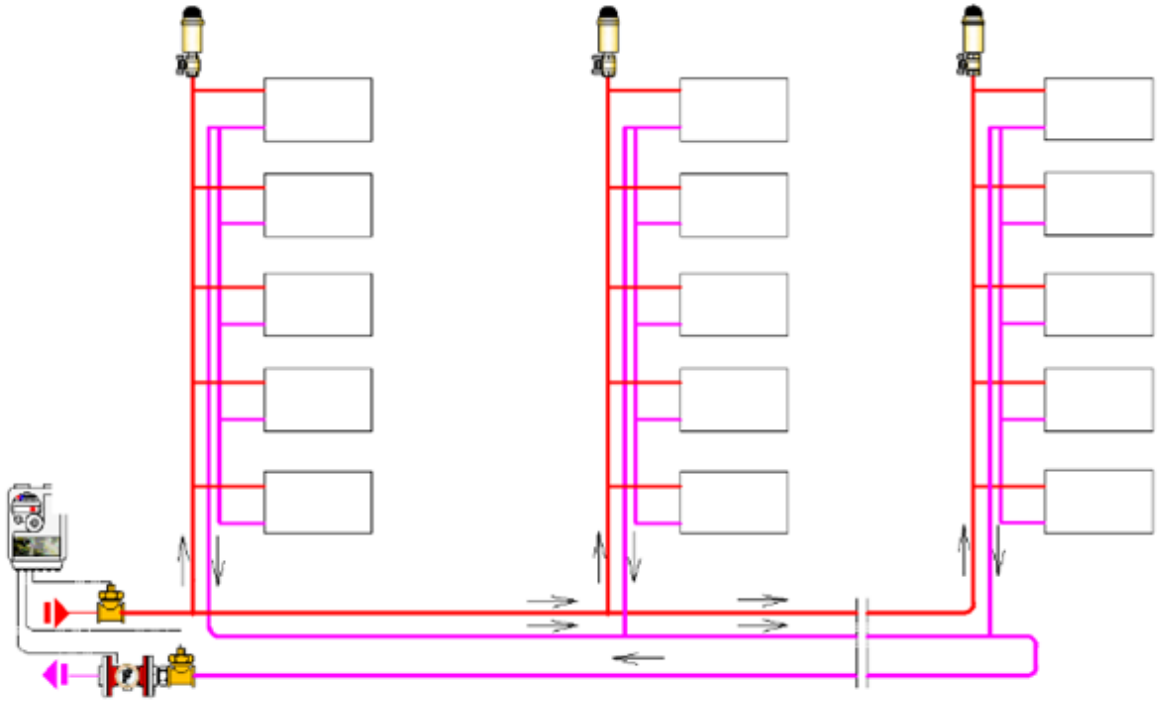




Two-pipe circuit with reverse return

Double-pipe distribution with **reverse return**

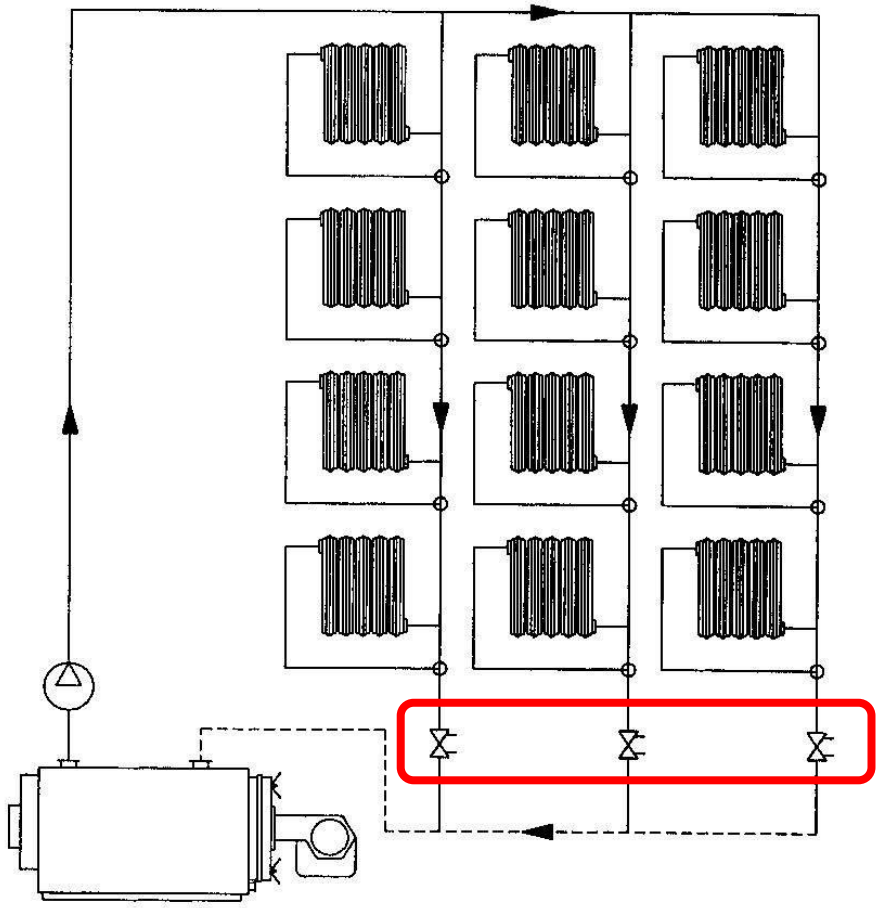
(Tichelmann loop)



[source: www.ctenergia.it]

One-pipe vertical circuit with direct return

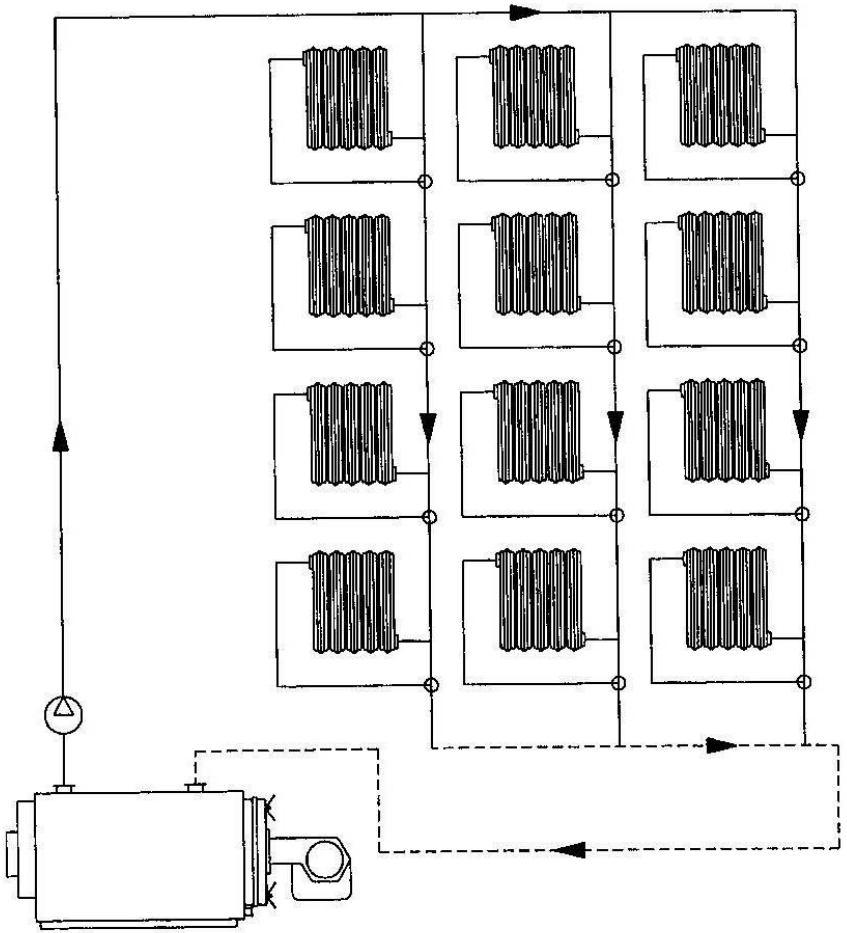
Single-pipe vertical circuit with **direct return**



Balancing valves

One-pipe vertical circuit with reverse return

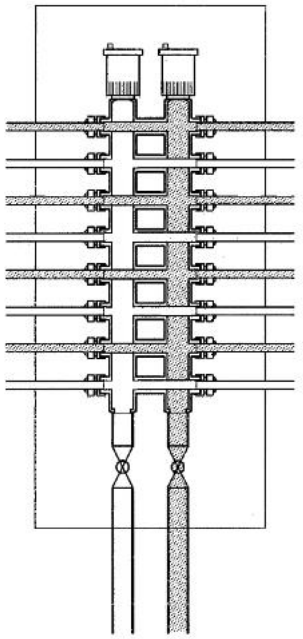
Single-pipe vertical circuit with **reverse return**



Two-pipe distribution with manifolds

Pros

- Possibility of realizing zone-based systems. Different zones of the building have same supply temperature, pressure difference and independent heat metering.
- Ease of installation because connections are pre-assembled.
- Working well with thermostatic valves on the terminal units.
- Uniform heat output during system start ups.



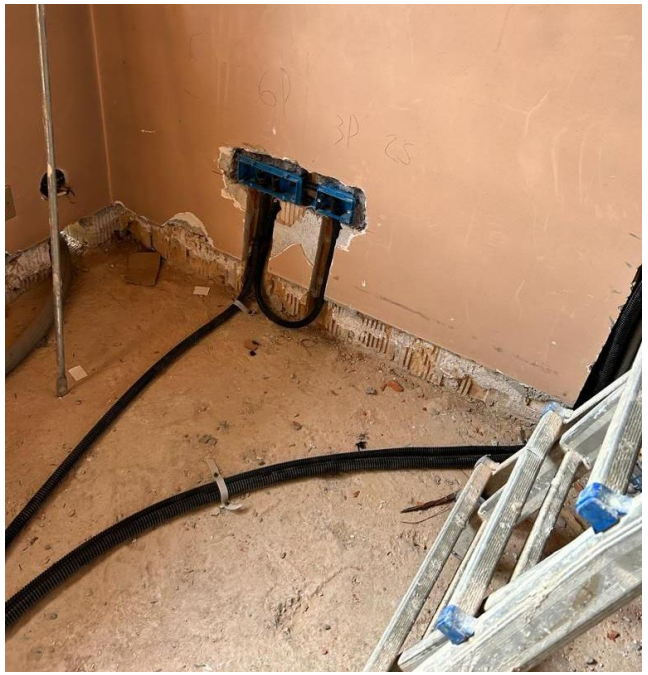
Rappresentazione di un collettore tipo

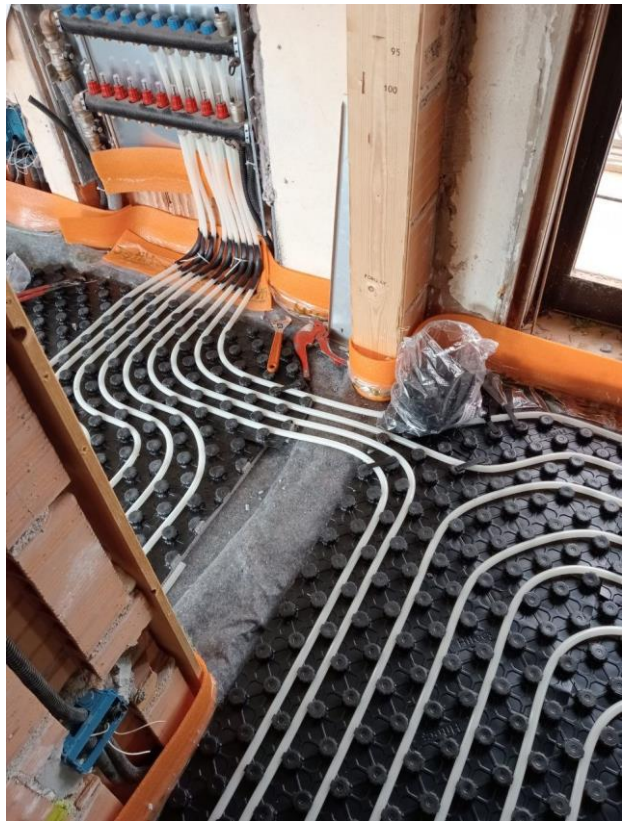
Two-pipe distribution with manifolds

Cons

- Each terminal unit needs a separate distribution line.

As a consequence, the floor has to be demolished in case of building retrofits.





Two-pipe distribution with manifolds

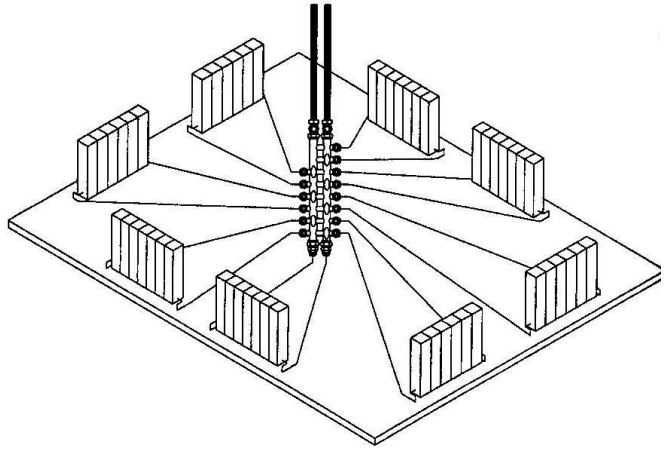
Where

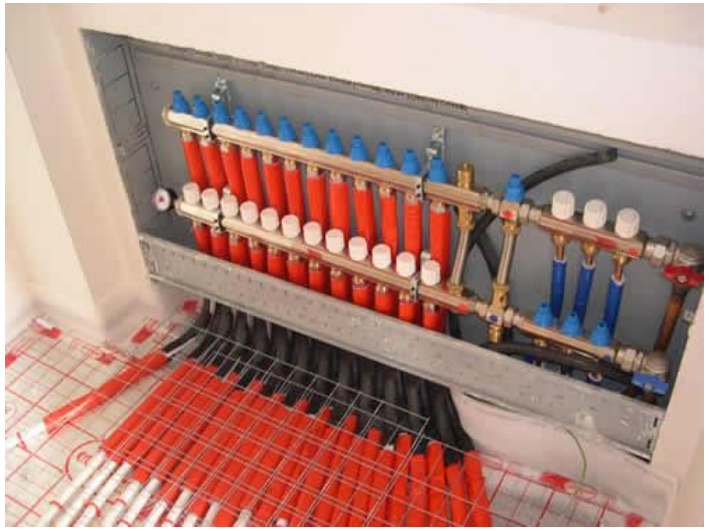
- **main manifold**: they are located in the heat supply station, downstream the heat generators.
- **zone manifold:** they receive the heat carrier fluid from the main manifold and distribute it locally to all the terminal units in the corresponding zone.

Two-pipe distribution with manifolds

Where

- To limit the development of internal circuits, manifolds are usually installed in a **barycentric area** with respect to the terminals to be served.
- It may also be convenient (especially in centralized systems) to place manifolds in **accessible cavities** (inspectable wall boxes, stairwells, cavediums).





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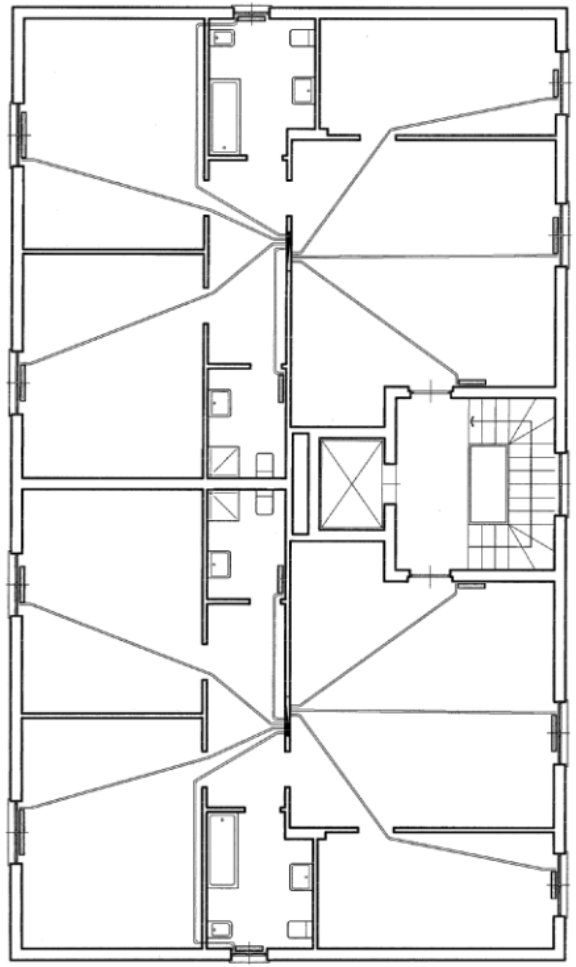
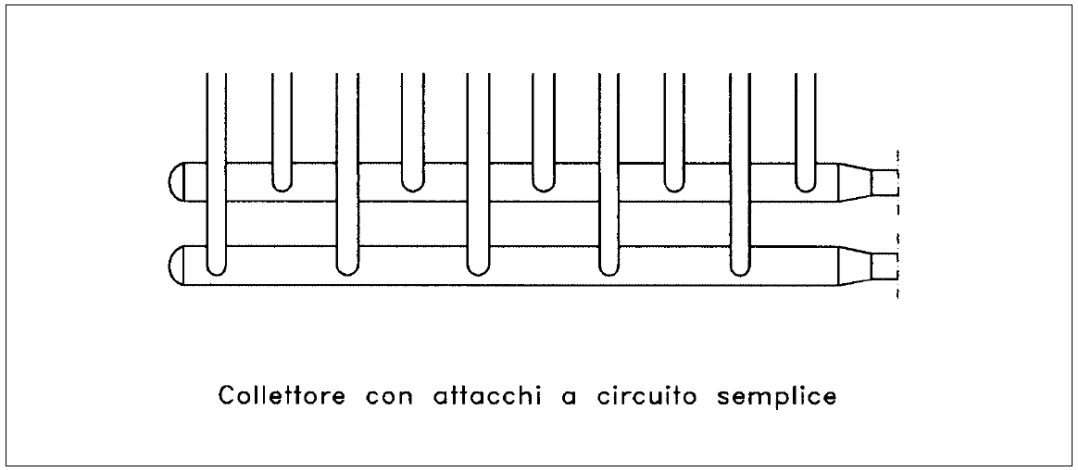
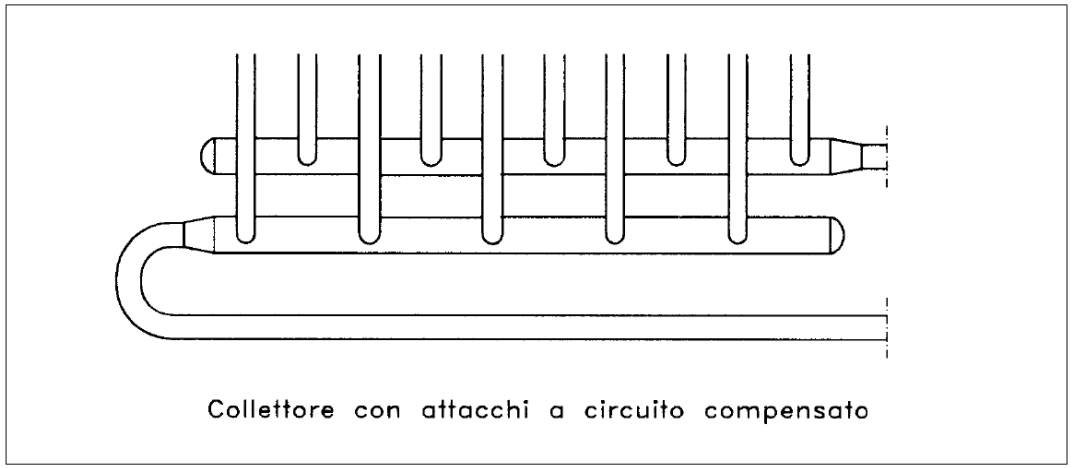


Two-pipe distribution with manifolds

Types



Collettore con attacchi a circuito semplice

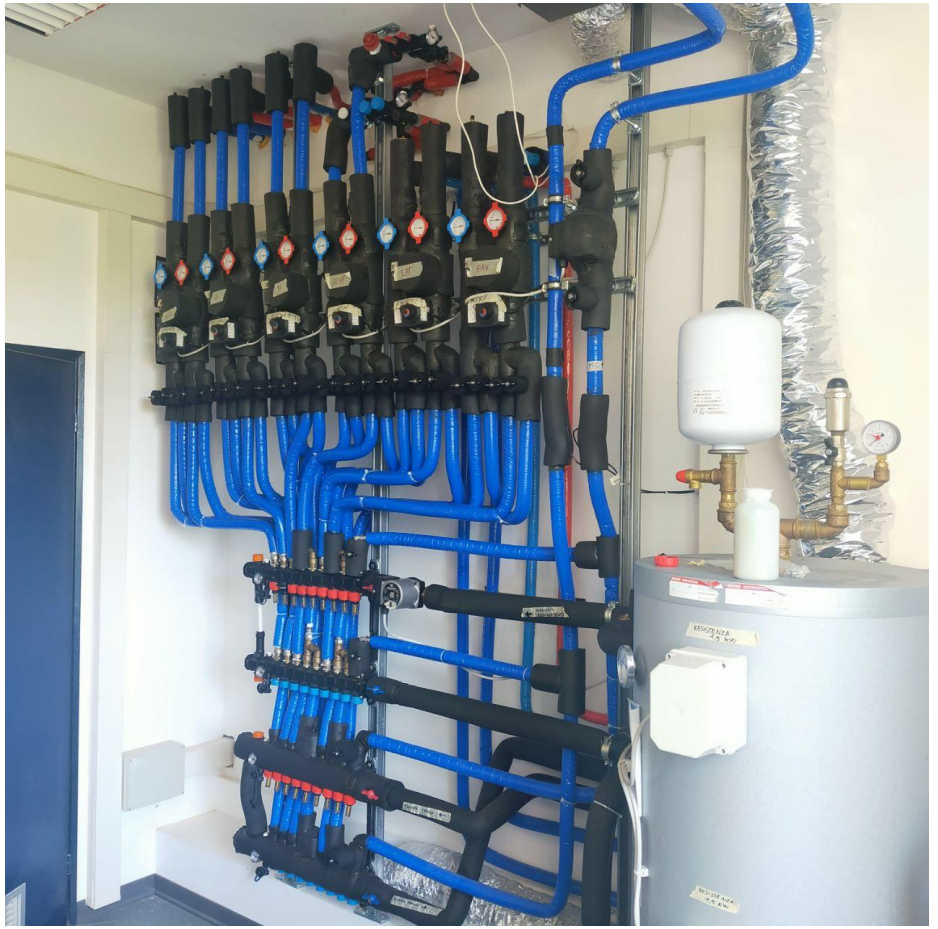


Collettore con attacchi a circuito compensato

Two-pipe distribution with manifolds

Core-Care Lab

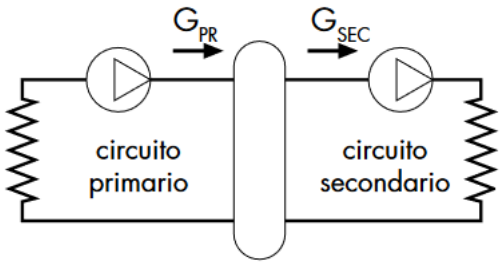
Heating and cooling manifolds supply the same radiant systems

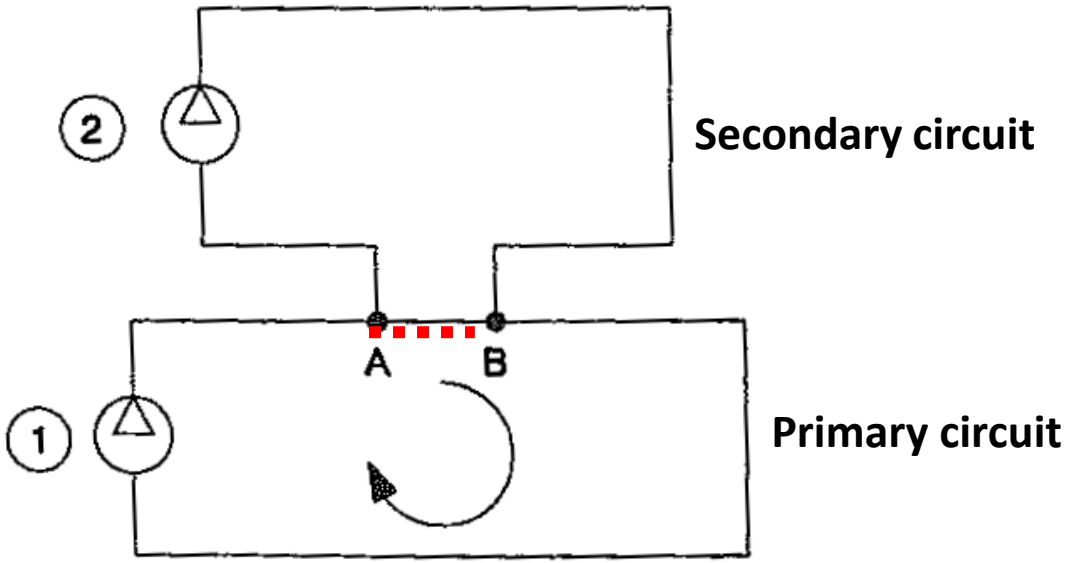


Two-pipe distribution

Hydraulic separator

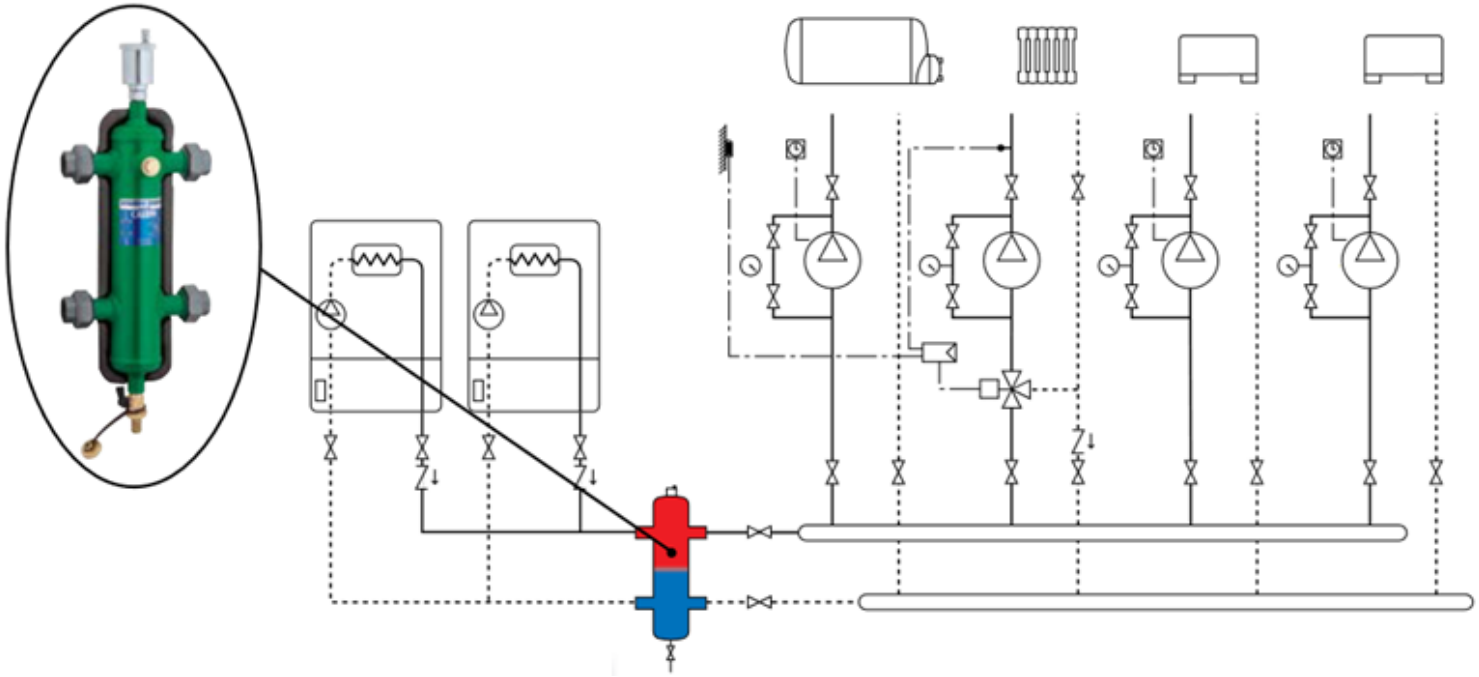
It is the easiest way to separate the pressure dynamics of the primary circuit from that of the secondary circuit.





Two-pipe distribution

Hydraulic separator

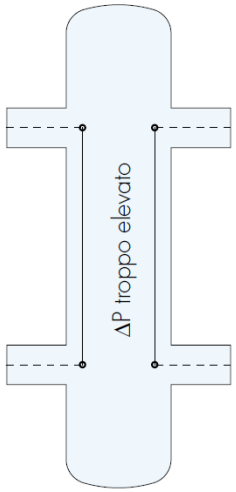


[source: www.caleffi.com]

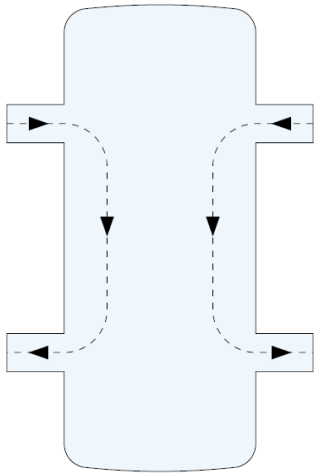
Two-pipe distribution

Hydraulic separator

A by-pass flow between supply and return pipe might occur if the separator is undersized (causing an excessive Δp) or not properly installed.



Rappresentazione separatore troppo stretto



Rappresentazione separatore troppo largo