Compendium of hydraulics for heating technicians with elements of ventilation 2

Laurent Socal | Benedetta Grassi

IVAR PUBLISHING

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Preface

The presentation of this second Compendium of Hydraulics gives me the chance to thank all those who have expressed an interest in the first volume.

This appreciation – not to mention the thousands of copies that have been ordered – filled us with satisfaction and encouraged us to prepare a new volume, picking up where the first volume left off to complete our look at hydraulics and enriching it with new content.

As is the case with the first volume, this volume reflects IVAR's mission to root its corporate philosophy on technical training and instruction. It also embodies a willingness to work closely with the technicians involved in designing and installing heating, ventilation and air-conditioning (HVAC) plants.

Our goal in publishing this new insight into modern plant technology is to support heating technicians and installers, providing them with useful, sound solutions written in a simple, straightforward style. Hence our decision to entrust this new volume to Laurent Socal and Benedetta Grassi, two professionals in the field with experience in the world of thermal engineering.

Let me finish by saying that we have poured the same passion and care into the production of this volume as we have been dedicating to the design and manufacture of our products for over thirty years. I hope that it will benefit all those who read it.

Umberto Bertolotti

Chairman of IVAR SpA

1 CIRCUITS AND MIXING VALVES

1.1 Introduction

The purpose of a heat generator is to heat water to the temperature set on the boiler thermostat. Water often has to be sent to the heating elements at a different temperature in order to control the heat output. In the case of just one user circuit, the simplest, most rational and immediate solution is to set the heat generator at the required temperature. If, however:

- the generator has its own minimum working temperature (e.g. biomass boilers),
- or there are several user circuits with different flow temperature requirements which have to be fed at the same time,

the only solution is to set the generator at the highest water temperature and then to reduce the flow temperature to each user requiring a lower temperature by using a **mixing circuit**.

Likewise, in the case of air-conditioning, the chiller may be asked to produce cold water at just one temperature (e.g. 7 °C) as the goal is to dehumidify the air. However, if other users need to avoid condensation, the flow temperature must be raised to suit the needs of these circuits by means of mixing.

The purpose of mixing valves is, therefore, to **change the flow temperature and to keep this at the right value for each user**.

In a heating system, the water coming from the boiler is cooled by mixing this with some return water, Figure 1. This is necessary if the boiler produces water at a higher temperature than that required by the heating system (e.g. underfloor heating systems).

The goal of a cooling system, meanwhile, is to increase the temperature of the cold water coming from the chiller in order to avoid unwanted condensation, Figure 1b.

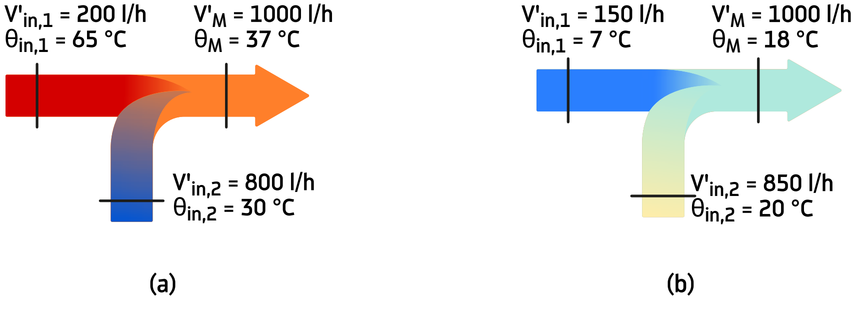


Figure 1. Examples of mixing in heating systems (a) and in cooling systems (b).

Mixing is a process governed by two laws of conservation:

1. conservation of mass: the sum of the incoming flows must equal that of all outgoing flow

$$V'_M = V'_{in,1} + V'_{in,2} \tag{1}$$

2. conservation of energy: the sum of all incoming energy must equal that of all outgoing energy

$$V'_M c_p \theta_M = V'_{in,1} c_p \theta_{in,1} + V'_{in,2} c_p \theta_{in,2} \tag{2}$$

By applying these two equations, we can make some simple descriptive calculations. More specifically, the Eq. (2) shows that **the temperature of mixed water θ_M always falls between the other two temperatures**. In other words, if we circulate water in a warm loop, the temperature is controlled by injecting a little hot water from the boiler (or cold water from the chiller).

To discover the temperature of the mixed water θ_M, we need to use this equation:

$$\theta_M = \frac{V'_{in,1}\theta_{in,1} + V'_{in,2}\theta_{in,2}}{V'_{in,1} + V'_{in,2}} \tag{3}$$

For instance, in a heating system:

$V'_{in,boiler}$ = 52 l/h
$V'_{in,return}$ = 100 l/h
$\theta_{in,boiler}$ = 70 °C
$\theta_{in,return}$ = 30 °C
→ θ_M = (52 × 70 + 100 × 30) / (52 + 100) = 44 °C

If, on the other hand, we want to find out how much water needs to enter at port '1' to get the required temperature, the equation becomes:

$$V'_{in,1} = V'_{in,2}\frac{\theta_{in,2} - \theta_M}{\theta_M - \theta_{in,1}} \tag{4}$$

In a cooling system:

$V'_{in,return}$ = 100 l/h
$\theta_{in,chiller}$ = 7 °C
$\theta_{in,return}$ = 18 °C
θ_M = 15 °C
→ $V'_{in,chiller}$ = 100 × (15 – 7) / (18 – 15) = 37,5 l/h

Always remember the following rules of thumb:

- the flow rate upstream of a mixing valve is often much lower than that downstream of it;
- to know whether a mixing valve is open or not, simply observe the change in temperature between the primary flow coming from the boiler (hot side) and that of the flow sent to the user.

1.2 Applications

When we think of mixing, our thoughts automatically go to underfloor heating, yet there are many other applications for this technique.

As a general rule, we can say that the mixing technique is used every time we need to control a temperature that cannot be adjusted at source. There are many reasons why we might wish to control temperature: perhaps to protect materials, prevent harm to the final users or ensure comfort.

In the case of radiant heating and cooling, the main reference for design calculations is European Standard **EN 1264** – "Water based surface embedded heating and cooling systems", split into five parts. Part 3, focusing on sizing, sets out the method for calculating the flow temperature based on the power needed in the worst case room. Part 4 deals with installation and recommends the maximum flow temperatures for various types of flooring materials.

Mixing is not confined to underfloor heating systems: radiators– while seen as a 'high temperature' heating system – may require mixing if the source is district heating or a high temperature generator, such as a biomass boiler.

Mixing can also be used to control the temperature of domestic water at the entrance of the network or at the tap, when user safety is paramount. See paragraph in Chapter 7 for more details on this topic.

1.3 Mixing techniques

1.3.1 Stroke and opening of a control valve

In order to understand this paragraph fully, we need to know the difference between the concepts of the 'stroke' and the 'opening' of a valve.

The 'stroke' is the action on the stem or on the lever that moves the valve disc. If a linear motion valve, such as a gate valve or a piston valve, the 'stroke' corresponds to the advance of the valve disc and is expressed in terms of length. If a rotary motion valve, like a ball valve or a butterfly valve, the stroke is the angle of rotation of the stem that controls the ball or the butterfly.

The 'opening', on the other hand, is the way we indicate the degree of aperture of the valve. The physical measure in this case is its 'Kv', that is the flow rate when the pressure drop across the valve is 1 bar.

The Kv when the valve is fully opened is known as the Kvs. The Kv/Kvs ratio is the 'percentage of opening' and always falls between 0 and 1.

The relationship between the stroke and the opening of a valve gives rise to its 'opening characteristic', depending on the profile (geometry) of the valve disc and on the valve seat. In fact, a valve disc can have a simple or complex profile, according to its envisaged use.

If the valve is only intended to open/close a passage way, the disc profile will be extremely simple and so the opening characteristic of the valve will be automatically decided by its construction. If we take a 'full passage' ball valve as an example, there will be a tiny gap as we start turning its handwheel; the opening increase gets bigger and bigger until we reach the halfway point, after which the opening increase gets smaller and smaller. In other words, an 'S' shaped relationship between the stroke and the opening is obtained.

If the purpose of the valve is to control the flow, the profile of the valve disc will be carefully designed to get the required opening characteristic. For instance, the opening characteristic of ball valve can be altered by adding a shaped insert inside the ball passage with the aim of controlling the gap that is gradually revealed as the ball rotates. This can only happen when the passage is partially obstructed, thus the 'full passage' characteristic is lost if we want to adjust the opening control characteristic.

1.3.2 Working characteristics of control valves

Mixing implies two inflows and one outflow. As we have already seen, the temperature of the water leaving a mixing valve depends on the flow rates and the temperatures of the water at the inlets.

A typical strategy adopted to get the required flow temperature is to use control valves to regulate the flow rates of the water entering the mixing zone. In practice, these valves can have two, three or four ports.

Since the whole purpose of the control system is to control the flow temperature, there are two factors of crucial importance:

1. the authority of the valve;
2. its opening characteristic.

In the case of a 2-way valve, these factors concern a single passage, whereas in a 3-way valve the most important passage is the 'straight-way' line between the water inlet at production temperature and the 'mixed' common port.

Valve 'authority' is the term used to describe how a valve impacts on the whole system and is a kind of 'relative size' with respect to the controlled circuit. This is a tricky parameter to get right, as we need to find the right compromise between:

- an 'authoritative' device, but with very high pressure losses;
- a device with low pressure losses, but affording poor control capacity for most of its stroke.

A good compromise is to stay somewhere in the middle, i.e. roughly 0.5 authority. See Chapter 11.4 in the first volume for an in-depth look at valve authority.

As already mentioned, the opening characteristic of a valve indicates the relationship between its stroke and variations in the flow coefficient Kv. There are three main opening characteristics used to fulfil very diverse needs:

1. linear characteristic;
2. equal percentage characteristic;
3. quick opening characteristic.

Figure 2 shows the different theoretical curves representing the percentage of flow coefficient compared to the fully-open position value, Kv/Kvs, as a function of the percentage of opening, z.

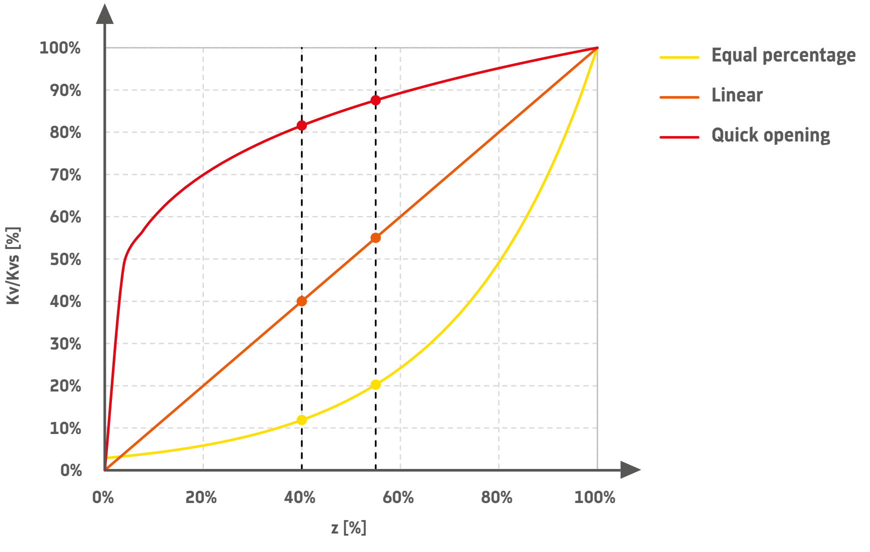


Figure 2. Characteristic valve curves: percentage of flow compared to fully-open position value depending on percentage of stroke.

The **linear** characteristic is the easiest to understand: the value of Kv is directly proportional to the valve opening. Mathematically speaking, the linear relationship shown in Figure 2 can be expressed as:

$$\frac{Kv}{Kvs} = z \quad \text{or} \quad Kv = Kvs \times z \tag{5}$$

where:

z	[%]	Percentage of valve opening
Kv	[m³/h]	Flow coefficient of the valve
Kvs	[m³/h]	Kv with valve in fully-open position (z = 100%)

NOTE: we assume that the valve is properly sized, whose fully-closed position corresponds exactly to the start of the stroke, and the fully-open position to the end of the stroke.

Example: a valve with a perfectly linear characteristic starts with an opening position of 15% (z = 15%, position 'P1') and then opens a further 15% (z = 30%, position 'P2'). The new flow rate will depend on the pressure difference across the valve. If this pressure differential remains constant, the original flow rate (15%) becomes 30% of the flow rate at fully-open valve, with an increase in Kv/Kvs opening also equal to 15% of the maximum value. If the valve then opens a further 15% (z = 45%, position 'P3'), both the increase in the flow rate and that in the valve opening compared to P1 will be 15+15 = 30%. In other words, a percentage rise in stroke will correspond to an equal percentage rise in valve opening, when the two quantities are evaluated with respect to the overall stroke and the fully-open position, respectively.

Valves with a linear characteristic are commonly used and, indeed, work well when the pressure difference at the ends of the valve does not change greatly as it opens (i.e., when the greatest pressure losses in the circuit occur within the valve, or if there is an upstream device, such as an electronic pump unit, that controls the available head).

However, the situation is usually different in practice: the more a valve closes, the greater the available differential pressure at its ends, as any reduction in flow rate in the controlled circuit will correspond to a reduction in other pressure losses compared to the pressure loss within the valve. This was pointed out in paragraph 3.5 of the first volume: every control valve that closes acts like a 'finger on a garden hose'. Hence, we need a valve that opens 'less' when almost closed and opens 'more' when open, thereby ensuring any change in the circuit flow rate is as proportional as possible to the stroke and is not affected by changes in pressures at the ends of the valve. In other words, we need to correct any flow rate distortion caused by pressure changes due to the stroke using a 'counter distortion' in the valve opening characteristic.

The **equal percentage** characteristic acts in this way and gets its name from the fact that each advance in stroke corresponds to an equal change in the percentage of valve opening compared to the previous value. This characteristic can be expressed as follows:

$$\frac{Kv}{Kvs} = e^{N\cdot(z-1)} \text{ or } Kv = Kvs \times e^{N\cdot(z-1)} \tag{6}$$

N is a coefficient that expresses the 'slope' of this characteristic: the higher the N value, the slower the initial opening, allowing for greater control, even when the valve is almost fully closed. Figure 3 shows an example where N = 8, meaning that 80% of the stroke is used to control just 20% of the valve opening. In other words, most of the opening occurs at the end of the stroke.

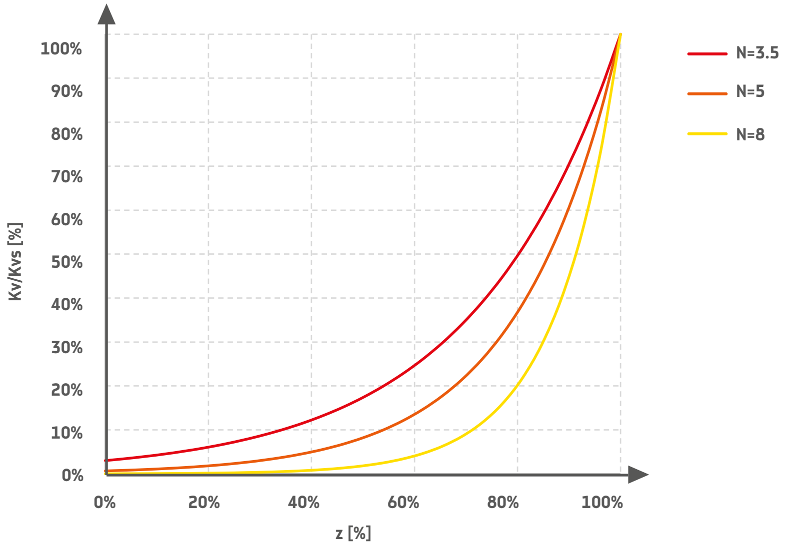


Figure 3. Equal percentage characteristics for different N coefficient values.

Using the same example as before, with the same positions, let us now see how an equal percentage valve behaves. Let us assume that the change in opening between P1 and P2 (stroke increase = 15%) rises from 4.7% to 8%, i.e. a rise in Kv/Kvs of 70%. In moving from P2 to P3 (another stroke increase of 15%, the flow rate rises again by a further 70%, but with respect to P2 this time, meaning that it will rise from 8% to 13.6%. However, 13.6 - 8 = 5.6%, which is not the same as 8 - 4.7 = 3.3%. This non linearity is also obvious if we look at the change from P1 to P3: compared to P0 (fully-closed position), the stroke is 15+15 = 30%, but the actual change in valve opening is (13.6 - 4.7)/4.7 = 190%, easily more than 70+70 = 140%, which we would expect with linear behaviour.

Put briefly, for each equal advance in the stroke:

- with a linear valve, we add an equal opening value;
- with an equal percentage valve, we multiply the valve opening by the same factor (i.e. we apply the same percentage of increase).

Clearly, the equal percentage characteristic is especially convenient when the differential pressure rises as the valve closes: indeed, the valve initially only opens very gradually to ensure constant control of the flow rate, then it rapidly goes wide open after the knee.

The **fast opening** characteristic produces the opposite effect: its function is to take the valve to its fully-open position as quickly as possible.

$$\frac{Kv}{Kvs} = z^{(1/c)} \quad \text{or} \quad Kv = Kvs \times z^{(1/c)} \tag{7}$$

where c > 1. The higher the value of c, the quicker the opening of the valve. Figure 2 shows that, with a fast opening valve, 50% of the opening is obtained with just 4% of the stroke. The goal here is not to control, but simply to open/close. This is typical of ON/OFF valves, which, on the other hand, must guarantee zero leakage.

Valves used for mixing must, therefore, have either an equal percentage characteristic or a linear characteristic.

The concepts of the authority and the characteristic of a valve must both be considered in the light of their impact on the circuit and our goals.

Figure 4 shows a comparison between valves with the same Kvs (c. 10), but with different control curves. There are two key aspects here:

1. the same valve will act differently in two different circuits: in the circuit with Kv = 10, its authority is roughly 50% when open, while in the other circuit it appears to be oversized (authority = 1%). As a result, the valve has greater control capacity in the first instance;
2. given the 'relative size', the equal percentage characteristic manages to control the flow rate more gently at lower opening values.

Of those shown below, the equal percentage valve with high authority is the best solution for applications where the flow rate at production temperature needs to be modulated for mixing purposes.

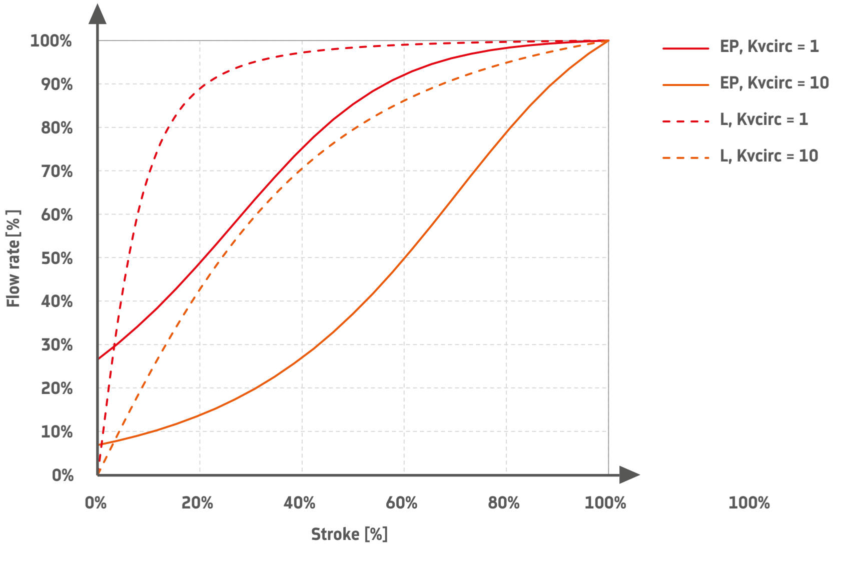


Figure 4. Behaviour of valves with Kvs = 10 in systems with different circuit resistance values (Kvcirc). Dashed lines: linear characteristic; solid lines: equal percentage characteristic.

1.3.3 2-way valves

A 2-way mixing valve lets us control only one inlet port dynamically. In this case, it is normally the inlet flow coming from the generator ('injected' flow rate) that is modulated, whereas the return flow from the heating system is only controlled statically (Figure 5).

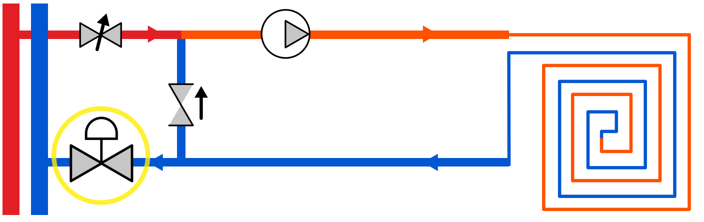


Figure 5. Use of a 2-way valve to control mixing.

NOTE: do not be surprised if the control valve is fitted on the return flow. It makes no difference whether a control valve is on the flow or return line to control the flow rate in a circuit. Other criteria determine the final decision (temperature, position, convenience, etc.).

Mixing can take place inside a chamber of a dedicated component (see Figure 6 below) or directly in the manifolds and fittings, as in the two examples in Figure 7.

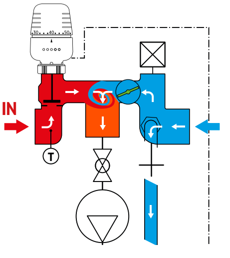


Figure 6. Mixing via injection inside a dedicated chamber.

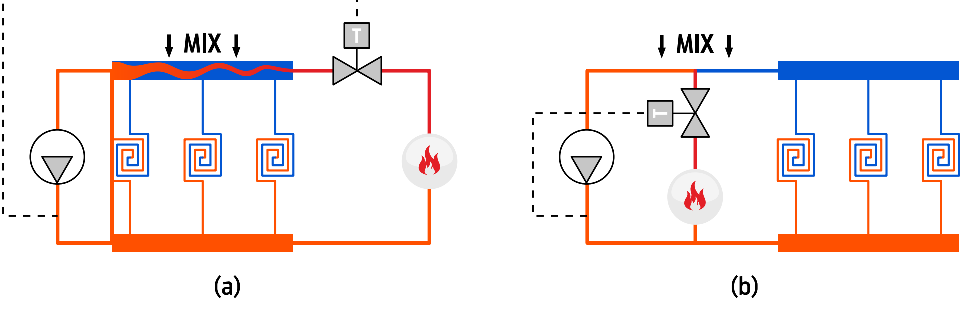


Figure 7. Mixing via injection inside the return manifold (a) and inside a 'tee' fitting (b).

Besides easier installation process, dedicated components generally offer greater control capability and, in some cases, greater capacity.

1.3.4 3-way valves

A 3-way valve has a valve disc that closes one inlet port as it opens the other, and vice-versa (Figure 8). Both ports are therefore controlled dynamically.

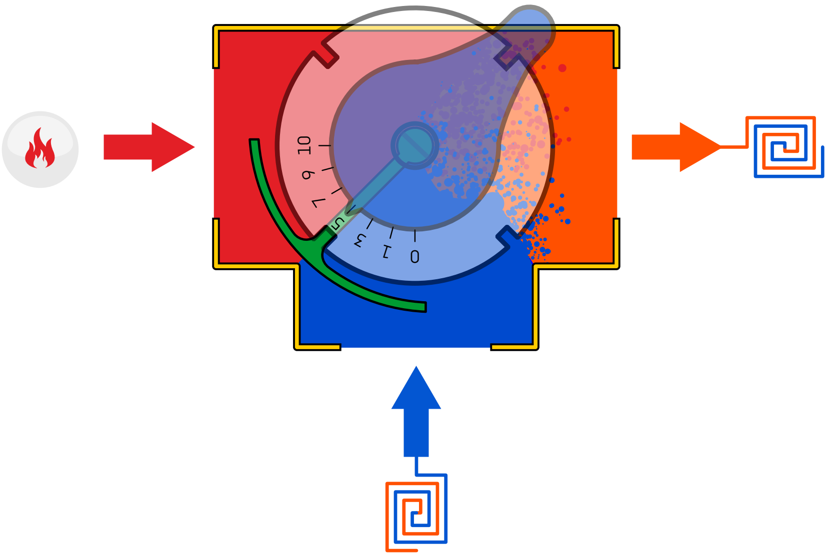
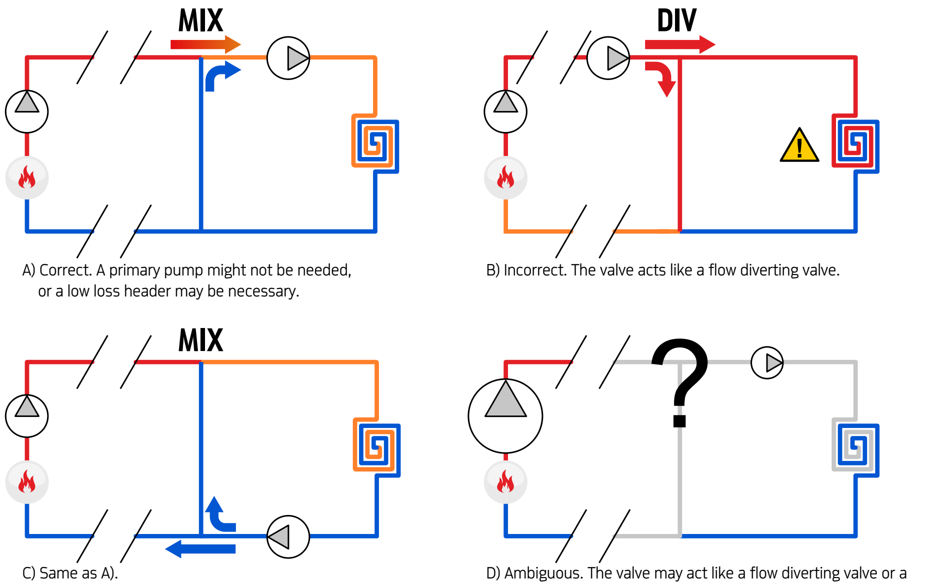


Figure 8. Example of 3-way mixing valve.

Unlike a 2-way mixing valve, a 3-way valve lets us close either of the inflow ports automatically and so is better suited to the characteristics of the generator and the system load.

However, there are certain rules that must be observed to ensure that a 3-way mixing valve behaves as we would expect. The most important of these rules is that the circulator pump must be fitted downstream of the confluence point. This is true whenever mixing takes place: if there is no circulator pump (or the driving force on the straight-way line is higher than that on the common line), the valve will simply divert the flow and mixing will only occur in the return line (Figure 9). In other words, we create a by-pass circuit instead of a mixed circuit.



A) Correct. A primary pump might not be needed, or a low loss header may be necessary.

B) Incorrect. The valve acts like a flow diverting valve.

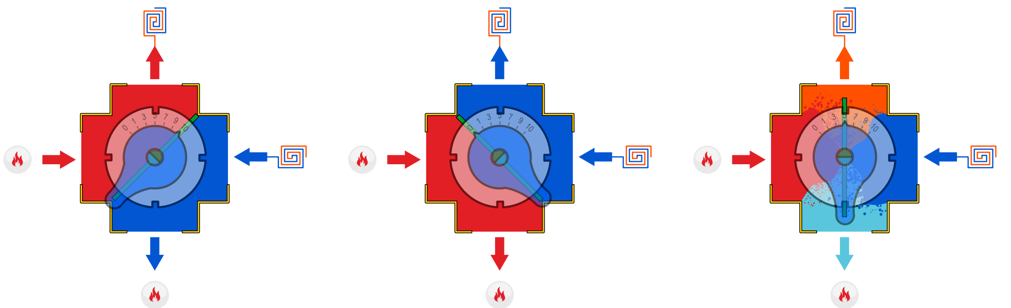
C) Same as A).

D) Ambiguous. The valve may act like a flow diverting valve or a mixing valve, depending on the relationship between the flow rates.

Figure 9. A few examples of 3-way valves used to mix or divert flows.

1.3.5 4-way valves

The purpose of 4-way valves is to provide an additional level of mixing in order to raise the return temperature. Figure 10 illustrates how a 4-way valve works. In practice, we tend to fit these valves downstream of any generators that might be damaged by condensate (e.g. old style boilers or biomass generators).



(a) (b) (c)

Figure 10. Diagram showing a 4-way mixing valve when fully open (a), fully closed (b) and in the halfway position (c).

Note that two pumps are needed to mix the return flow if we use a 4-way valve (Figure 11).

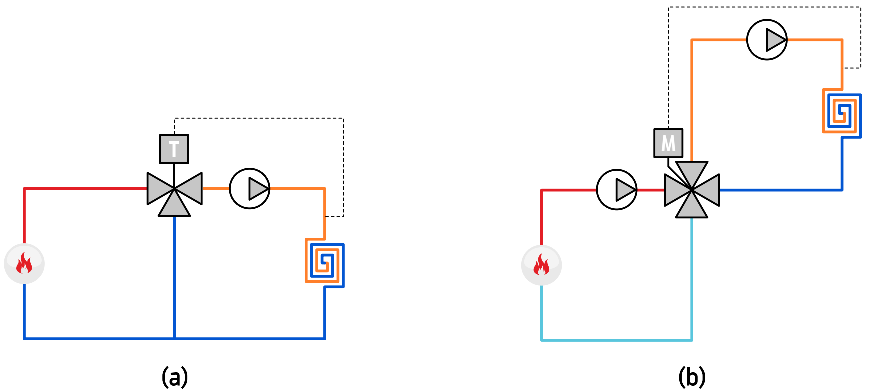


Figure 11. a) Circuit with a 3-way valve: one pump is enough. b) Circuit with a 4-way valve: 2 pumps are needed.

In the past, 4-way valves were sometimes used with just one pump (on the user side) and a condensate pump on the boiler side, as pressure losses in the boiler were very low.

1.3.6 Pre-mixing/Post-mixing

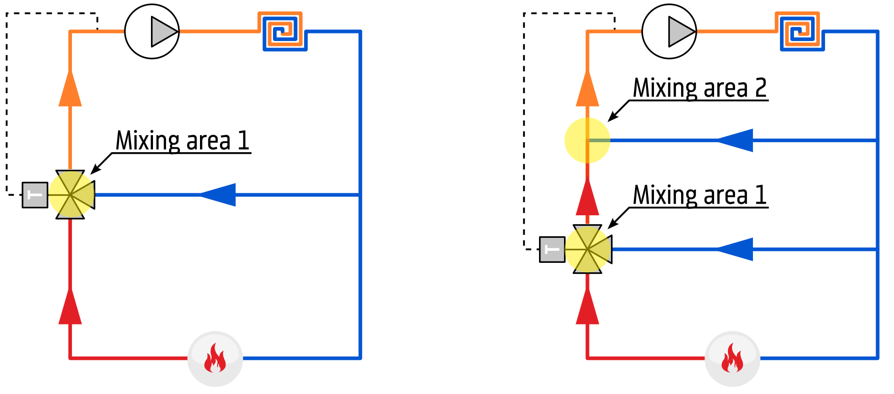
Mixing is often done automatically by a controller: it receives a signal indicating the measured value and then reacts accordingly. The controller therefore plays an important role, but it is not always a straightforward process.

For instance, imagine we have an underfloor heating system where the hot water is produced by a generator at a particularly high temperature. The controller in this case needs to keep the straight-way line almost completely closed… and the actuator might have some difficulty, especially if the valve characteristic is not progressive enough near the fully-closed position and the pressure differential across the circuit is significant. A second mixing chamber comes in very handy here.

In practice, the mixing process is split into two stages:

- one stage occurs in a static mixing device, calibrated to suit the maximum load;
- another stage involves a dynamic device, that further reduces the flow rate at the generator temperature when the load drops with respect to the design conditions.

Compared to a conventional mixing process (Figure 12a), a dual mixing (Figure 12b) allows to provide most of the required return through the ‘static’ area, meaning the ‘dynamic’ actuator is only expected to make fine adjustments (Figure 13).



(a) (b)

Figure 12. System with a single mixing chamber (a) and with a post-mixing chamber (b).

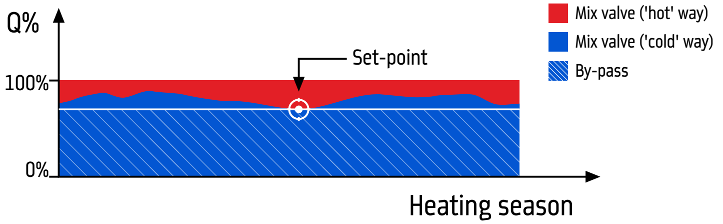
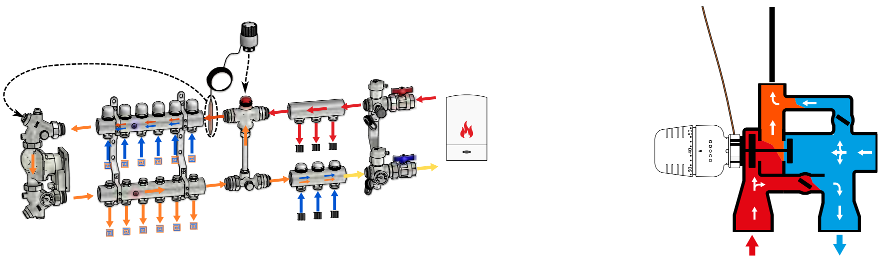


Figure 13. Contributions from the two mixing areas during the season: most of the return flow comes via the static device, whereas the dynamic device provides fine adjustment when the load drops.

The second mixing stage can be created by using either a 2-way valve (Figure 14a) or a 3-way valve (Figure 14b).



(a) (b)

Figure 14. Examples of mixing units with two mixing areas: (a) 2-way valve with pre-mixing and mixing in the return manifold; (b) 3-way valve with secondary mixing in a by-pass line.

These additional mixing areas are created by extra passages controlled by selector-type or lockshield-type valves.

The manufactures generally provide two adjustment procedures:

1. the 'analytical' method;
2. the 'empirical' method.

If using the analytical method, we need to have access to a simplified circuit diagram and component characteristic curves in order to calculate the fully-open position of the control valve.

Example. Find the number of turns of the by-pass responsible for the secondary mixing in a 3-way mixing valve.

Solution. With reference to Figure 15a, by-pass line BII needs to be controlled to get the minimum required 'return' flow, which corresponds to the maximum load (e.g. the coldest day of the year for a heating system). This condition corresponds to the full opening of the straight-way (SW) and, in the light of how a 3-way mixing valve works (Figure 15b), to the full closing of the return line (AW). Let us assume that the head supplied by the primary pump, ΔP_p, is exactly what is needed to correct the pressure loss in the primary circuit, ΔP_l. The circuit in this case could be simplified to have the straight-way and by-pass lines in parallel (see Figure 15c).

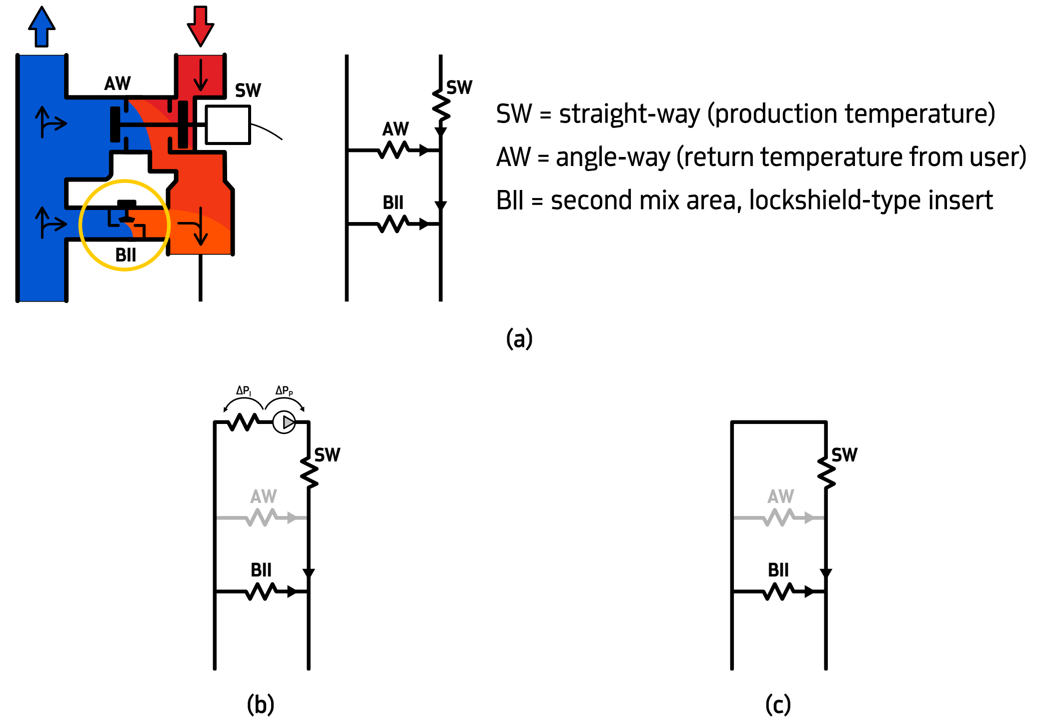


Figure 15. Mixing valve with secondary by-pass (a). Maximum load condition with angle-way closed (b). Simplified circuit (c).

We need to collect the design data if we want to find the number of turns for the correct opening for BII. We need to find the water temperature produced by the generator θ_S, lthe temperature required downstream of the mixing valve θ_M and the return temperature from the users θ_R, which is generally already known as this is important for sizing.

Let us assume that:

θ_S = 55 °C

θ_M = 40 °C

θ_R = 30 °C

Now we apply equations (1)-(2):

$$V'_S + V'_{BII} = V'_M \tag{8}$$

$$V'_S\theta_S + V'_{BII}\theta_R = V'_M\theta_M \tag{9}$$

where V'_{BII} is the flow rate through the by-pass and θ_R is the return temperature from the system. We can now obtain the equations to find the proportions of each flow:

$$V'_S = V'_M \frac{\theta_M - \theta_R}{\theta_S - \theta_R} \tag{10}$$

$$V'_{BII} = V'_M - V'_S \tag{11}$$

As V'_S and BII are in parallel, they have the same pressure losses, thus we can write:

$$\left(\frac{V'_{BII}}{Kv_{BII}}\right)^2 = \Delta P_{BII} = \Delta P_{SW} = \left(\frac{V'_S}{Kv_{SW}}\right)^2 \tag{12}$$

where Kv_{BII} is the flow coefficient of the by-pass in the correct control position. Kv_{SW}, on the other hand, is the flow coefficient of the straight way when fully open (provided by the manufacturer).

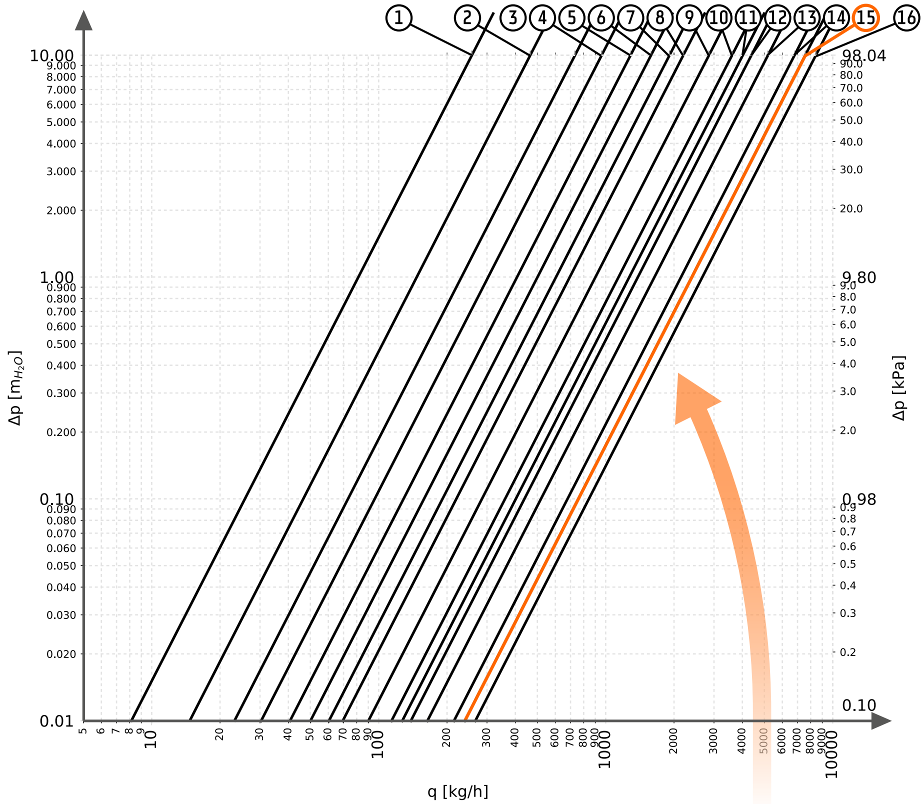
If we combine the above equations, we get:

$$Kv_{BII} = Kv_{SW}\left(\frac{V'_{BII}}{V'_S}\right) = Kv_{SW}\left(\frac{\theta_S - \theta_M}{\theta_M - \theta_R}\right) \tag{13}$$

If Kv_{SW} = 5,2, we get:

$$\theta_m = -K \times \left(\theta_e - \theta_{e,max}\right) + \theta_{m,min} \tag{14}$$

The manufacturer also provides a graph showing the different flow coefficients for each level of opening. We can use this to decide how far to open the valve (Figure 16).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DN	1/4	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	3 1/2	4	4 1/2	6	8	10	MAX
Kv	0.26	0.47	0.74	0.97	1.3	1.6	1.93	2.22	2.88	3.64	4.06	4.43	5.24	6.86	7.65	8.52

Figure 16. Identification of the opening position using manufacturer data.

We will therefore adjust the by-pass so that it is almost fully open and then fit an actuator on the mixing valve to intervene in part load conditions.

The greater the difference between the production temperature and the flow temperature, the more the by-pass must be opened. It is not infrequent for the calculated Kv_{BII} value to be higher than the maximum declared by the manufacturer. This is not a problem: we are currently ignoring the flow coming from the angle-way line (AW), which will be automatically modulated once the actuator has been fitted on the mixing valve.

The second procedure to adjust the position of the additional mixing device is of a far more practical nature. No calculations required: we only need a thermometer to read the flow temperature to the user.

We always start with the mixing valve in the fully-open position (no actuator). Then we fully open also the adjustment device (BII in the example above) and wait for the flow temperature to stabilise.

If the observed temperature is higher than the design flow rate, then nothing more can be done: simply fit the actuator, which will automatically control the straight-way opening to get the right temperature.

If, however, the temperature is lower than expected, we need to start closing BII very slowly, again allowing the temperature to stabilise, until it approaches the set-point. Now we can fit the actuator, which will automatically react to any changes in the load.

1.3.7 Drive technology

Axial valves have a piston, driven by an actuator and moving a valve disc, and a valve seat against which the valve disc rests when fully closed, sealing the passage. With axial control valves, water must circulate in the direction that opens the valve disc and pushes it away from the valve seat: if the direction of flow is reversed, it will tend to close the valve disc, not uncommonly leading to a series of rapid opening/closing events (hammering). In the case of 3-way mixing valves, it is crucial to create a geometry that allows for the correction of the varying pressure differentials acting between the straight-way branch and the common branch, and between the return branch and the common branch.

The key information we need regarding an axial valve is:

- the direction of flow;
- an indication on the minimum closing force required of the actuator, provided by the manufacturer (e.g. 100 N).

In the case of a rotor mixing valve, the closing element is a rotating wall (or ‘sector’) that obstructs either of the two inlet ports, depending on the value of the controlled quantity. These are normally devices with lower pressure losses, but also lower tightness capability, than axial valves. This information may be provided as the leakage defined in terms of the full open valve capacity (e.g. 0.5% of Kvs value). Another important parameter that the manufacturer must provide is the minimum torque required to move the valve disc (e.g. 1 N·m).

1.3.8 Warnings and precautions for use

When dealing with control valves, some factors should be considered that could result in good or poor performance. Such factors are presented in Chapter 11 of the first volume.

Differential pressure across the valve is a very important parameter, not just in terms of authority (control capability), but also of operation. In fact, the actuator applies a force to the piston (or a torque to the rotor), but if the differential pressure across the valve is too high, this force will not be enough for a proper control and - in the worst case - may not even be able to drive the valve closed.

The inlet ports are usually indicated on the body of a 3-way mixing valve with a symbol like that in Figure 17 below. Unless otherwise indicated by the manufacturer, a 3-way valve may also be used as a flow diverting valve by connecting the inlet port to the ‘common’ line and the two alternative outlet ports to the two inlets.

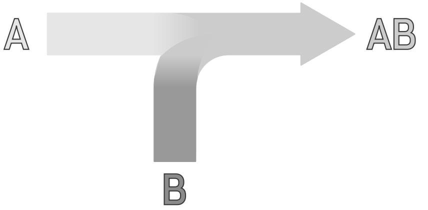


Figure 17. Symbol indicating the direction of flow in a 3-way valve. When used as a mixing valve, 'AB' is the common outlet port; if used as a diverting valve, it becomes the inlet port from which the water is sent to either outlet port 'A' or outlet port 'B'.

It is not unusual to stumble across 'creatively' mounted mixing valves, which can produce some surprising effects...

Once again, we must stress just how important it is to position the circulator pump correctly: it must be on the common branch downstream of the two mixing inlet ports. If in the wrong position, the valve will act as a flow diverting device, not a flow mixer, and the entire circuit will behave unexpectedly.

1.4 Control: principles and devices

1.4.1 Purpose

Good mixing control must ensure:

1. to reach the required flow temperature;
2. to keep it stable.

As a general rule, all valves can be 'controlled' manually, but this is not what we mean here. Manual control (adjustment) implies a fixed position and does not allow for continuous adaptation to changes in surrounding conditions. The main principles of automatic control are explained in Chapter 10 of the first volume. Here is a brief review of the various types of valves, actuators and regulators used to control mixed circuits.

The first distinction is between mechanical and electronic systems. Mechanical systems are mainly dedicated to keeping a parameter constantly at the same value. 'Fixed point' mixing circuits are a typical example, using thermostatic heads very much like those used for radiator valves. The sensor in this case is a bulb containing a heat-sensitive liquid that expands and contracts according to the temperature of the water (and not the ambient air, as is the case with radiator valves). As the liquid expands, it moves the stem of the valve disc; connection is guaranteed by a capillary tube.

This is a P (proportional) controller. A scaled 'head' lets us select the temperature at which the valve disc closes the passage. This mechanism is identical to that used in thermostatic valves on radiators, but the control temperatures shown on the head (from 25 °C to roughly 70 °C) are clearly quite different to those on thermostatic heads.

The bulb may sit in a pocket within the flow (Figure 18a/b) or be in contact with a metal part along the flow line (e.g. the manifold), provided that thermal paste and suitable fittings are used (Figure 18c).

(a) (b) (c)

Figure 18. Thermostatic head used to control mixing with immersed pocket(a) and example of installation (b). Example of a contact head with sensing element fixed to the flow manifold (c).

Less common, but still found on the market, are thermostatic mixing valves with an incorporated sensor. In this case, the heat sensitive element (expanding wax) comes into direct contact with the mixed liquid. Owing to how they work, thermostatic mixers with an incorporated sensor only come in 3-way version.

Mechanical devices only allow for 'fixed point control', where the 'fixed point' is the value of the temperature set-point which we set on the knob once and for all.

There are so many different devices on the market today letting us do so much, but we must know what we want. When selecting a mixing control system, we need to ask ourselves a few fundamental questions:

1. Is it just a heating system?

In case of heating and cooling system, then we already know we need electronic control so that we can have at least two independent set-points (one for summer and another for winter).

2. Does the mixing device impose any restrictions in terms of which actuators can be used?

Not all valve discs can be controlled by any actuators. For example, if the actuator is not self-adapting, the valve disc must be able to cope with additional factors such as the extra-stroke of the motor (Figure 19).

(a) (b)

Figure 19. Examples of valve discs for thermostatic control (a) and motorised control (b) in a 2-way valve.

3. Do I need a compensated system?

If so, here, too, mechanical devices are not the solution. By ‘compensation’ we mean the correction of the flow temperature to suit another variable parameter, such as the outdoor temperature. This technique improves the stability of the system’s response to changing loads. It is often already included in generator control systems, thus it should not be duplicated, e.g. by controlling a mixing valve in the user circuit.

Insight: compensation

Fixed point control of the mixing process ensures that the flow temperature is always kept at the same value (unless the user intervenes during the heat season, which rarely happens). More specifically, the set-point does not change as the load changes.

However, we can see that if the load drops (in heating operation, for instance), a lower flow temperature is enough to guarantee good levels of comfort. Indeed, lowering the temperature according to the load helps stabilise the control of the room temperature, because, otherwise, the control valves would have to open by a small degree, leading to the risk of oscillation and overshoot, i.e. temperatures in excess of the required room temperature.

The solution is to vary the set-point according to a quantity that well represents the thermal load. The best known strategy is the so-called ‘weather compensation’, i.e. the set-point is altered by an electronic controller as a function of the outdoor temperature. In other words, the thermal load is expected to be higher when it is cold outside, and so the set-point is also higher; on the other hand, the set-point is lowered in midseason, when the weather is mild.

Dedicated controllers let us change the way the set-point depends on the outdoor temperature by setting a few parameters (specifically, the slope and the deviation). In practice, this function depends on the maximum water temperature corresponding to *the minimum outdoor temperature, and it is limited by the desired room temperature. For example: the minimum outdoor temperature of a given location is –10 °C, which corresponds to a maximum flow temperature of 45 °C. If we want to obtain a room temperature of 20 °C, we assume this is the minimum flow temperature entering the circuit. If the outdoor temperature is 15 °C, we can calculate the slope of the curve as K = (45 – 20)/(15 – (–10)) = 1. From this result, given an outdoor temperature* θ_e*, the flow temperature can be calculated as*

$$\theta_m = -K \times \left(\theta_e - \theta_{e,max}\right) + \theta_{m,min} \tag{15}$$

Hence, if the outdoor temperature is 5 °C, according to this curve the corresponding flow temperature should be –1 × (5 – 15) + 20 = 30 °C.

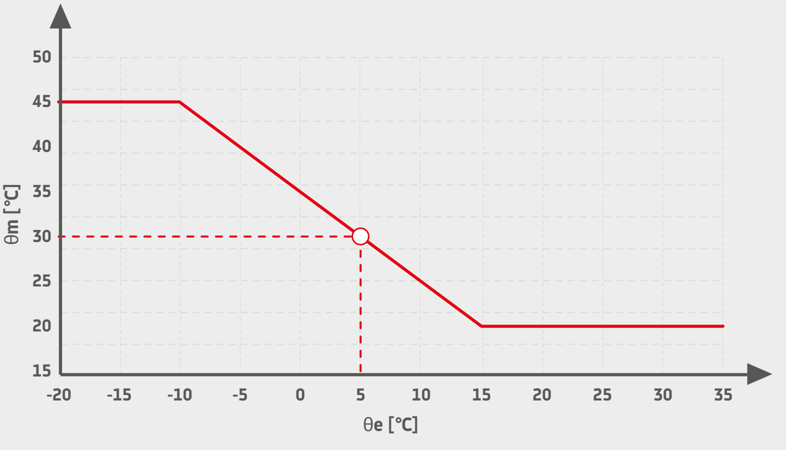


Figure 20. Example of a weather compensation curve.

Another compensation technique is to vary the set-point so that the temperature difference across the user remains constant. This is done by adjusting the set-point as a function of the return temperature: the idea here is that the return temperature tends to increase if the user requires less power, and so it makes sense to reduce the flow temperature.

Finally, we can move the set-point of the water temperature directly on the basis of the deviation between the measured and the required room temperature. This can also be done in combination with weather compensation.

Note that compensation is not a room temperature control system, as it only adapts the available power to suit the expected load in order to assist the actual control system.

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