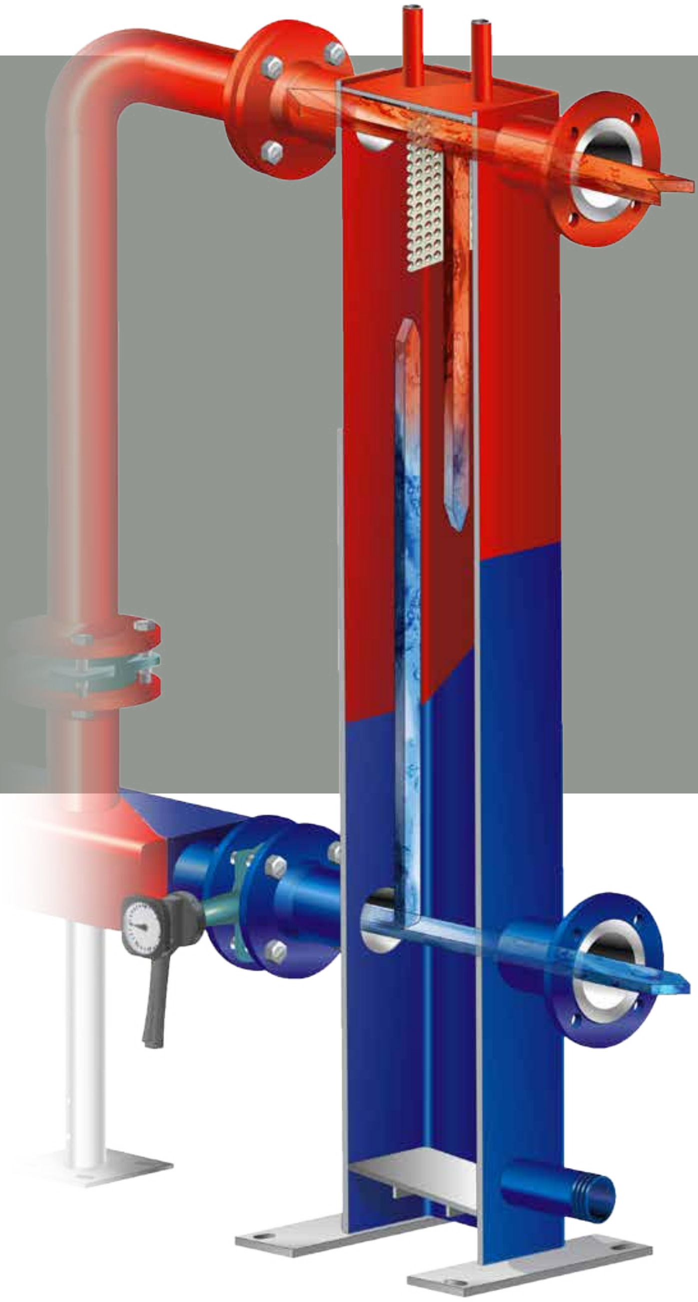


Balancing load and power

The function and operating principle of hydraulic separators

heating & cooling systems

Topic	Page

1. Scope of application

The term hydraulic separator is used to refer to a suitably dimensioned container – taking into account the defined design criteria – through which hot water from both the boiler system and the consumer circuit flows. This container is generally formed of a pipeline, which has a relatively large internal diameter in comparison to the pipelines of the flow and return. Hydraulic separators can either be vertically or horizontally installed in the network of pipes. The difference in temperature and the associated difference in density leads to the formation of layers in the separator, whereby the upper section of the hydraulic separator contains warm flow water and the lower section contains the colder return-flow water.

The main function of hydraulic separators in heating and cooling systems is to hydraulically decouple the boiler circuit or cooler and the consumer circuit(s) from one another.

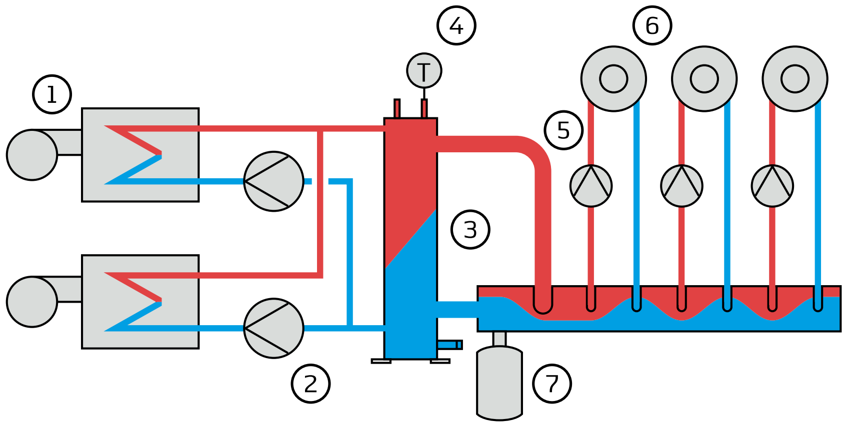
The use of hydraulic separators is the best way to eliminate hydraulic switching faults, especially when the volume flows from the heat consumer and the heat generator(s) differ in size. This is also generally the case in less complex systems, as the system hydraulics, the network of pipes, the pumps, control valves and

Modern heating system with integrated hydraulic separator (Sinus Caskade Unit)

other assemblies are designed for operation under full load. However, under the climatic conditions in Central Europe, full load operation is only necessary during 1.5 to 2.5% of the operating time. Furthermore, differing mass flows and temperature levels within the various heating and/or consumer circuits in a system contribute to an increase in complexity, giving rise increasingly to hydraulic problems. The pressure losses in the heating and heat consumer circuits are not constant. The number of operational heat generators and the setting of the control devices in the consumer circuits (e.g. mixers, three-way valves, thermostatic valves) influence the pressure loss in the overall system. Only if the heat supply systems are designed in such a way that there is an overall balance between the heat generation circuit and the heat consumer circuits does the heat transfer medium behave in accordance with the design in all operating situations – that is, with the lowest partial load operation and when operating at full load. The system functions as desired.

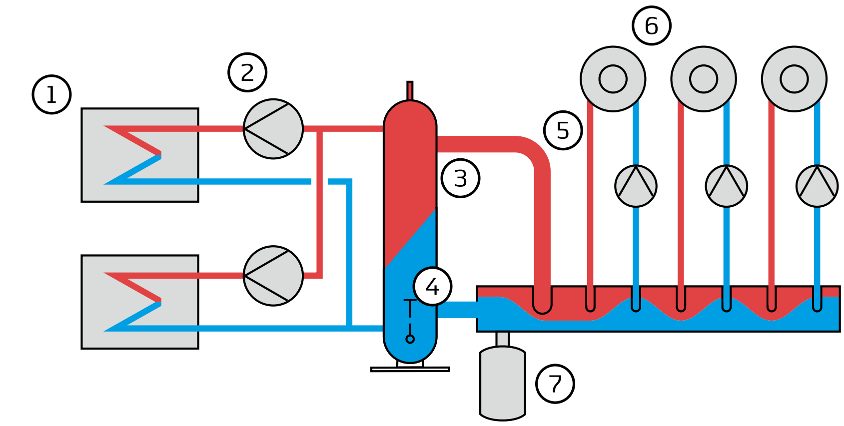
In the condensing boiler technology prevalent today, this is only possible if the water flows of the heat generator and the heat consumer circuits are hydraulically decoupled from one another, since, for the aforementioned reasons, the generator circuit must provide varying quantities to the consumer circuit. In practice, this balanced operating state can only be achieved through the use of a (correctly dimensioned) hydraulic separator. The zone in which the decoupling between the primary and secondary circuits within the hydraulic separator takes place is referred to as the system zero point. If the hydraulic separator is correctly dimensioned, this takes place precisely in the centre of the separator body. Assuming that the hydraulic separator is properly dimensioned, decoupling takes place with only negligible pressure and efficiency losses and flow velocities.

1.1. In heating systems



1 Heat generator
2 Circulating pumps for boiler circuit
3 Hydraulic separator
4 Heating circuit temperature control
5 Circulating pumps for heating circuit
6 Consumer
7 Expansion tank

1.2. In cooling systems



1 Cooler
2 Circulating pumps for boiler circuit
3 Hydraulic separator
4 Temperature control
5 Circulating pumps for heating circuit
6 Consumer
7 Expansion tank

As well as with warm water pump systems, hydraulic separators are also used in cooling systems. Here too, they provide an effective separation of primary and secondary pumps.

In principle, building such a system is like building heating systems, and surprisingly, the warmer medium is again connected at the top. The inlet flows are therefore connected to the lower section of the hydraulic separator. The sensor sleeves for the control system are positioned in this section as well.

When insulating the hydraulic separator, please ensure that an impermeable material is used if the system temperatures are below the dew point. Furthermore, when choosing the type of separator, the shape of the main body should be selected in such as way as to enable the complete insulation of the hydraulic separator without leaving relatively large thermal bridges.

2. Operating states

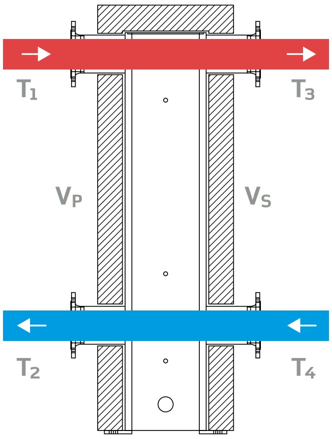
2.1. Volume flow of the heat generator is equivalent to the volume flow of the consumer circuits

In this case the hydraulic separator is in a neutral position. The volume flow of the primary circuit (V_P) and the volume flow of the secondary circuit (V_S) are equal.

The temperatures (T) in the primary circuit correspond to those in the secondary circuit. The heat quantity (Q) is also the same.

$V_P = V_S$ $T_1 = T_3$

$T_2 = T_4$ $Q_P = Q_S$



Operating state 1

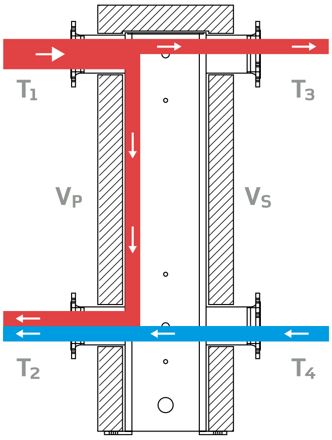
2.2. Volume flow of the heat generator is greater than the volume flow of the consumer circuits

This case occurs particularly frequently in systems with unregulated boiler circuit pumps. In the partial load range, the boiler circuit pump conveys considerably more water through the heat generator than is required by the consumer side.

In this case, the required volume flow is taken from the flow water from the heat generator and added to the return-flow water from the consumer circuits by means of the hydraulic separator.

$V_P > V_S$ $T_1 = T_3$

$T_2 > T_4$ $Q_P > Q_S$



Operating state 2

2.3. Volume flow of the heat generator is less than the volume flow of the the consumer circuits

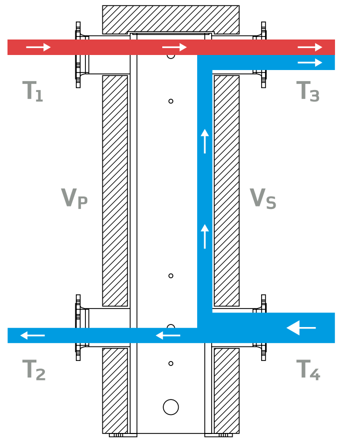
The situation whereby the consumer requires more water than is provided by the generator circuit is one that occurs regularly during the morning heating-up period, for example. The hydraulic separator balances the circuits by adding return-flow water from the consumer circuits to the flow water from the primary circuit. This prevents hydraulic problems and ensures that all consumers heat up uniformly.

The operating state mentioned also regularly occurs following the cleaning of old systems. The heat generators belonging to the new generation of heating boilers currently available on the market have only a very low water content.

The boiler would reach the set point value within just a few minutes without heat consumption. Only the installation of a hydraulic separator can avoid ''pulsing'' of the heat generator under these conditions.

Due to the partial mixture of volume flows of differing temperatures, the use of the hydraulic separator in operating states 2 and 3 is of course not temperature-neutral. If the current volume flow of the circulating pumps on the consumer side is larger than in the heat generator circuit, a partial quantity of the consumer's own return-flow water is added to the flow water on the consumer side. This reduces the flow temperature on the consumer side. The same applies inversely in operating state 2.

$V_P < V_S$ $T_1 > T_3$
$T_2 = T_4$ $Q_P < Q_S$



Operating state 3

3. Design

In order to ensure they are functioning as well as possible, the hydraulic separators must fulfil certain structural design requirements. These are presented briefly below.

The first requirement is that the hydraulic separator is correctly dimensioned so that, even under full load, the flow conditions – which are preferably laminar or steady – exhibit low pressure losses[1]. In this case, the liquid flows in layers, which do not mix. The average value for water should be a flow velocity of 0.2m/s in order to prevent the occurrence of turbulence (eddying or cross flows). Otherwise this may cause unintentional mixing of the volume flows from the flow and return.

For laminar flows, an approximate value for the pressure loss can be determined using the equation according to Darcy and Weisbach[2]. However, in contrast to a turbulent flow, this is negligible and thus causes only a very slight loss in efficiency.

Because the hydraulic separator is connected in parallel to the consumer circuit, in the event of the larger volume flow at the heat generator side the surplus water quantity is divided between the separator and the consumer circuit, in accordance with the pressure differences. The entire pressure build-up, and thus the efficiency of the system, results from the parallel connection[3] of the resistors of the hydraulic separator and the consumer circuit. In order for the control unit of the consumer circuit to be efficiently decoupled from the water quantity from the heat generator circuit, the pressure loss in the separator must therefore be kept to a minimum. A recommended guideline for the design of small separators is that the distance between the flow and return nozzles should be ten times as large as the diameter of the connection line.

In the case of large separators, the distance between the flow and return nozzles should be at least three times the diameter of the separator body. This guarantees thermal layering of the flow and return-flow water and the laminar flow[1] of the medium. As such, impairment due to eddying is avoided.

If this distance cannot be kept to due to conditions on site, then sheet layering and/or nozzle pipes are used to support the thermal layering and prevent turbulence.

[1] Source: Prof. Dr. R. Gross, Physik I – Mechanik, Akustik, Wärme (Physics I – Mechanics, Acoustics, Thermal Energy), Munich University of Technology, 2000

In the case of laminar flow, flow resistance is caused solely by the internal friction of the medium. To determine the flow, the dimensionless Reynolds number Re=w•d/υ applies, where υ is the kinematic viscosity [m2/s]; for water at 70°C this is 0.3877•10-6 m2/sec.
Depending on the size of the Reynolds number, a differentiation is made between the laminar flow type (Re≤2320, where 2320 is the critical point) and turbulent flow type (Re>2320). In technically smooth pipes (glass, brass, copper), in certain circumstances it is possible to achieve up to Re=8000 with laminar flow states.

[2] Source: H. J. Matthies, K. T. Renius, Einführung in die Ölhydraulik (Introduction to Oil Hydraulics), 5th Edition, Teubner Verlag, 2006, P. 47

The equation for pressure losses in flow pipelines assuming constant thickness is:

$$\Delta p = \frac{\rho u^2}{2} \cdot \left(\lambda \cdot \frac{l}{d} + \sum \zeta_i \right)$$

This is the equation according to Darcy and Weisbach, which does not take account of the term m for static height as it is considering a circuit system.

- t Density [kg/m³]
- u Average flow velocity [m/s]
- λ Pipe-friction coefficient according to Darcy and Weisbach
- l Length of the pipeline [m]
- d Diameter of the pipeline [m]
- ζ Flow resistance coefficient

[3] Source: W. Weißgerber, Elektrotechnik für Ingenieure 2 (Electrical Engineering for Engineers 2), 6th edition, Vieweg Verlag, 2007, p. 107

In electrical engineering and electronics, parallel connection describes a way of connecting the elements (two-terminal components) in a circuit: Components are connected in parallel if each pair of like poles is connected together. Any number of components can be connected in parallel.

SINUS VERTEILER

4. Alternatives to the hydraulic separator

As an alternative to the hydraulic separator, the only suggestion offered up in previous specialist literature was the installation of an open manifold (pressureless manifold with an overflow line). With this solution, the heat generator was supplied with the required water quantity in every operating situation, thus guaranteeing operational safety and a long operating life. With manifolds such as this, the boiler circulation pump should ensure, by means of a design with appropriately large dimensions, that there is always a certain quantity of water flowing, even in full load operation, thus preventing "pulsing" of the heat generator.

"The disadvantage of this design is that there are always differing volume flows and pressures upstream of the control valves and pumps on the secondary side. This influences the flow capacity of the control valves. This also applies for the circulating pumps currently in operation in the control circuits that must be used with electronic control in delta P-mode. This results in an unfavourable control behaviour. An exact configuration of circulating pumps and actuators to suit the water quantities required in the control circuit is, on the whole, very difficult with open manifolds."

Source: W. Zweers, Die Hydraulische Weiche (The Hydraulic separator), IKZ-HAUSTECHNIK, Edition 6/1996, Page 28 ff.

The "open manifold" also behaves problematically during the start-up phase and in partial load operating mode, as the required volume flow on the secondary side is larger than that on the primary side. In this phase, the heating circuit which is closest to the overflow line receives only its "own" return-flow water, if necessary. Under these circumstances, uniform heating of the consumers can no longer be guaranteed. Likewise, complete hydraulic decoupling with the help of an open manifold is not possible, as the cross-sectional area of the overflow line is no larger than that of the manifold beam. This is one reason why the open manifold has not become widely used in practice.

Another alternative could be to install a bypass line on the primary side, in order that the primary-side flow is not interrupted in the event of closed mixers and actuators. In this case, the volume flow differences would be balanced out on the primary side. The combined temperature of the flow to the heating circuits results from the mixing of all heating and boiler circuit volume flows. However, in such a case the positioning of the flow temperature sensor is problematic. If it is positioned behind the bypass, when looking from the boiler, it will no longer be exposed to temperature when the heating circuits are closed. If it is installed in front of the bypass, then the measured temperature will only be that of the boiler flow and not the heating circuit flow temperature, which is lower in the case of larger volume flows on the secondary side. If the temperature sensor is mounted at the intersection of the bypass and the boiler flow line, it appears, at least in theory, to precisely record the combined flow temperature.

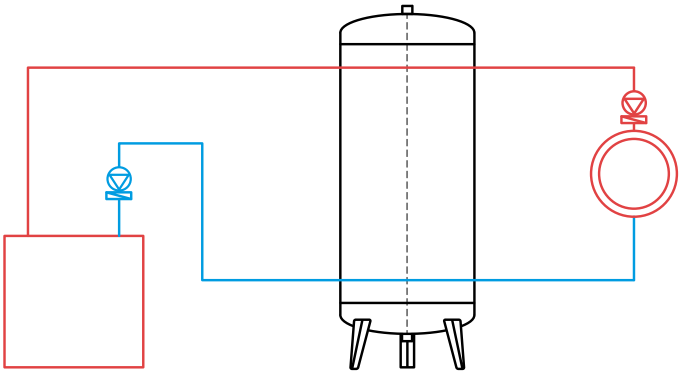
However, practical experience and test series have shown that, even with professionally laid bypass lines, complete mixing does not occur, even over longer sections of pipe. Here we talk of a "clustering flow". Similarly to the open manifolds, here too the boiler and heating circuits are not completely decoupled from one another. In the case of oversize boiler circuit pumps and a relatively small cross-sectional area of the bypass line, the heating circuits are continually influenced by the boiler circuit. Thus, even a bypass line is not an adequate alternative to the hydraulic separator.

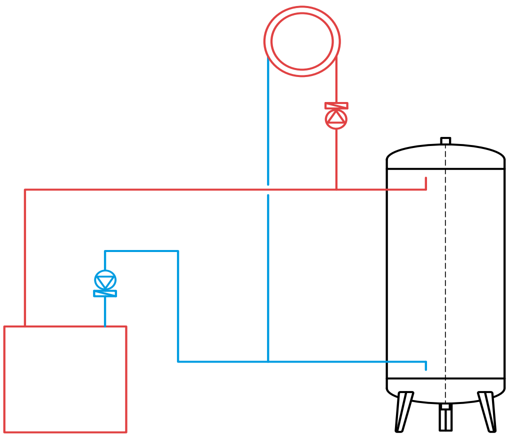
5. Integrating buffer tanks as hydraulic separators

In a lot of cases, buffer tanks will have to be integrated in a warm or cold water pump system. This can occur as a result of many different requirements, such as a reduction in pump frequency or the storage of unused amounts of energy.
There is often the possibility in such a situation to use the tank that is going to be implemented as a hydraulic separator as well. Connecting up such a tank can be done in several ways.
Some examples are:

Separator circuit

Connecting the buffer tank is carried out – as with classic hydraulic separators – via four nozzles that separate the primary and secondary circuits from one another. These connections are often linked with nozzle pipes to avoid turbulence. With this system, it is only the difference in water volume that is passed to the tank, filling or emptying it.



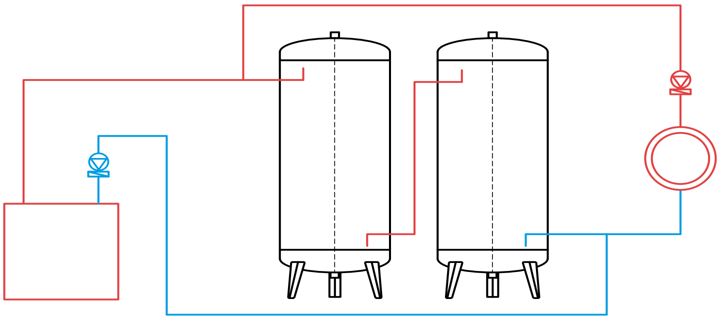


Cascade circuit

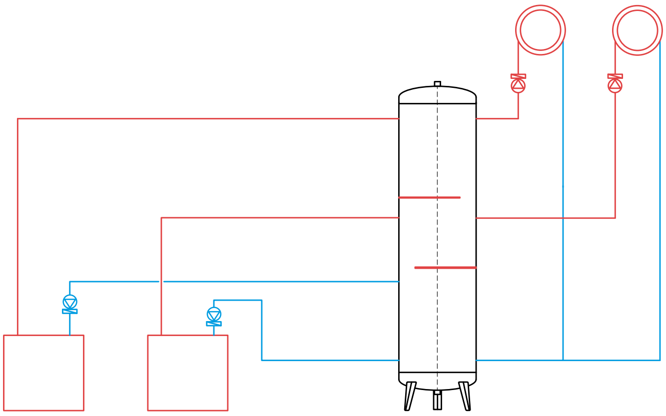
The tank in this circuit has two nozzles. The system of filling and emptying is based on the same principle as the separator circuit, whereby two or more tanks can be connected in a row. The advantage of such a series circuit is ideal layering with a relatively large storage volume.

Series circuit

To optimise the running period of a warm water generator or cold water system, a buffer tank is connected in parallel with the primary and secondary circuits and thus functions simultaneously as a hydraulic separator. The greater water storage enables the efficient operation of a solid fuel boiler or reduces the pump frequency of a cold water unit.



Layer storage



A storage integration variant that is becoming increasingly relevant is the connection of layer storage to a multivalent heating system. In accordance with the temperature level that is to be stored, the tank has connections at various heights with which containers can be filled or emptied, with or without control valves. Layer storage optimises the energy yield of a warm or cold water network. It is important to ensure the layering is not destroyed by excessively high flow velocities.

6. Typical problems in heating systems without a hydraulic separator

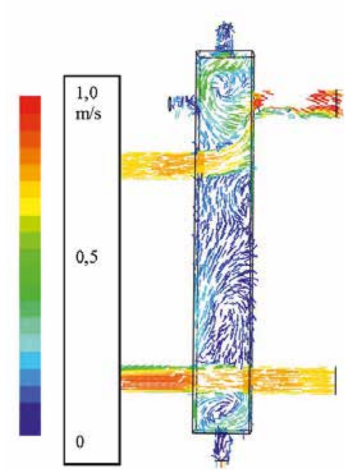
Typical practical problems in heating systems without a hydraulic separator are summarised below:

a) In full load operation, the heat generators cannot provide the required volume flow, meaning that hydraulic influences on the individual control circuits inevitably occur in the secondary circuits. This results in an insufficient supply to certain parts of the building, which in turn causes annoyance on the part of the consumer.

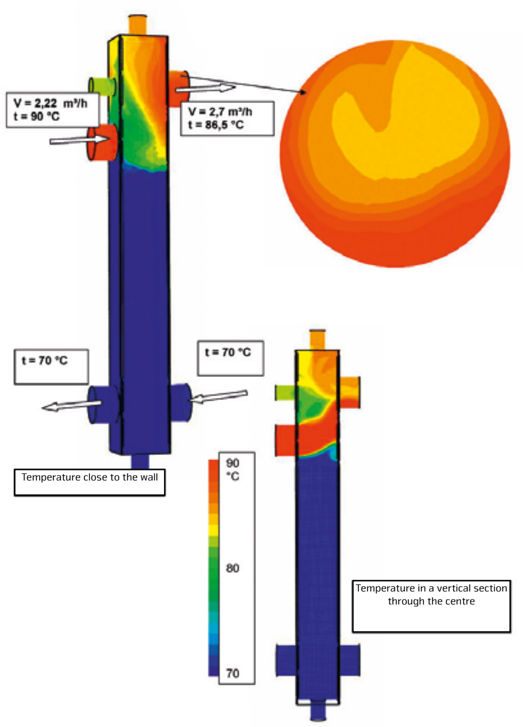
b) If an excessive volume flow is fed to the boiler by the secondary circuit pumps, this can result in material deposits inside the boiler due to turbulent flows. The service life of the heat generator is significantly impacted in this case.

c) In the lowest partial load range (e.g. summer transition phase) the required volume flow is not available to the heat generator after shutdown, meaning that in many cases overheating can occur. In this case, the residual heat can no longer be dissipated, as the control valves on the manifold have already been closed. Under these conditions, a very low service life of the heat generator can also be anticipated.

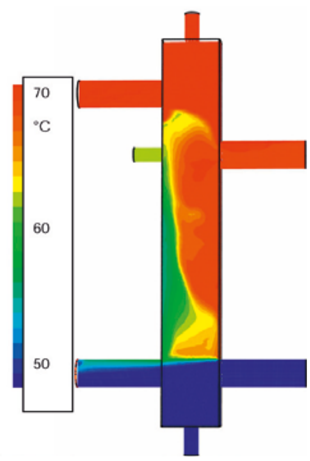
Only the proper installation of a hydraulic separator, which is properly designed and dimensioned, prevents the identified problems and ensures that the system functions according to plan.



See a)



See b)



See c)

7. Added benefits of using hydraulic separators

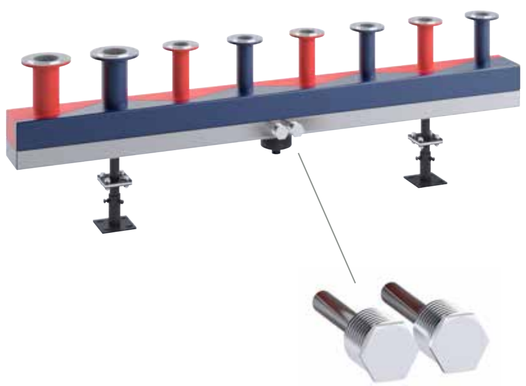
The main function of the hydraulic separator is the hydraulic decoupling of heat generator and consumer circuits. In addition to this, hydraulic separators available on the market offer additional benefits that promote and support the proper operation of the heating system.

A hydraulic separator provides the best location for the positioning of the flow temperature sensor (sensor for boiler circuit control). It must be mounted in such a way that it can measure both the boiler flow temperature and the mixing water temperature in order to control the boiler sequence if the secondary water quantity is larger than the primary.

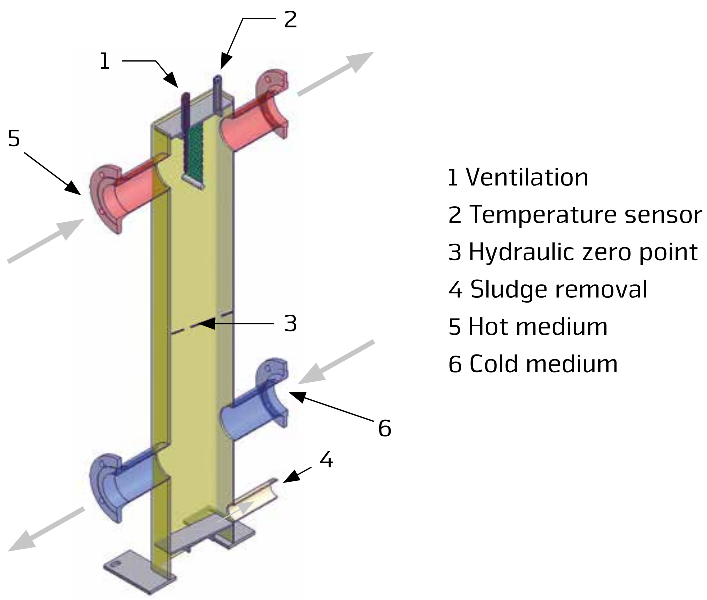
Due to the low flow velocities required on account of the respective function, the separator is also suitable for the separation of gases and entrained particles. While gases rise and can be discharged through a ventilation nozzle integrated into the dome/lid of the separator, entrained particles accumulate on the bottom of the hydraulic separator and can be disposed of from there through the sludge removal nozzle.

If new condensing boilers are installed in renovated systems, deposits and washouts from the pipeline systems and heating surfaces within the sensitive heat generator can result in the accumulation of sludge. Ultimately this can even result in the destruction of the valuable condensing boiler. Therefore, in their separators, Sinusverteiler offers the option of magnetite segregation by means of magnetite filter cartridges within the hydraulic separator, with a view to ensuring a long service life and optimum functioning of the high-performance boiler.

Finally, an indirect yet important added benefit is the energy efficiency in systems with correctly dimensioned hydraulic separators. Reduced pump output, the avoidance of boiler pulsing and the continuous operation of the components within the optimum characteristic value range are the main factors contributing to a high level of system efficiency.



HydroFixx with magnetite application



Hydraulic separator

8. Sinus HydroFixx, manifold with integrated Hydraulic separator

The Sinus HydroFixx combines many positive features in one component. Firstly, the integrated hydraulic separator guarantees excellent hydraulic decoupling of the boiler circuit from the consumer circuits, and secondly, the arrangement of the Sinus compact manifold horizontally above the separator makes possible a space-saving layout of the heating circuits.

Within the building services sector, developed especially for use in single-boiler systems, the small HydroFixx offers the ideal solution for combined and space-saving heating circuit distribution. In the case of a system with two or more heating circuits, this does not entail either increased outlay on installation or additional space. If the condensing boiler has a separator control with primary-side volume flow adjustment, an increase in return flow is avoided. The system flow temperature is detected in the Sinus HydroFixx and compared with the boiler flow temperature. It is thus possible to draw conclusions as to the volume flow conditions in the hydraulic separator and react by adjusting the speed of the device's internal pump.

These advantages also apply to the large design of the HydroFixx. Here, time-saving installation, hydraulic decoupling and minimised space requirements have a particularly positive impact on the construction costs and the effectiveness of the system. There are many reasons for choosing this combined manifold and hydraulic separator.

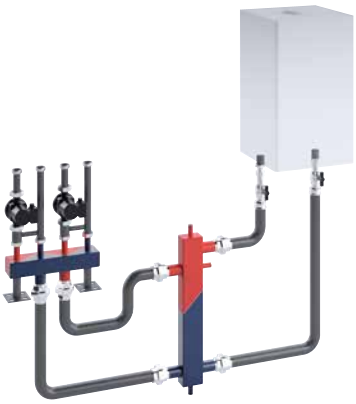
Sinus HydroFixx with two regulated heating circuits

Sinus HydroFixx, large design for systems of up to 9 MW

8.1. Advantages of the Sinus HydroFixx

The HydroFixx, consisting of a heating manifold with an integrated hydraulic separator, incorporates many positive features in one unit. Firstly, the integrated hydraulic separator guarantees excellent hydraulic decoupling of the boiler circuit from the consumer circuits, and secondly, the arrangement of the heating manifold horizontally above the separator makes possible a space-saving layout of the heating circuits.

Small construction

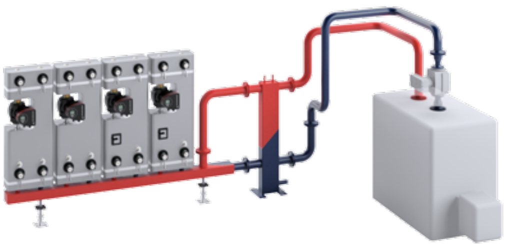


Manifold with separate Hydraulic separator

HydroFixx

- As stock item in a set including insulation and wall bracket
- Designed for industry standard pump groups
- Compact design optimised for use in roof spaces

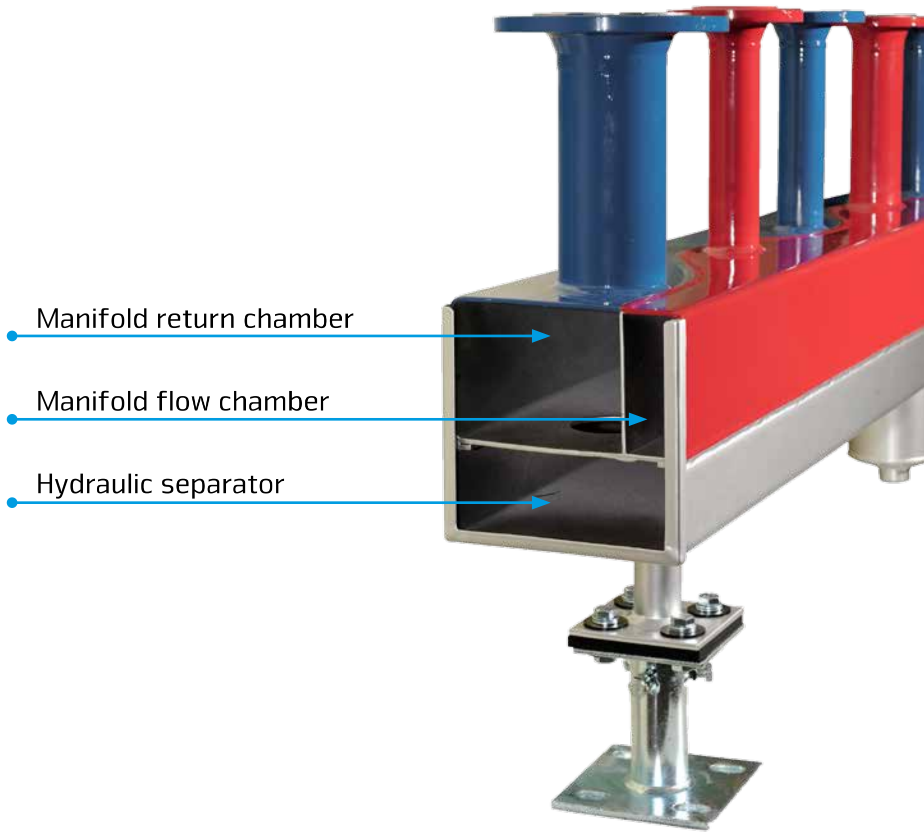
Large construction



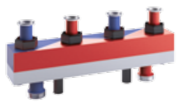
Manifold with separate Hydraulic separator

HydroFixx

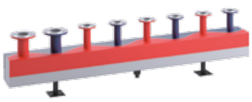
- Can be connected as per the Tichelmann-System
- Very short installation time as no pipework is necessary as between traditional separators and manifolds
- Compatible with all makes and models of condensing boiler



8.2. Product line



Type	Flow rate in m³/h	Nozzle spacing in mm	Power at ΔT 20 K in kW	Boiler connection	Heating circuit connection	Heating circuits
80/80	3.0	125	70	1½ " Threaded nozzle	1½" Union nuts	2 to 4
120/80	7.0	125	160	2" Threaded nozzle	1½" Union nuts	2 to 4



Type	Flow rate in m³/h	Nozzle spacing in mm	Power at ΔT 20 K in kW	Boiler connection max.	Heating circuit connection max.	Heating circuits
120/120	7.0	200 or 250	160	DN 65	DN 50	from 2
160/160	10.8	250 or 300	250	DN 80	DN 65	from 2
180/180	17.2	250, 300, 350	400	DN 100	DN 80	from 2
200/200	25.8	250, 300, 350	600	DN 125	DN 100	from 2
280/320	53.8	300 or 350	1,250	DN 150	DN 125	from 2
300/350	68.8	300 or 350	1,600	DN 150	DN 125	from 2
400/400	90.0	variable	2,100	DN 150	DN 150	from 2
450/450	150.0	variable	3,500	DN 200	DN 200	from 2
500/550	194.0	variable	4,500	DN 250	DN 250	from 2

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