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Hydraulics in HVAC Applications

Preface

Apart from the benefits of increased comfort and ease, the introduction of pumped warm water heating into buildings also produced problems in connection with the ever larger heating systems used to supply buildings.

The problem was that it was too cold in apartments located further away from the plant room whilst it was often too warm in apartments which were closer to the plant room. Obviously, the water in the pipes always sought the path of least resistance, which leads to the heating water flow rate near pumps being much greater than the quantity which flows through more remote pipes, although the pipe network nominal diameter is the same.

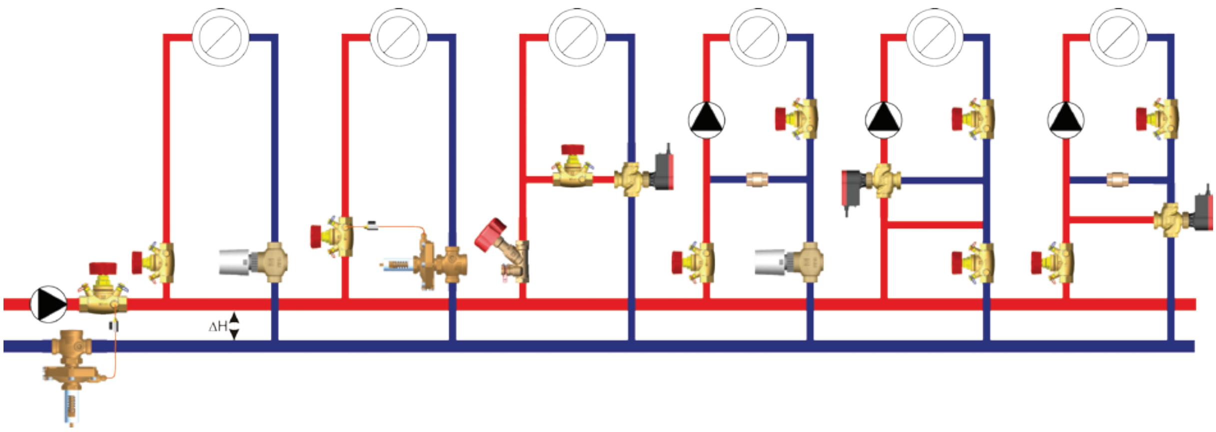
The question which now arose was whether the flow rate could be changed so that the same quantity of heating medium for consumers of the same size might be available at any given distance from the pump if artificially fitted resistors were fitted – larger ones near the pump and smaller ones further away.

The idea for hydraulic balancing and the means of implementing them was born.

During the energy crisis in the 1970s, it was recognised that energy can also be saved with balanced systems, as the average temperatures in buildings can be reduced with hydraulic balancing, although comfort in the heated building is increased at the same time.

The primary aim of balancing, whether it be in the field of heating or cooling, is to make the flow rates available to all heat consumers under nominal conditions. Furthermore, the differential pressure should hardly change across all circuits and the flow rates remain compatible at the system interfaces.

The hydraulic integration of consumer and distributed heat systems is possible in a very wide range of circuits. The selection of the right option for this integration depends on many factors. These include the use of the respective system and also the energy source which is necessary and available for the heat supply. This document explains the most important basic circuits and the calculation of these basic circuits by means of examples.



Systems with automatic balancing and throttling configuration, differential pressure regulator, diversion circuit, injection circuit with through valve, dual mixing circuit (from left to right).

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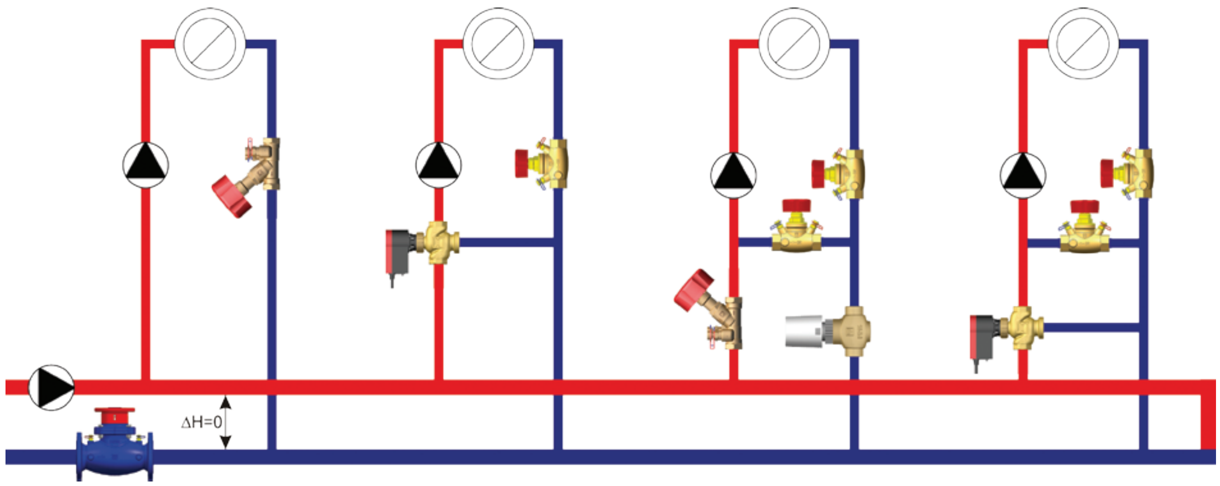


Systems with static balancing and circuit control valve, diversion circuit, injection circuit with through valve, dual mixing circuit.

Introduction

The most important prerequisite for a functioning system is the presence of the correct hydraulics in the system. Without this, subsequent problems are inevitable in the planning phase.

Special attention is therefore paid to the function of individual circuits but also to the interaction with the other circuits in the system and their mutual influence when selecting the hydraulic circuits.

The hydraulic integration of consumer and distributed systems is possible in a very varied number of circuits. The selection of the right integration option depends on many factors. These include how the respective system is used and the energy source which is necessary for the heat supply. The most important basic circuits and their pros and cons are explained. Basically, there are three areas in the pipe network – producers, distribution and consumers (terminal units).

If there is a differential pressure between the feed and return circuits in the distribution network, differential pressurised connections are used. With hydraulically decoupled distributors using a damper or a hydraulic switch there is no differential pressure – it is a pressureless distributor. Here, differential pressure-free connections are used. Pressureless distributors are used above all in smaller heating systems. It should be noted that every consumer must have its own pump.

Abbreviations

The following abbreviations apply to all schemes and example calculations:

Δp_L	Pressure loss via the consumer [kPa]
Δp_V	Pressure loss via the control valve [kPa]
Δp_{SRV}	Pressure loss via the circuit regulating valve [kPa]
Δp_{ab}	Pressure loss via the isolating valve [kPa]
Δp_{Schmu}	Pressure loss via the strainer [kPa]
q_p	Volume flowrate in the distribution circuit [l/h]
q_s	Volume flowrate in the consumer circuit [l/h]
t_v	Supply temperature in the consumer circuit [°C]
t_R	Return temperature [°C]
t_P	Supply temperature in the distribution heat circuit [°C]
ΔH	Pressure difference at the distributor [kPa]
Δp_{mv}	Pressure difference in the variable-volume section [kPa]

(Indexing is used with several components of the same kind)

Calculation fundamentals:

To calculate the hydraulic circuits, only the components (control and regulating valves) are used, since the losses in the pipes are practically negligible in contrast to the components (due to the short pipe lengths).

Definition of valve authority:

$$a = \frac{\Delta p_V}{\Delta p_{mv} + \Delta p_V}$$

Basic hydraulic circuits

Overview of circuits

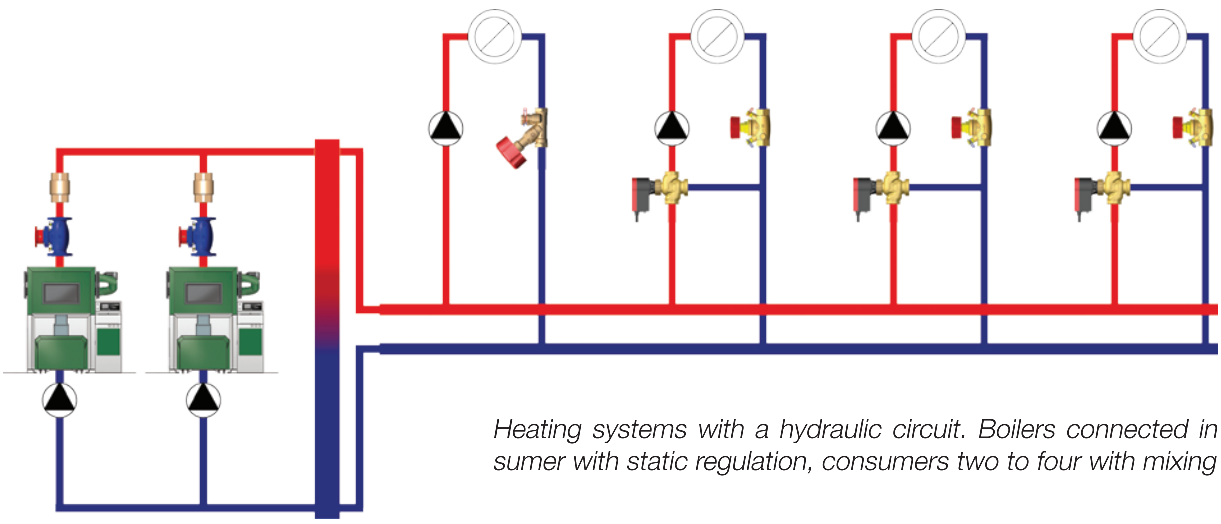
Circuit		Distribution heat circuit		Consumer circuit		Special feature
		Return flow boost	Volume flow	Return flow boost	Volume flow	
Pressurised distributor	Throttle circuit	No	Variable	Constant	Variable	Influence on other consumers
	Diversion circuit	Yes	Constant	Variable	Variable	No influence on other consumers
	Injection circuit with two port valve	No	Variable	Constant	Constant	Underfloor heating/ radiator combinations possible
	Injection circuit with three-port valve	Yes	Constant	Variable	Constant	Always distributed heat temperature at valve, good controllability
Pressureless distributor	Single mixing circuit	No	Variable	Variable	Variable	Always distributed heat temperature at valve, good controllability
	Dual mixing circuit	No	Constant	Variable	Constant	Underfloor heating/ radiator combinations possible

Table 1: Overview of circuits

Quick selection table

Circuit / Application case	Pressurised distribution				Pressureless distribution	
	Throttle circuit	Diversion circuit	Injection circuit Through valve	Injection circuit Through valve	Mixing circuit Single	Mixing circuit Dual
Distributed heat	♡					
Condensing boiler systems	♡					
Radiator systems			♡	♡	♡	
Underfloor heating			♡			
Combined underfloor heating / radiators			♡	♡		♡
Electric air heaters		♡	♡		♡	
Cooling coils		♡				
Zone regulation	♡	♡				

Fig. 1: Quick selection



Heating systems with a hydraulic circuit. Boilers connected in parallel. First consumer with static regulation, consumers two to four with mixing circuit.

Hydraulic circuits for differential pressure connections in heating systems

Various control-related circuits require a differential pressure at the distributor. To size the control valves correctly the differential pressure must be known, otherwise the control valves will be incorrectly dimensioned.

Four basic circuit arrangements come into consideration with differential pressure connections

Throttle circuit

With this form of hydraulic circuit the adjustment is made by throttling the flow rate. In this case, the control valves take over the task of changing the flow rate in the control circuit, e.g. to influence the thermal output of a heat exchanger.

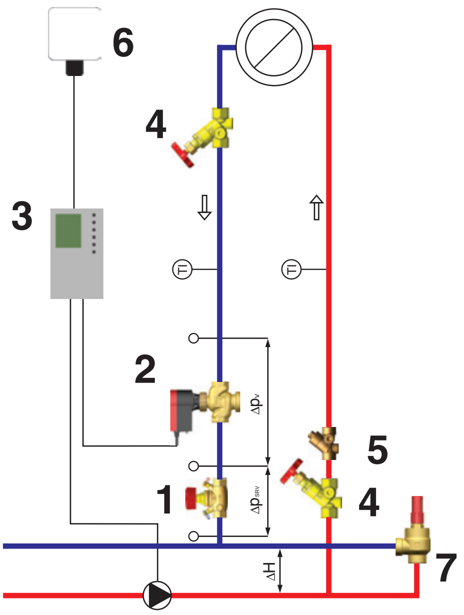


Fig. 2: throttle circuit

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Mixing valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolation valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111					
6	Temperature sensor	7793					
7	DP Overflow valve	4004					

Table 2: throttle circuit

Features: Water volume variable on both the distributed heat and consumer sides. Temperature on the distribution heat side constant (depending on the central temperature regulation) and constant on the consumer side. Output is regulated by altering the flow rate.

Benefits: This produces good diversity and is therefore suitable for condensing boiler and distributed heat systems.

Drawbacks: With several throttle circuits in the piping network the pump operating point is displaced by the change in valve travel and the associated pressure change. The pressure difference which occurs has an influence on individual consumers.

The return flow control valve keeps the pressure constant and limits the flow rate. This guarantees reliable control without any influence.

Throttle circuits are used wherever low return temperatures and variable flow rates are required. The thermal behaviour features decreasing return temperatures with a decreasing load.

Specifically this circuit is to be found:

- In the distribution of district heating plants,
- In connections to buffer storage, and also
- In integration of the consumer network with condensing boiler systems.

Further areas of use are:

- Zone control in radiator and underfloor heating systems with supply temperature regulated by the outdoor temperature and also for
- Small supplementary heaters and heat exchangers of all sizes.

Sizing example

Q = 70 kW
t_V = 90 °C
t_R = 50 °C
Δp_L = 10 kPa
ΔH = 30 kPa

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} =$$

$$= 3600 \cdot \frac{70}{4.19 \cdot (90 - 50)} = 1504\ l/h$$

⚠ The pipe size depends on the pipe material and the permissible pipe friction.

Requirement 1:
$\Delta p_v \geq \Delta p_L$ (the differential pressure via the control valve must be greater than or equal to the differential pressure via the consumer).

Step 1:
Calculation of the minimum available differential pressure:

Requirement 2:
$\Delta H \geq \Delta H_{min}$ (the available differential pressure at the distributor must be greater than or equal to the required minimum differential pressure)

$$\Delta H_{min} = \Delta p_{V,min} + \Delta p_L + \Delta p_{SRV} + \Delta p_{Ab} + \Delta p_{Schmu}$$

⚠ Δp_{SRV} minimum 3 kPa

The kv_s values for size DN 25 were used to determine the pressure loss via the shutoff valve (4115) and the strainer (4111) mesh size.

$$\Delta H_{min} = 10 + 10 + 3 + 0.7 + 1.2 = 24.9\ [kPa]$$

Since ΔH = 30 kPa, requirement 2 is fulfilled.

Step 2:
Calculation of the theoretical kv value of the control valve: ($\Delta p_{V,min}$ = 10 kPa)

$$k_{v,theo} = \frac{q_s}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{1504}{100 \cdot \sqrt{10}} = 4.75$$

Step 3:
Selection of the kv_s value from the valve class. The 4037 valves in question are the DN 15 valve with a kv_s value of 4.0 and the DN 20 valve with a kv_s value of 6.3. Generally it can be assumed that the smaller kv_s value is selected to achieve the necessary pressure loss.

If kv_s = 6.3

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{1504}{100 \cdot 6.3}\right)^2 = 5.7\ kPa$$

Requirement 1 was **not fulfilled**.

If kv_s = 4.0

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{1504}{100 \cdot 4.0}\right)^2 = 14.1\ kPa$$

Requirement 1 was fulfilled.

The control valve has a kv_s value of 4.0 and the size DN 15

The valve authority is:

$$a = \frac{\Delta p_v}{\Delta H} = \frac{14.1}{30} = 0.47$$

The valve authority should be between 0.35 and 0.75 but may not be less than 0.25, otherwise the system becomes unstable.

Step 4:
The sizing of the circuit supply regulating valve

Determination of the differential pressure to be dissipated:

$\Delta p_{SRV} = \Delta H - (\Delta p_V + \Delta p_L) =$
$= 30 - (14.1 + 10) = 5.9$ kPa

Determination of the kv value:

$$k_{v,SRV} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{SRV}}} = \frac{1504}{100 \cdot \sqrt{5.9}} = 6.2$$

The default setting for a 4217 straight regulating valve of 1" size is 3.3.

Diversion circuit (distribution circuit)

This circuit is a variant of the throttle circuit.

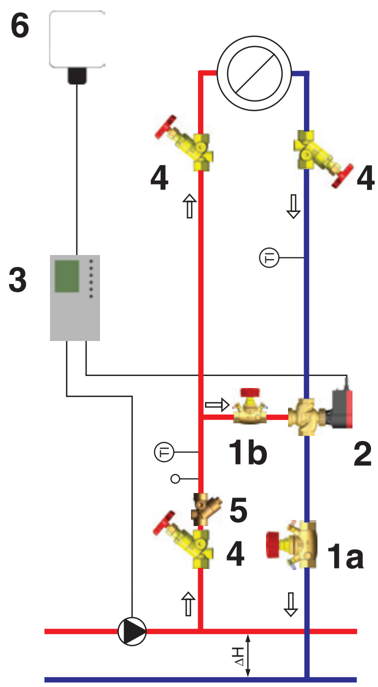


Fig. 3: Diversion circuit

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Mixing valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolating valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111	2662				
6	Temperature sensor	7793					

Table 3: diversion circuit

Features: Water volume constant on distributed heat system side, variable on consumer side. Temperature constant on distributed heat system side (depending on the central temperature control), constant on the consumer side. Output in the consumer circuit is regulated by altering the flow rate.

Application: Electric air heaters, cooling coils, zone regulation

Benefits: An outlet-regulated pump is not required on the distributed heat side due to the constant flow rate. The differential pressure does not change and the individual consumers do not influence one another.

Drawbacks: The temperature at the consumer is always the same as the distributed heat temperature

The hydraulic advantages of this circuit are the constant quantity of heating medium in the distributed heating circuit which means that output-regulated pumps are not required. The authority of the control valve depends only on the load, i.e. the three-port valve is installed independently of the distribution network since there is no interaction. The disadvantage of the diversion circuit is that the temperature at the consumer is always the maximum temperature of the distribution system supply and it is not possible to make use of any separate temperature level between the distributed heat and consumer circuits. Furthermore, installation is unsuitable and not permitted for buffer storage, condensing boiler systems and distributed heating systems, since warm supply medium is always mixed with the return valve and raises the return flow temperature during partial load operation.

The rapid availability of hot distributed heat medium has large control-related benefits for the consumer. Constant-flow operation of the energy source, heat or cold generator, also has a control-related and also a partial operationally related benefit. From an energy efficiency point of view, however, the constant flow rate in the distributed heat circuit also brings a disadvantage with it since no pump energy can be saved.

Sizing example

Q = 40 kW
t_V = 6 °C
t_R = 12 °C
Δp_L = 25 kPa
ΔH = 70 kPa

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} =$$
$$= 3600 \cdot \frac{40}{4.19 \cdot (12 - 6)} \cong 5730\ l/h$$

⚠ The pipe size depends on the pipe material and the permissible pipe friction

Requirement 1:
$\Delta p_v \geq \Delta p_L$ (The differential pressure via the control valve must be greater than or equal to the differential pressure via the consumer)

Step 1:
Calculation of the minimum available differential pressure:

Requirement 2:
$\Delta H \geq \Delta H_{min}$ (The available differential pressure at the distributor must be greater than or equal to the minimum required differential pressure)

$$\Delta H_{min} = \Delta p_{V,min} + \Delta p_L + \Delta p_{SRV} + \Delta p_{Schmu}$$

⚠ Δp_{SRV} minimum 3 kPa

The kv_s values for the DN 40 size were used to determine the pressure loss via the shutoff valve (4115) and the strainer (4111) mesh size.

$$\Delta H_{min} = 25 + 25 + 3 + 0.8 = 53.8\ [kPa]$$

Since ΔH = 70 kPa, requirement 2 is fulfilled.

Step 2:
Calculation of the theoretical kv value of the control valve: ($\Delta p_{V,min}$ = 25 kPa)

$$k_{v,theo} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{5730}{100 \cdot \sqrt{25}} = 11.46$$

Step 3:
Selection of the kv_s value from the valve class. The 4037 valves in question are DN 25 valves with a kv_s value of 10.0 and the DN 32 valve with a kv_s value of 16. Generally it can be assumed that the smaller kv_s value is selected to achieve the necessary pressure loss.

If kv_s = 16

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{5730}{100 \cdot 16}\right)^2 = 12.82\ kPa$$

Requirement 1 was not fulfilled.

If kv_s = 10

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{5730}{100 \cdot 10}\right)^2 = 32.8\ kPa$$

Requirement 1 was fulfilled.

The control valve has a kv_s value of 10 and a size of DN 25

The valve authority is:

$$a = \frac{\Delta p_V}{\Delta p_L + \Delta p_V} = \frac{32.8}{25 + 32.8} = 0.57$$

The valve authority should be between 0.35 and 0.75 but must not be below 0.25, otherwise the system becomes unstable.

Step 4:
The sizing of circuit supply regulating valve 1a in the return flow

Determination of the differential pressure to be dissipated:

$$\Delta p_{SRV1a} = \Delta H - (\Delta p_V + \Delta p_L + \Delta p_{Schmu}) =$$
$$= 70 - (32.8 + 25 + 0.8) = 11.4\ kPa$$

Determination of the kv value:

$$k_{v,SRV1a} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{SRV1}}} = \frac{5730}{100 \cdot \sqrt{11.4}} = 17.0$$

The default setting for a 4217 straight regulating DN 40 valve is 4.8.

Step 5:
Bypass sizing:
Should the consumer not collect any output it must be possible to divert the entire mass flow via the bypass.

Requirement 3:
$\Delta p_{SRV_2} = \Delta p_L$

Requirement 4:
$q_{Bypass} = q_S$

The kv value of the valve in the bypass can be determined with these requirements.

$$k_{v,SRV1b} = \frac{q_{Bypass}}{100 \cdot \sqrt{\Delta p_{SRV_2}}} = \frac{5730}{100 \cdot \sqrt{25}} = 11.46$$

The default setting for a 4217 straight regulating valve of DN 40 size is 4.0.

Injection switching with two port valve

Unlike with throttle circuits, the water volume in the consumer system in this system is constant.

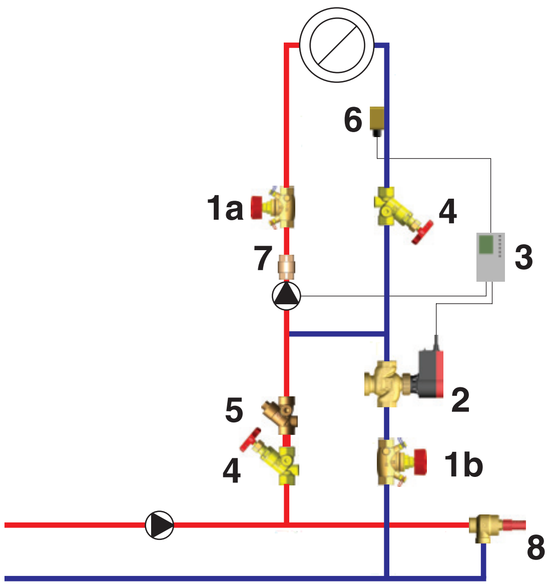


Fig. 4: Injection circuit with two port valve

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Control valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolation valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111	2662				
6	Outdoor temperature sensor	7793					
7	Non-return valve	2622					
8	DP Overflow valve	4004					

Table 4: Injection circuit with two port valve

Features: Distributed heat system-side water volume variable and consumer-side constant. Consumer temperature variable

Application: radiator systems, underfloor heating, electric air heaters, low-temperature heating

Benefits: For systems with low return temperatures (distributed heating systems, condensing boiler systems), different temperature levels for distributed heat and consumer sides (e.g. 45 °C and 90 °C)

Drawbacks: To size the control valve the differential pressure must be known, there is a frost risk for preheating radiators in the case of long pipe runs.

Sizing example

Q = 25 kW
t_V = 45 °C
t_R = 35 °C
ΔH = 25 kPa
$\Delta t_{primär}$ = 70 °C

$$q_P = 3600 \cdot \frac{Q}{c \cdot (t_p - t_R)} =$$

$$= 3600 \cdot \frac{25}{4.19 \cdot (70 - 35)} = 614\ l/h$$

The pipe size depends on the pipe material and the permissible pipe friction.

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} =$$

$$= 3600 \cdot \frac{25}{4.19 \cdot (45 - 35)} = 2148\ l/h$$

Requirement 1:
$\Delta p_v \geq \Delta H$ (The differential pressure via the control valve must be greater than or equal to the differential pressure via the distributor)

Step 1:
Calculation of the theoretical kv value of the control valve: ($\Delta p_{V,min}$ = 25 kPa)

$$k_{v,theo} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{614}{100 \cdot \sqrt{25}} = 1.2$$

Step 2:
Selection of the kvs value from the valve class. The 7762 valves in question are the DN 10 valve with a kv_s value of 1.0 or 1.6. A larger value can be selected here. The remaining differential pressure is dissipated via circuit control valve 2.

If kv_s = 1.6

$$\Delta p_v = \left(\frac{q_P}{100 \cdot Kv_s}\right)^2 = \left(\frac{614}{100 \cdot 1.6}\right)^2 = 14.7\ kPa$$

The control valve has a kv_s value of 1.6 and a size of DN 10

The valve authority is:

$$a = \frac{\Delta p_V}{\Delta H} = \frac{14.7}{25} = 0.59$$

The valve authority should be between 0.35 and 0.75 but must not be less than 0.25, otherwise the system is unstable.

Step 3:
Sizing of circuit regulating valve 1a in the supply circuit

Determination of the differential pressure to be dissipated:

$$\Delta p_{SRV1a} = \Delta H - \Delta p_V = 25 - 14.7 = 10.3\ kPa$$

Determination of the kv value:

$$k_{v,SRV1a} = \frac{q_P}{100 \cdot \sqrt{\Delta p_{SRV2}}} = \frac{614}{100 \cdot \sqrt{10.3}} = 1.9$$

The required 10.3 kPa are dissipated via the circuit regulating valve.

The default setting for a 4217 straight regulating valve of DN 15 size is 2.9.

Step 4:
Sizing of circuit regulating valve 1b:
Circuit regulating valve 1b should be sized with a nominal pressure loss of 3 kPa.

$$k_{v,SRV1b} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{stad2}}} = \frac{2148}{100 \cdot \sqrt{3}} = 12.4$$

The default setting for a 4217 straight regulating valve of DN 32 size is 4.3.

Injection circuit with three-port valve

With this hydraulic circuit, the volume flows in the distributed heat circuit and the consumer circuit are constant.

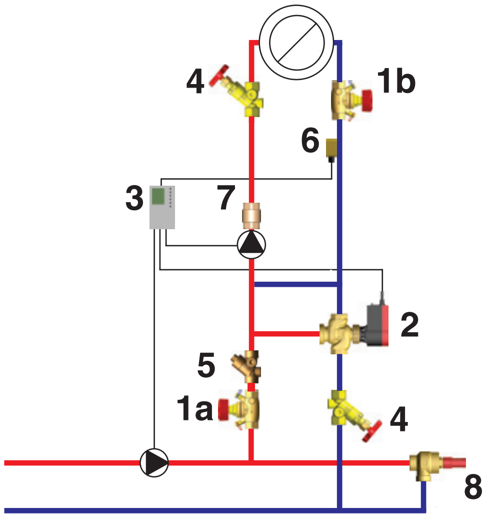


Fig. 5: Injection circuit with three-port valve

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Mixing valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolation valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111	2662				
6	Outdoor temperature sensor	7793					
7	Non-return valve	2622					
8	DP Overflow valve	4004					

Table 5: Injection circuit with three-port valve

Features: Water volume in both distributed heat circuit and consumer sides constant. Consumer-side temperature variable

Application: Radiator systems, low-temperature systems with almost equal distributed heat and consumer temperatures, electric air heaters, if the differential pressure is not known.

Benefits: excellent controllability due to the constant consumer-side flow rate.

Drawbacks: Permanent return temperature increase, and therfore this in not suitable for district heating or condensing boilers.

The benefits of this circuit lie in the low or totally negligible dead time as hot water is permanently available at the control valve. This characteristic is exploited with the installation of heating coils where large quantities of energy are required quickly. A further, already discussed benefit is the valve authority of almost 1, since there is almost no resistance in the variable-volume circuit.

Sizing example

Q = 90 kW
t_V = 75 °C
t_R = 55 °C
ΔH = 40 kPa
$T_{primär}$ = 90 °C

$$q_P = 3600 \cdot \frac{Q}{c \cdot (t_p - t_R)} =$$

$$= 3600 \cdot \frac{90}{4.19 \cdot (90 - 55)} = 2209\ l/h$$

⚠ The pipe dimension depends on the pipe material and the permissible pipe friction.

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} =$$

$$= 3600 \cdot \frac{90}{4.19 \cdot (75 - 55)} = 3866\ l/h$$

Requirement 1:
$\Delta p_v > 3$ kPa

Step 1:
Calculation of the theoretical kv value of the Control valve:

$$k_{v,theo} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{3866}{100 \cdot \sqrt{3}} = 22.3$$

Step 2:
Selection of the kv_s values from the valve class. The 4037 valves in question are the DN 32 valve with a kv_s value of 16 and the DN 40 valve with a kv_s value of 25

If $kv_s = 25$

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{3866}{100 \cdot 25}\right)^2 = 2.4\ kPa$$

If $kv_s = 16$

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{3866}{100 \cdot 16}\right)^2 = 5.8\ kPa$$

The control valve has a kv_s value of 16 and a size of DN 32.

The valve authority is

$$a = \frac{\Delta p_V}{\Delta p_v} = \frac{5.8}{5.8} = 1$$

(The variable-volume circuit is limited to the bypass)

Step 3:
The sizing of circuit regulating valve 1a in the supply flow

Determination of the differential pressure to be dissipated:

$$\Delta p_{SRV1a} = \Delta H - \Delta p_V = 40 - 5.8 = 34.2\ kPa$$

Determination of the kv value:

$$k_{SRV_2} = \frac{q_P}{100 \cdot \sqrt{\Delta p_{SRV_2}}} = \frac{3866}{100 \cdot \sqrt{34.2}} = 6.6$$

The default setting for a 4217 straight regulating valve of DN 40 size is 3.0.

Step 4:
Sizing of circuit regulating valve 1b in the Return flow
Circuit control valve 1b should be sized with a nominal pressure loss of 3 kPa

$$k_{SRV_{1b}} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{SRV_1}}} = \frac{3866}{100 \cdot \sqrt{3}} = 22.3$$

The default setting for a 4217 straight regulating valve of DN 40 size is 5.8.

Step 5:
Sizing of the bypass

The bypass must be able to accept the entire consumer water volume.

Hydraulic circuits for differential pressure-free connections in heating systems

Various control-related circuits permit no differential pressure at the distributor. With these circuits, it must be taken into account that each consumer requires its own pump, even those with low power ratings.

Two basic circuits come into consideration for differential pressure-free circuits

Hydraulic circuits for differential pressure-free connections and pressureless hydraulically separated distributors.

Practice has shown that the hydraulic separation of heat generation and heat consumption circuits is beneficial. The use of a hydraulic separator ensures constant conditions on the consumer side despite strongly varying flow rates on the heat generation side. This creates improved conditions for the overall behaviour of the system.

Mixing circuit

In contrast to the diversion circuit this hydraulic circuit works with a variable water volume on the distributed heat side and a constant volume of heating medium in the consumer circuit. The mixing circuit for the consumer is controlled by a variable-temperature and constant-volume control. This form of hydraulic circuit is the most widespread circuit in heating technology as it is very simple to achieve.

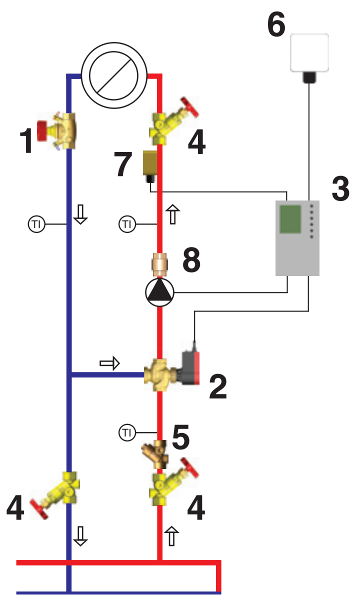


Fig. 6: Mixing circuit

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Three-port valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolation valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111	2662				
6	Temperature sensor	7793					
7	Outdoor temperature sensor	7793					
8	Non-return valve	2622					

Table 6: Mixing circuit

Features: Distributed heat-side water volume variable, constant on consumer side, distributed heat-side temperature variable.

Application: Radiator systems, electric air heaters

Benefits: Excellent controllability due to the constant consumer-side flow rate.

Drawbacks: The distributed heat-side and consumer-side temperature level must be almost equal. This means that a low-temperature system cannot be coupled to a high-temperature system. No distributed heat-side differential pressure is permitted.

The control valve in the return flow limits the flow rate.

Sizing example

Q = 20 kW
t_V = 80 °C
t_R = 60 °C
Δp_L = 25 kPa

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} =$$

$$= 3600 \cdot \frac{20}{4.19 \cdot (80 - 60)} = 860\ l/h$$

⚠ The pipe size depends on the pipe material and the permissible pipe friction. The data is taken from the calculated system

Step 1:
Calculation of the theoretical kv value of the control valve: ($\Delta p_{V,min}$ = 3 kPa)

$$k_{v,theo} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{860}{100 \cdot \sqrt{3}} = 4.9$$

Step 2:
Selection of the kv_s value from the valve class. The 4037 valves in question are the DN 20 valve with a kv_s value of 6.3 and the DN 15 valve with a kv_s value of 4. Normally it can be assumed that the smaller kv_s-value is selected to achieve the necessary pressure loss.

If kv_s = 6.3

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{860}{100 \cdot 6.3}\right)^2 = 1.86\ kPa$$

Δp_v < 3 kPa!

If kv_s = 4.0

$$\Delta p_v = \left(\frac{q_S}{100 \cdot Kv_s}\right)^2 = \left(\frac{860}{100 \cdot 4.0}\right)^2 = 4.62\ kPa$$

Δp_v > 3 kPa

The control valve has a kv_s value of 4.0 and a size of DN 15.

The distributed heat circuit contains two shutoff valves (4115 3/4”) and a strainer (4111, 3/4” mesh size 0.75 mm). The valve authority is

$$a = \frac{\Delta p_V}{\Delta p_v + 2 \cdot \Delta p_{Ab} + \Delta p_{Schmu}} =$$

$$= \frac{4.62}{4.62 + 2 \cdot 0.7 + 1.3} = 0.63$$

The pressure loss in the mixing valve must be additionally provided by the pump.

Step 3:
Sizing of the circuit regulating valve to 3 kPa

$$k_{v,SRV} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{SRV}}} = \frac{860}{100 \cdot \sqrt{3}} = 4.9$$

The default setting for a 4217 straight regulating valve with a size of DN 20 is 3.7.

Dual mixing circuit

Another form of mixing circuit is the mixing circuit with fixed bypass which is used in applications where differences occur in the temperature levels of the distributed heat and consumer circuits. This time, the bypass is in the consumer circuit before the control valve via which a permanent quantity of return medium flows regardless of the three-port valve setting. This circuit is in widespread use with underfloor heating and also condensing boiler, storage and distributed heat systems.

Mixing circuits are constructed with three-port valves and direct distributed heat-side connection to the heat generator.

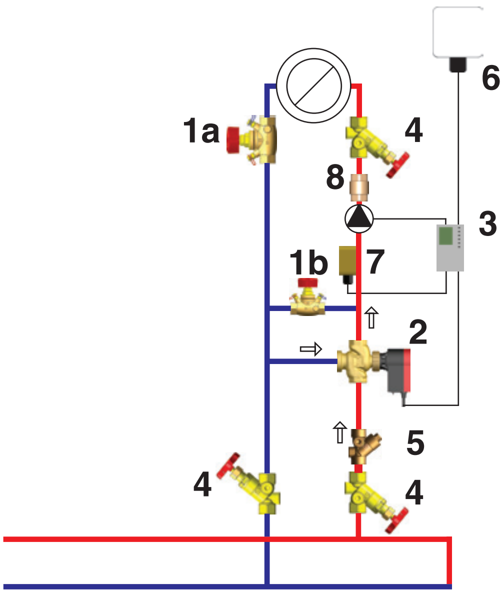


Fig. 7: Dual mixing circuit

Pos	Designation	Article no.					
1	Circuit regulating valve	4217	4117	4017	4218		
2	Three-port valve with drive	4037 7712	2117 7712				
3	Heating control	7793					
4	Isolation valve	4115	4112	4113	4215	4125	4218
5	Strainer	4111	2662				
6	Temperature sensor	7793					
7	Outdoor temperature sensor	7793					
8	Non-return valve	2622					

Table 7: Dual mixing circuit

Features: Distributed heat-side water volume constant, consumer-side volume constant. Consumer-side temperature variable

Application: Low-temperature heating with different distributed heat and consumer temperatures. Especially for underfloor heating systems in a high-temperature system

Benefits: The control valve authority is almost 1 when used with pressureless or low-pressure distributors (i.e. good controllability). Can be used to connect low-temperature heating (e.g. 45 °C to 90 °C).

Drawbacks: The distributed heat-side supply temperature must be higher than the consumer-side supply temperature. No distributed heat-side differential pressure is permitted. If a distributor under pressure is used, a “pressureless” mixing circuit must be used.

Sizing example

Q = 40 kW
t_V = 45°C
t_R = 35 °C
t_P = 70 °C
Δp_L = 25 kPa

$$q_P = 3600 \cdot \frac{Q}{c \cdot (t_p - t_R)} = $$
$$= 3600 \cdot \frac{40}{4.19 \cdot (70 - 35)} = 982\ l/h$$

⚠ The pipe dimension depends on the pipe material and the permissible pipe friction.

$$q_S = 3600 \cdot \frac{Q}{c \cdot (t_V - t_R)} = $$
$$= 3600 \cdot \frac{40}{4.19 \cdot (45 - 35)} = 3437\ l/h$$

Step 1:
Calculation of the theoretical kv value of the control valve: ($\Delta p_{V,min}$ = 3 kPa)

$$k_{v,theo} = \frac{q_P}{100 \cdot \sqrt{\Delta p_{v,min}}} = \frac{982}{100 \cdot \sqrt{3}} = 5.7$$

Step 2:
Selection of the kv_s value from the valve class. The 4037 valves in question are the DN 20 valve with a kv_s value of 6.3 and the DN 15 valve with a kv_s value of 4. Normally it can be assumed that the smaller kv_s value is selected to achieve the necessary pressure loss.

If $kv_s = 6.3$

$$\Delta p_v = \left(\frac{q_P}{100 \cdot Kv_s}\right)^2 = \left(\frac{982}{100 \cdot 6.3}\right)^2 = 2.4\ kPa$$

$\Delta p_v < 3$ kPa

If $kv_s = 4.0$

$$\Delta p_v = \left(\frac{q_P}{100 \cdot Kv_s}\right)^2 = \left(\frac{982}{100 \cdot 4.0}\right)^2 = 6.0\ kPa$$

$\Delta p_v > 3$ kPa!

The control valve has a kv_s value of 4.0 and a size of DN 15.

The valve authority is:

$$a = \frac{\Delta p_V}{\Delta p_v + \Delta p_{SRV_2}} = \frac{6,0}{6.0 + 6.0} = 0.5$$

The pressure loss in the mixing valve must be additionally provided by the pump.

Step 3:
Sizing for circuit regulating valve 1a is 3 kPa

$$k_{v,SRV1a} = \frac{q_S}{100 \cdot \sqrt{\Delta p_{SRV_1}}} = \frac{3437}{100 \cdot \sqrt{3}} = 19.8$$

The default setting for a 4217 straight regulating valve with a size of DN 40 is 5.3

Step 4:
Sizing of the bypass

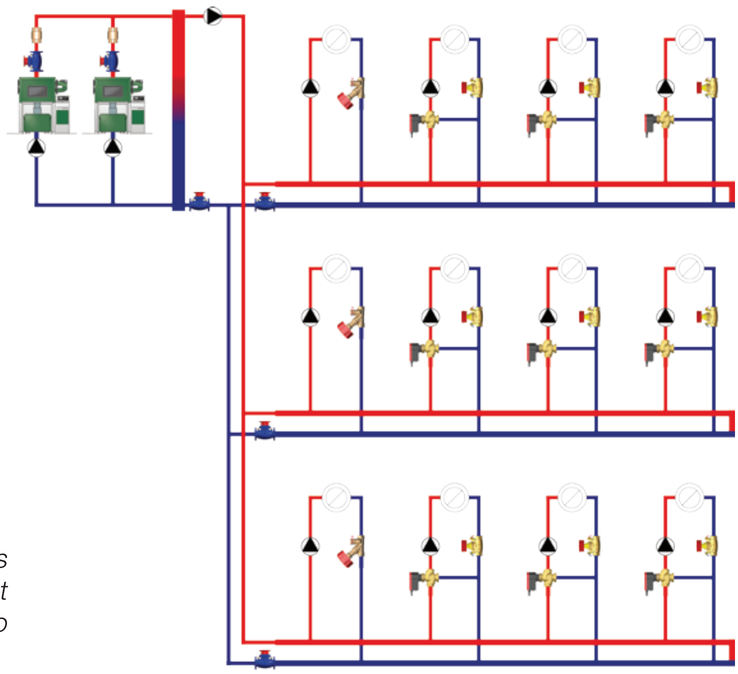
The bypass flow rate is calculated from:

$q_{Bypass} = q_S - q_p = 3437 - 982 = 2455$ [l/h]

Circuit control valve 1b is sized to the control valve's pressure loss (7.6 kPa)

$$k_{v,SRV1b} = \frac{q_{Bypass}}{100 \cdot \sqrt{\Delta p_{SRV_2}}} = \frac{2455}{100 \cdot \sqrt{6.0}} = 10.0$$

The default setting for a 4217 straight regulating valve with a size of DN 32 is 4.0.



Heating systems with a hydraulic switch. Heat generators connected in parallel. Static regulation of the circuits. First consumer per circuit with static regulation, consumers two to four with mixing circuit.

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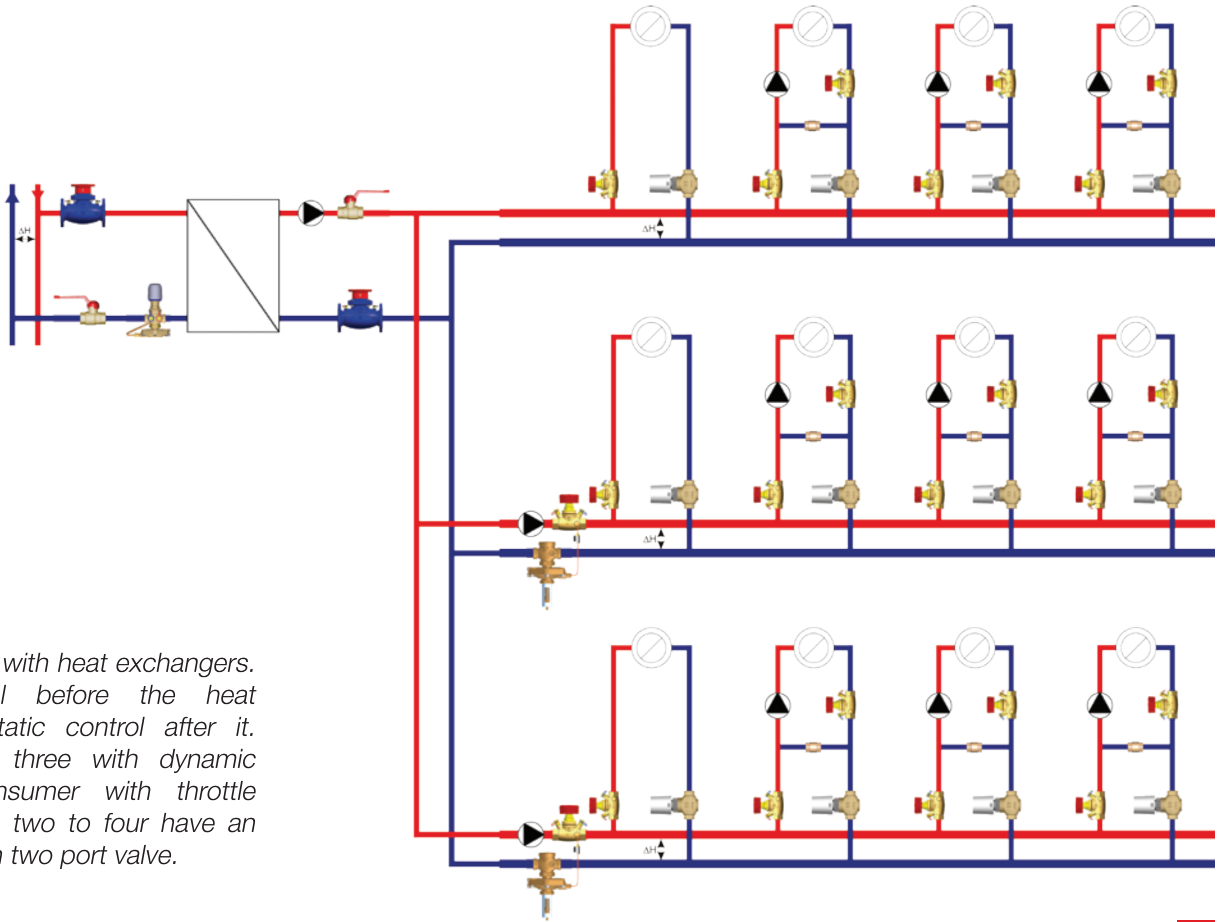

System separation with heat exchangers. Automatic control before the heat exchanger and static control after it. Circuits two and three with dynamic control. First consumer with throttle circuit. Consumers two to four have an injection circuit with two port valve.

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