Intelligent pressure maintenance of combined Heating-cooling Systems

Automated Change-Over-Systems

Compact solutions for hydraulic design of circulating systems with combined heating/cooling elements

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a powerful brand for decades

Reflex Winkelmann GmbH — part of the Building+ Industry division — is a leading provider of high quality heating and hot water supply technology systems. Under its Reflex brand, the company, which has its headquarters in Ahlen in the German region of Westphalia, develops, produces and sells not only diaphragm expansion vessels, but also innovative components and holistic solutions for pressure maintenance, water make-up, degassing and water treatment, storage water tanks and plate heat exchangers, as well as hydraulic manifold and tank components. Reflex Winkelmann GmbH has about 2,000 employees worldwide, giving it an international presence in all major markets.

With its energy-efficient and sustainable products, the company is already doing its bit to help the environment, as evidenced by its commitment to sustainability and the climate policy goals agreed by the German Federal Government. This support is built on proven technologies and future-oriented innovations. What's more, Reflex Winkelmann GmbH works together with others as equals, always maintains its focus on the customer and offers additional services such as its own factory service centre fleet and a comprehensive range of training options.

Content

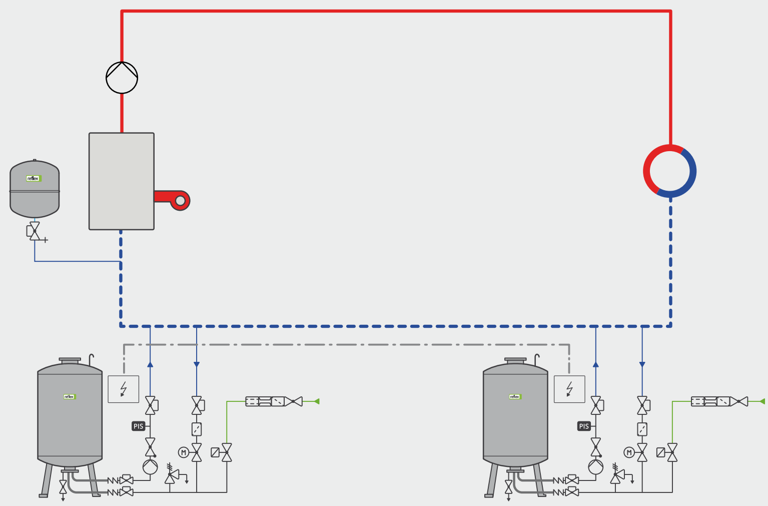
General information

Basics

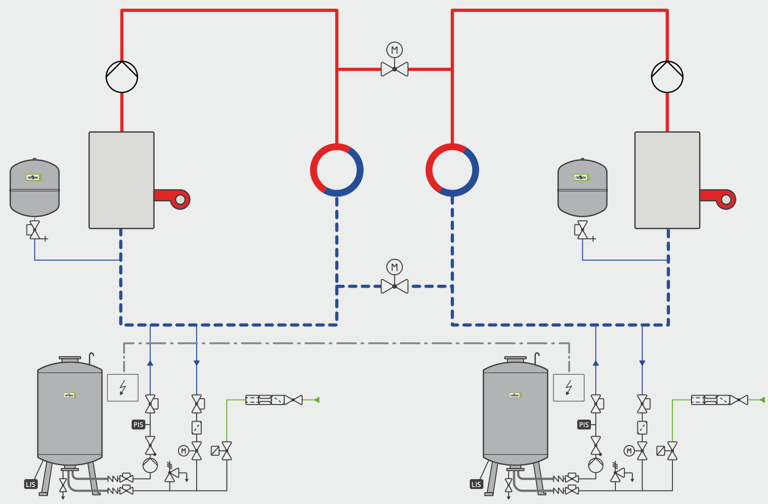
The heating and cooling of spaces using the same transfer devices is an approach that is becoming increasingly common, particularly in commercial buildings, where state of the art technology is used to maintain a comfortable and safe working climate. This architecturally influenced comfort requirement is achieved by using either heating or chilled water beams, when the concrete structure, is used as an active component, or space heating/cooling devices located in the void above suspended ceilings. The units known as Fan Coil Units, or FCUs. The FCUs have fans that blow a combination of fresh and recirculated air across heating and cooling heat exchangers. On a 'wet' system, there will be connection to a four-pipe supply, with flow and return for both heating and cooling. Modulation of valves changes the space temperature, this can be either through the setting of thermostats by the space users, or as is becoming more prevalent, active monitoring by the Building Management System (BMS). Compatible components such as 6-way ball-valves are available in the market, in a wide range. Despite the shared consumers/FCUs, the design phase is based simply on the assumption of separate boiler/chiller circuits. In most instances, on these apparently complex systems, simple heating or cooling circuits are from and back to these devices in parallel. The fresh and exhaust air, to and from the FCUs, is ducted from

Typical schemes for connected consumer/producer circuits

Consumer/producer
Redundant or connected pressurisation



Connected systems with redundant/alternative heat supply
with system-autarcic or connected pressurisation

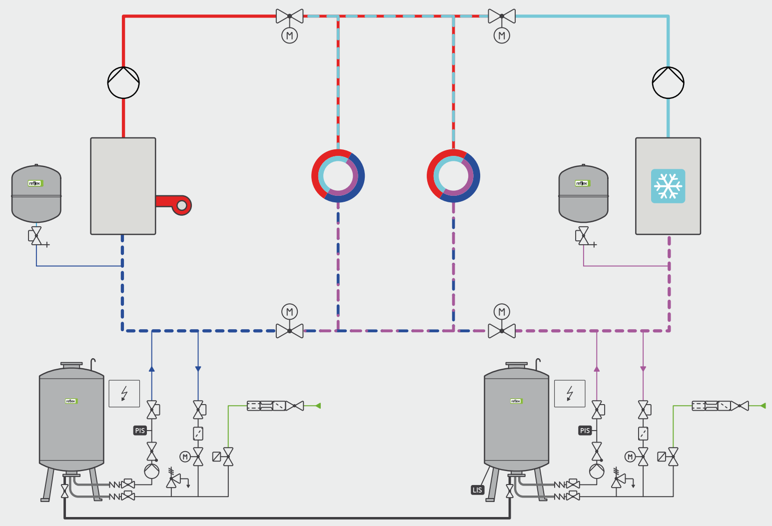


and back to units known as Air Handling Units (AHUs). These are generally located in a plantroom, with fresh air being ducted in from outside the building. Fans are used to both draw the fresh air in, and force it out to the FCUs, located around the building. Dependant on the outside ambient temperature, the fresh air supply may be pre-heated/cooled by passing through heat exchangers. The BMS dictates which heat exchangers are to be active and modulates control valves accordingly. Exhaust air also passes through the AHUs, where sometimes, heat is reclaimed.

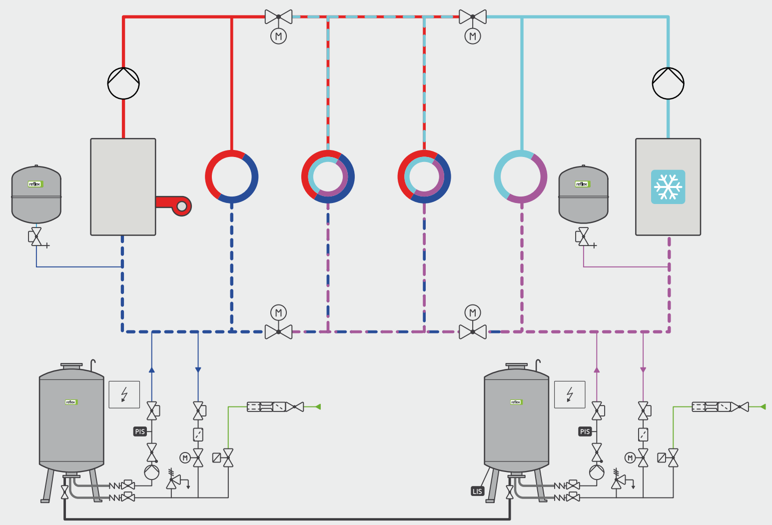
The AHUs are generally fed by the same boilers and chillers, as the FCUs, so when calculating system content at the design stage, the potential volume of associated pipework and heat exchangers, should be allowed for.

Caution!
When talking about heating/cooling systems or change-over-systems, supply networks with consumers are meant, which are used for both heating and cooling purposes and are supplied by different generator circuits.

Cooling flow | Heating flow
Cooling return | Heating return



Change-Over-System
connected system, heating/cooling, temporary switch-over with generator circuit-specific pressure maintenance incl. heat transfer mass compensation



Change-Over-System
Additionally, with pure cooling or heating consumers, pressurisation in the generator circuit incl. heat transfer mass compensation

Hydraulic circuits

Connection of the combined consumers to the producer circuit

Illustration 1
4-pipe system with four 2-way actuators for flow and return connections.

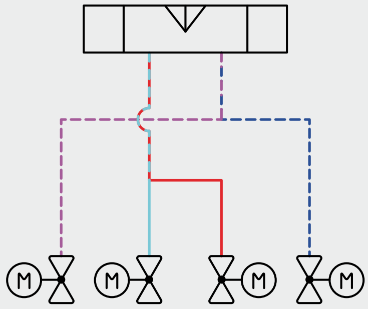


Illustration 2
4-pipe system with two motor-controlled 2-way actuators and one 3-way actuator for the returns.

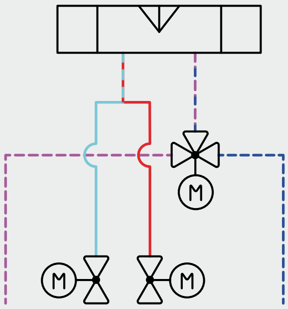


Illustration 3
4-pipe system with a motor-controlled 6-way actuator.

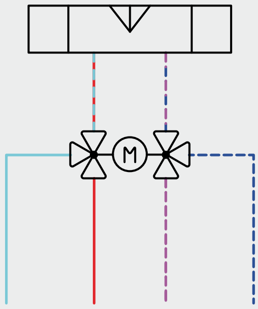
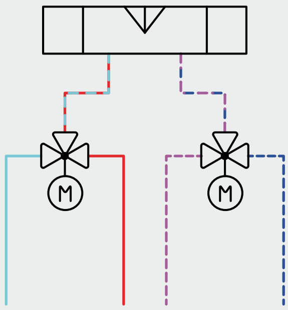


Illustration 4
4-pipe system with two motor-controlled 3-way actuators.



The diagrams serve only to illustrate the connections. They must be adapted and specified according to local conditions.

Cooling flow | Heating flow
Cooling return | Heating return

Examples of potentially occurring operating problems

If the examples of hydraulic circuits on the previous pages are not fully implemented or if there is a lack of correct function, hydraulic problems almost always occur. Just as frequently these result in assumed malfunctions in the pressurisation system.

1. **Volume flow in transfer pipe**
A permanent volume flow in an existing transfer pipe indicates a simultaneously existing but negatively acting other connection between heating and cooling circuits. This can be an indicator for incorrect functioning of the heating and cooling systems.

Example:
In the heating system the pump delivers the medium to the consumer. At the consumer, the heating return valve is not open, rather the cooling return valve and the circuit is closed by the transfer pipe.
→ Flow via transfer pipe!

2. **Pressure maintenance without hydraulic connection of the circuits (transfer pipe)**
If a transfer pipe is not used for static pressurisation in both networks or in mixed systems with dynamic and static pressurisation, temporary very large pressure differences can occur between the circuits, e.g. due to a temperature-induced mass transfer of the heat transfer medium.

Example:
These may then be reduced by switching or valve leakage rates. This can lead, among other things, to un-desired water hammer and the associated noises. If the corresponding valve design prevents overflow in the event of changeover, a medium-term negative pressure formation is to be expected due to emptying, especially in the cooling water circuit.

3. **Filling level in the pressure maintenance system**
Repeated overfilling during heating-water pressurisation or necessary make-up in the cooling-water network.

Example:
Return of the displaced water is not possible because there is no permanent hydraulic connection of the circuits and the necessary communication of the pressurisation system is also missing.

Planning guidelines

Initial situation

Systems that are obviously hydraulically separate (e.g., heating circuit, cooling circuit) but which are temporarily using the same consumers (change-over) are already included in the mass-balance of the systems associated with the heat transfer medium solely as a result of the thermal load cases in the consumers, and must also be treated accordingly:

Principles

1. **Mass transfer**
Each time the consumers are switched (from cooling to heating – or heating to cooling), heat transfer medium (e.g. water) is moved from one circuit to the other. Due to the different temperatures of the heating or cooling medium, it then has a different density dependent on the previous operating case.

As a result, if the medium content (volume) in the heating/cooling element remains constant, the corresponding differential water mass must be replaced or discharged by the respective active system. When switching from cooling to heating, more mass of the heat transfer medium is displaced than when switching from heating to cooling. Especially the latter changeover type and the associated mass transfer can lead to a pressure drop or disfunction of the pressurisation system up to and including the pressure loss below the allowed minimum working pressure in the cooling circuit.

Also, the mass of water received by the heating system may not be problem-free from the pressurisation point of view and may overfill the system. This normal behaviour must be taken into account accordingly.

For corresponding recommendations see **variants for integration** p. 16 – 19

2. **Media mixing**
Due to the mass displacement that occurs and the resulting mixing of the media from both generating circuits, the media must have the same properties from the outset (e.g. water quality, glycol concentration). For this reason, the corresponding underlying planning principles and/or materials used must also be adapted.

3. **Pressurisation when the consumer is at a standstill**
It must be ensured that a combined heating/cooling element with shutoffs in both flow and return, especially at a standstill, cannot build up a high or low pressure (valve's own relief circuit, secure permanent connection to a pressurised generator circuit).

Note!

I. **It is possible to equip supply networks with thematically separate generator hydraulic systems, which can, however, act temporarily and separately on the same consumers, each with system-specific pressurisation of the same design and function.**

a. Pump pressurisation with connected head-symmetrical expansion vessels at the same installation level and in the same location.

or

b. Dynamic pressurisation systems are connected electronically (master/slave) and a connection (transfer pipe) is created between the circuits at the respective hydraulic zero point.

or

c. Static pressurisation systems (diaphragm expansion vessels) must be combined into a pressurisation system indirectly via a transfer pipe that connects the circuits at the respective hydraulic zero point.

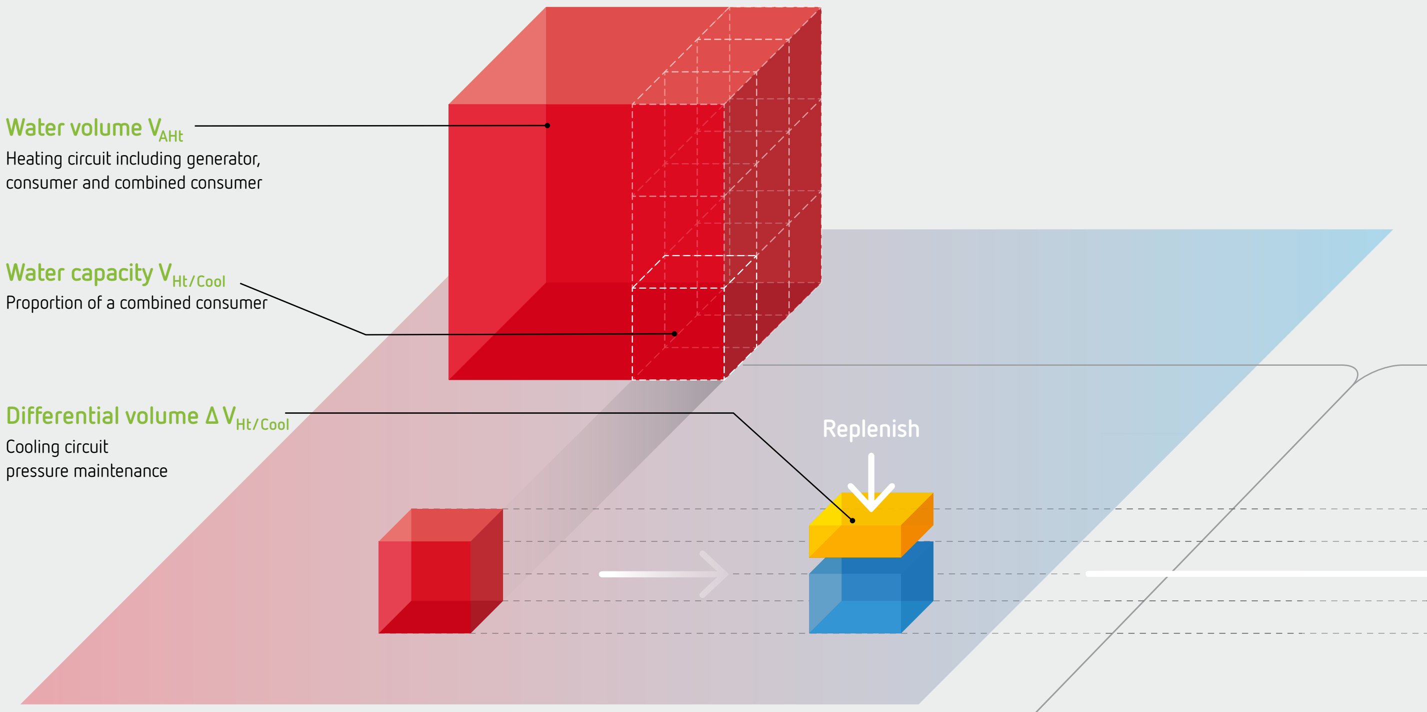
II. **The objective is to ensure that networks with thematically separate generation hydraulics which, however, temporarily and separately act on the same consumers, are given a common pressurisation system and are thus hydraulically connected or must be connected at a defined point.**

III. **Heating-cooling-systems (change-over systems) should be planned hydraulically in such a way that the participating generating circuits apply the same basic hydraulic principles (admission pressurisation, holding pressurisation position of hydraulic zero point in the circuit, e.g. upstream of the generator, at the hydraulic zero point).**

Mass transfer in the heat transfer medium

Temperature-induced heat transfer medium mass-transfer in heating / cooling operation

Case 1:
Switching from heating to cooling mode



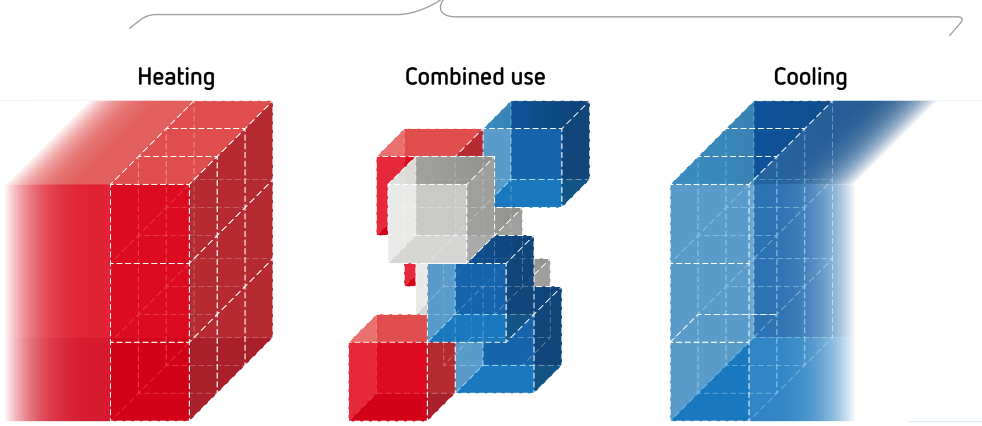
Common consumer contents

Common consumer contents can be temporarily assigned to the heating circuit, the cooling circuit or no circuit (standstill). There can also be several consumers at different stages.

Common consumer content assigned to the **heating circuit**

Common consumer content that is assigned to the **cooling circuit**

Common consumer content, which is at **standstill**

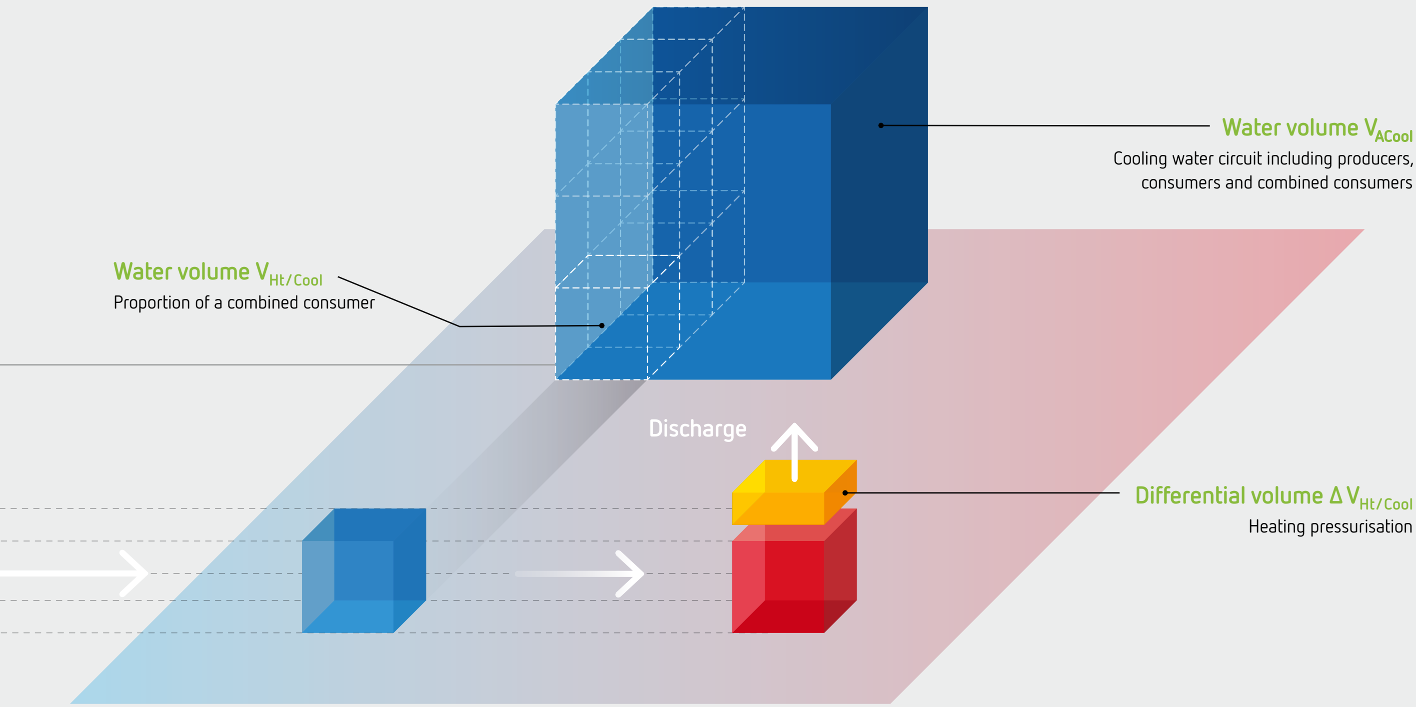


Water volume $V_{AHt/Cool}$
combined consumer assigned to **heating**

combined consumers in **mixed** use

combined consumers assigned to **cooling**

Case 2:
Switching from cooling to heating mode



Other causes for a heat transfer medium mass-transfer

- Incorrect timing when swtiching hydraulically from heating to cooling mode
- Leakage rate in control or shut-off devices between heating/cooling water circuit
- Defect in control or shut-off devices between heating/cooling circuit
- Unknown/undefined other hydraulic connections of the networks
- Strong pressure differences when connecting isolated heating surfaces

Summary:
For heating/cooling water circuits with change-over operation, mass return of the heat transfer medium must be provided

Example calculations

For possible temperature-related mass transfer

Key data

Office building with **120 offices** which are equipped with heating/cooling ceiling operating in change-over principle

Heating temperature program	t_{HFL}/t_{HRL}	= 35°C / 30°C	Number of offices	n	= 120 Pcs.
Cooling temperature program	t_{CFL}/t_{KRL}	= 16°C / 19°C	Average density of heating water in heating mode	ρ_H	= 993,0 kg/m³
Ceiling temperature at standstill	t_{CSt}	= 20°C	Average density of heating water in cooling mode	ρ_K	= 999,0 kg/m³
Water volume heating/cooling ceiling office	V_C	= 10 l/Pcs.	Density of heating/cooling water at standstill	ρ_{St}	= 998,3 kg/m³

Calculation example

1. Standstill → Heating mode

Transition from standstill to heating mode, calculation of the possible mass transfer into the active heating network during a heating process in all offices per day.

The heating network has to receive **6.0 litres per day** due to the density change during the heating process or compensate it by pressurisation assuming this process occurs in all offices. In **10 days** this amounts to **60 litres**. The filling level in the pressurisation unit in the heating circuit increases.

Calculation example

$$\Delta V_C = V_C \times \left(\frac{\rho_{St}}{\rho_H}\right) - V_C = 10\,l \times \left(\frac{998{,}3\ kg/m^3}{993{,}0\ kg/m^3}\right) - 10\,l = 0{,}05\,l/Pcs.$$

$$\Delta V_{Ctot} = \Delta V_C \times n = 0{,}05\,l/Pcs. \times 120\,Pcs. = 6{,}0\,l$$

2. Heating mode → Cooling mode

Transition from heating to cooling mode. Calculation of the possible mass transfer into the active cooling water circuit during a cooling process in all offices per day.

The cooling circuit must supply **7.2 litres per day** due to the change in density during the cooling process, or compensate for this by pressurisation, insofar as this process takes place in all offices, this equates to **72 litres** in **10 days**. The filling level in the pressurisation unit in the cooling water circuit decreases.

Calculation example

$$\Delta V_C = V_C \times \left(\frac{\rho_H}{\rho_K}\right) - V_C = 10\,l \times \left(\frac{993{,}0\ kg/m^3}{999{,}0\ kg/m^3}\right) - 10\,l = -0{,}06\,l/Pcs.$$

$$\Delta V_{Ctot} = \Delta V_C \times n = -0{,}06\,l/Pcs. \times 120\ Pcs. = -7{,}2\,l$$

3. Cooling mode → Standstill

Transition from cooling mode to standstill, calculation of the possible mass transfer into the active cooling water circuit during a cooling process in all offices per day.

At this point, the focus should be on the fact that a change in density can also occur. In the neutral position of the control elements, the pressure increases in the heating and cooling ceiling associated with density change must be compensated.

See **Example No. 3** on p. 7

Calculation example

$$\Delta V_C = V_C \times \left(\frac{\rho_K}{\rho_{St}}\right) - V_C = 10\,l \times \left(\frac{999{,}0\ kg/m^3}{998{,}3\ kg/m^3}\right) - 10\,l = 0{,}007\,l/\text{Pcs.}$$

$$\Delta V_{Ctot} = \Delta V_C \times n = 0{,}007\,l/\text{Pcs.} \times 120\ \text{Pcs.} = 0{,}8\,l$$

4. Cooling mode → Heating mode

Transition from cooling to heating mode, calculation of the possible mass transfer into the active heating water circuit for a load case of this type per day in all offices per day.

The heating network must discharge **7.2 litres** per day due to the change in density during the heating process or compensate for this by pressurisation, assuming this process takes place in all offices, in **10 days** this equates to **72 litres**. The filling level in the pressurisation unit of the heating water circuit increases.

Calculation example

$$\Delta V_C = V_C \times \left(\frac{\rho_K}{\rho_H}\right) - V_C = 10\,l \times \left(\frac{999{,}0\ kg/m^3}{993{,}0\ kg/m^3}\right) - 10\,l = 0{,}06\,l/\text{Pcs.}$$

$$\Delta V_{Ctot} = \Delta V_C \times n = 0{,}06\,l/\text{Pcs.} \times 120\ \text{Pcs.} = 7{,}2\,l$$

Overview

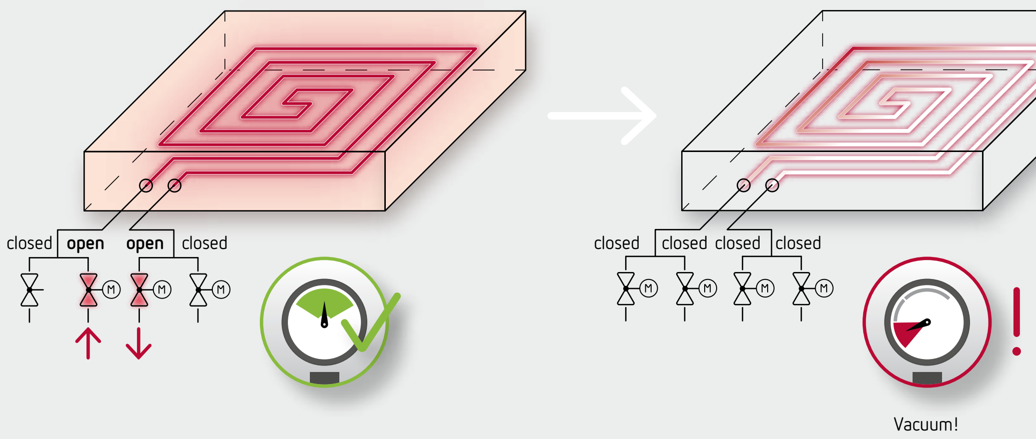
Load case	Switching case	Active network	Pressurisation in the active network
1	standstill → heating	heating circuit	Filling level increases
2	heating → cooling	cooling circuit	Filling level decreases
3	cooling → standstill	–	Risk of overpressure or vacuum in the consumer if there is no pressurisation unit for standstill/shutdown operation.
4	cooling → heating	heating circuit	Filling level increases

The analysis shows that density changes alone tend to cause mass transfers from the cooling circuit to the heating circuit. Corresponding compensation measures in the in the area of pressure maintenance are therefore necessary.

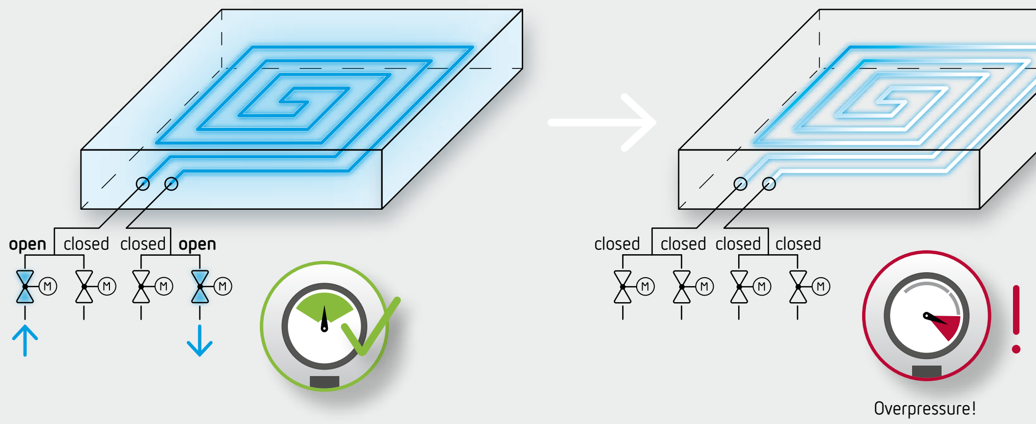
Problem definition standstill

Hydraulically insulated heating / cooling surface

Case 1:
Switching from heating to cooling mode



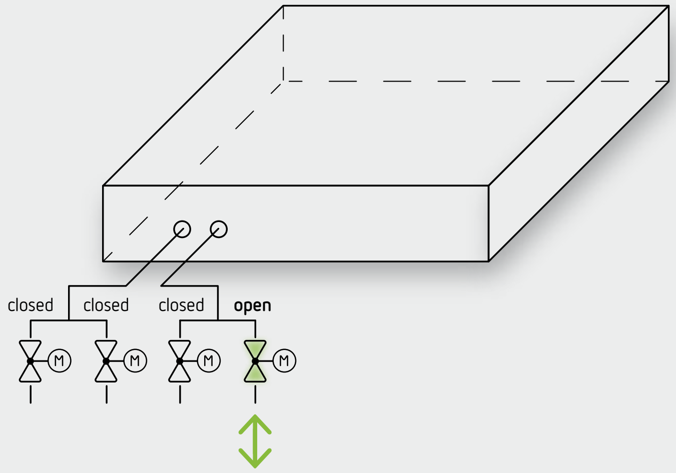
Case 2:
Switching from cooling mode to standstill



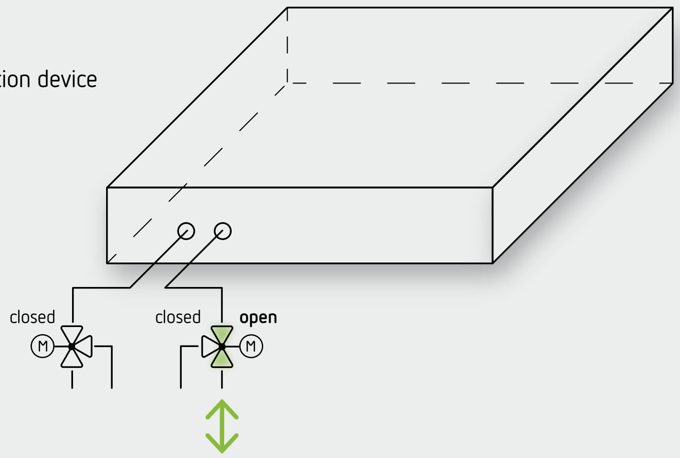
To provide pressure relief for combined heating / cooling surfaces, it must be ensured at all times that the corresponding consumers are connected to a pressurisation system, as otherwise unwanted under- or over-pressure may occur.

Hydraulically non-insulated heating / cooling surface – Solutions

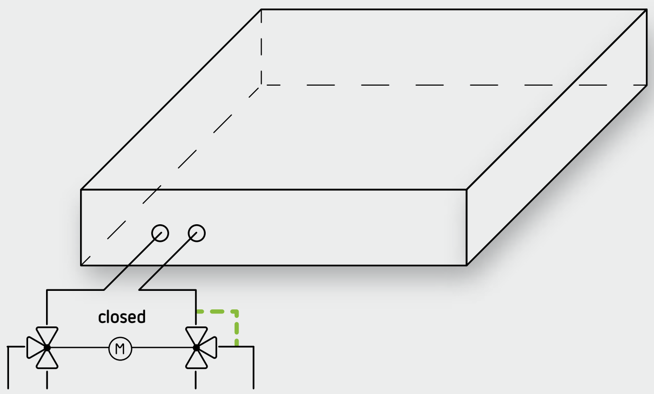
Solution 1:
4 × 2-way valve



Solution 2:
2 × 3-way valve
With pressure equalisation device

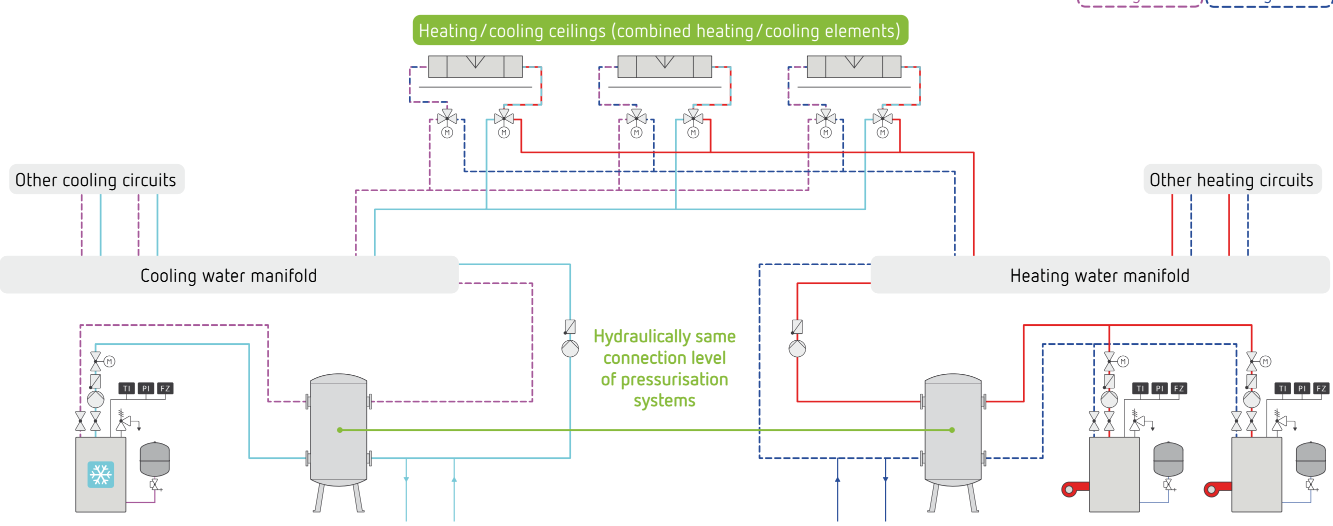


Solution 3:
6-way-ball-valve
with pressure relief



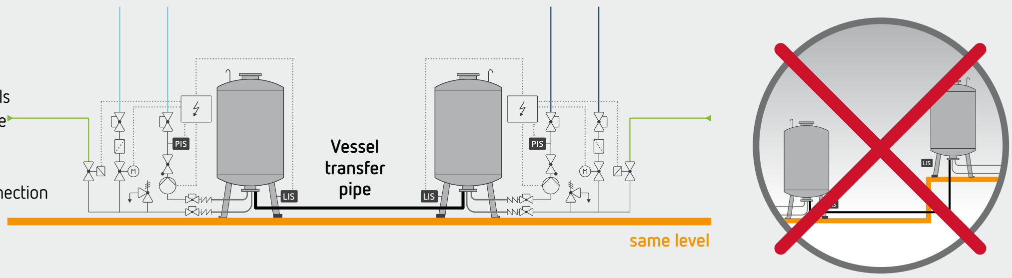
Integration options

Principle circuit diagram



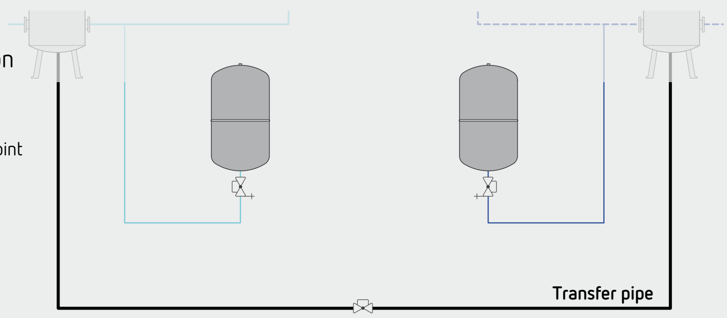
Autarcic pump pressurisation

- with associated extension vessels of the same geometry and at the same installation level
- without other fixed defined connection of the circuit hydraulic elements
- according to notes
  Ia II



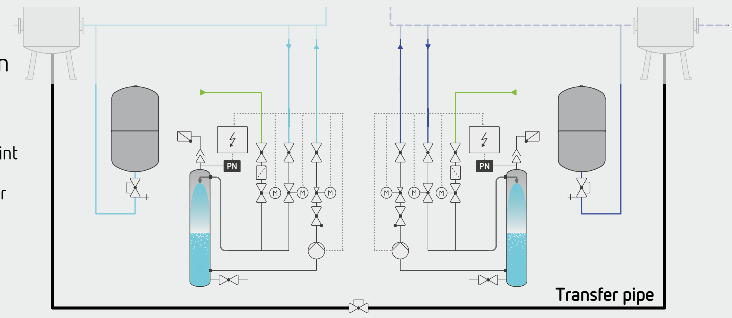
Static pressurisation using diaphragm expansion vessel

- with defined connection of the circuits at the hydraulic zero point
- according to notes
  Ic III



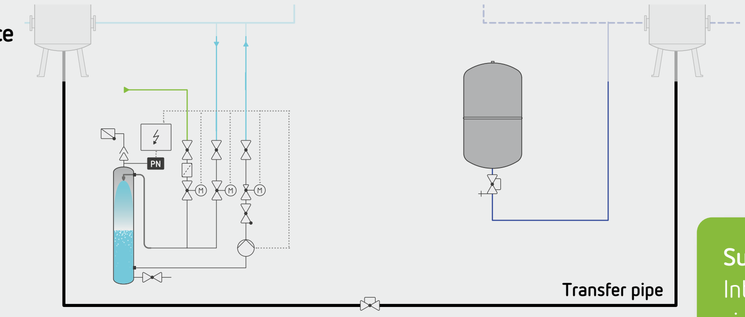
Static pressurisation using diaphragm expansion vessel

- with defined connection of the circuits at the hydraulic zero point
- with degassing in both producer circuits
- according to notes
  Ic II III



Autarcic pressure maintenance by means of diaphragm pressure expansion vessel

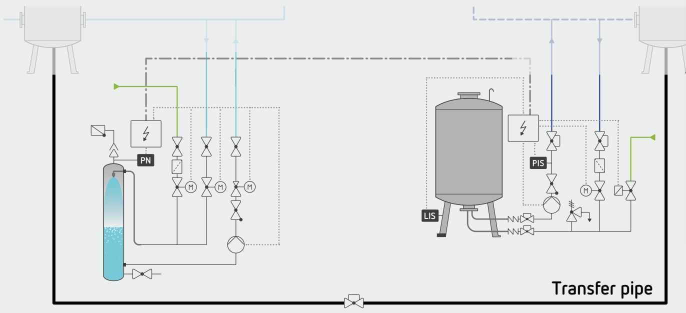
- with defined connection of the circuits at the hydraulic zero point
- with degassing in cooling circuit
- according to notes II III



Summary:
Interconnected circuits with thematically separate generator circuits and common consumers must be connected in a targeted manner at one point due to unavoidable temperature-related heat transfer medium mass transfer processes.

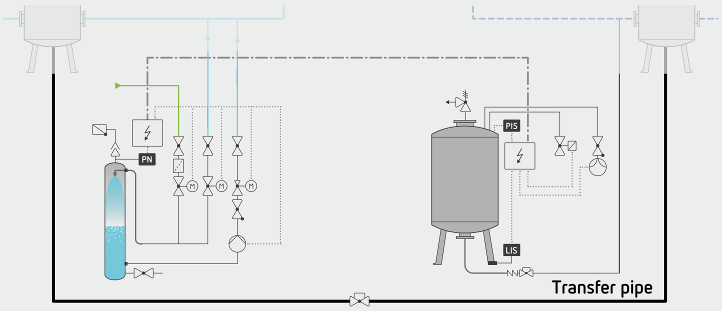
Autarcic pressuration unit pump controlled

- with defined connection of the circuits at the hydraulic zero point
- with degassing in cooling circuit
- optional pressurisation unit
- according to notes II III



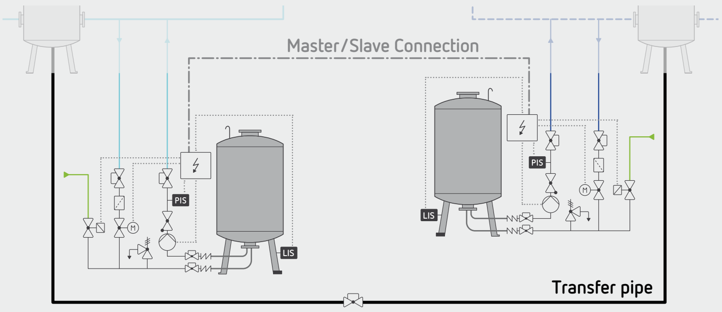
Autarcic pressuration unit compressor controlled

- with defined connection of the circuits at the hydraulic zero point
- with degassing in in the cooling water circuit
- optional pressurisation unit
- according to notes II III



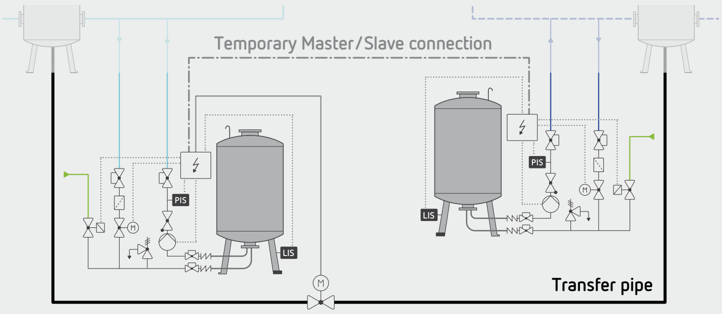
Pressurisation unit with master/slave connection

- with defined connection of the circuit at the hydraulic zero point
- according to notes Ia Ib II



Pressurisation unit with temporary master/slave connection

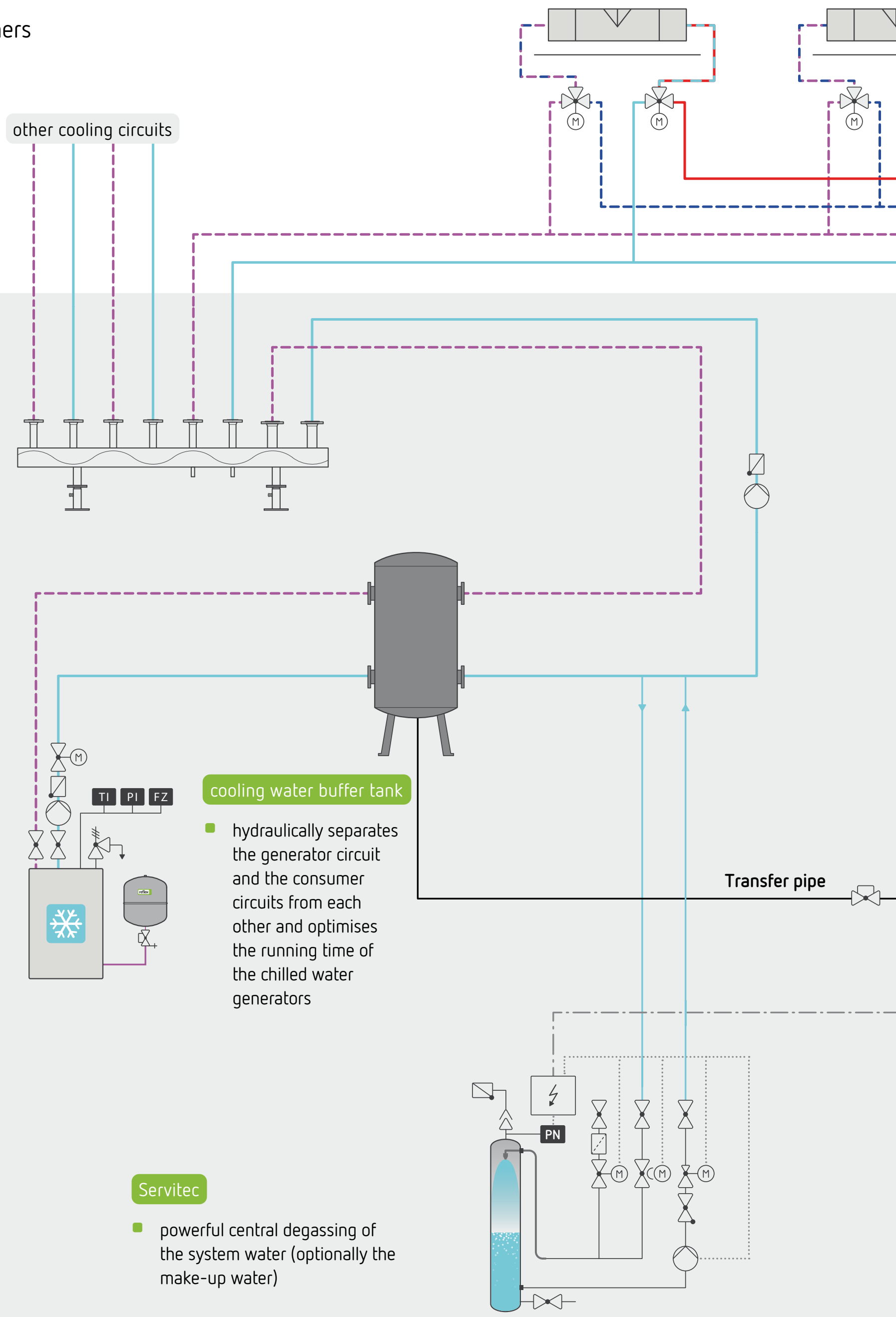
- with controlled temporary connection of the circuits at the hydraulic zero point
- according to notes Ia Ib II



The diagrams serve only to illustrate the connections. They must be adapted and specified according to local conditions.

Installation example

Pressurisation, degassing, replenishment and heat flow distribution in a heating and cooling system with consumers in change-over principle.



Common pump controlled pressurisation with vacuum spray tube degassing in the cooling water circuit

Sinus compact manifold

- as a link between the generator and the consumer circuit
- space-saving arrangement of flow and return
- good flow behaviour due to sinusoidal arrangement of the flow and return chamber
- easy to install, compact design

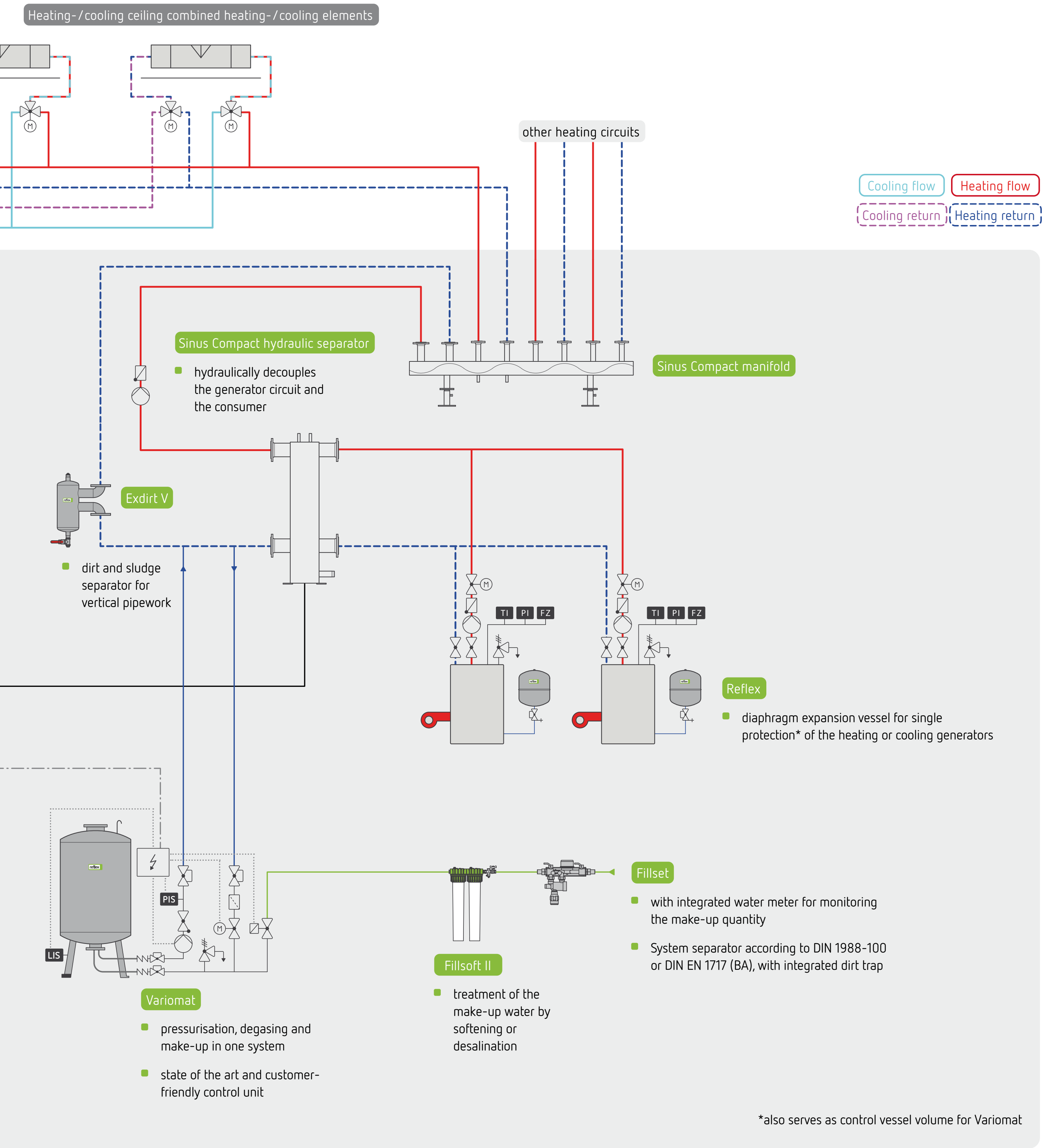
cooling water buffer tank

- hydraulically separates the generator circuit and the consumer circuits from each other and optimises the running time of the chilled water generators

Servitec

- powerful central degassing of the system water (optionally the make-up water)
- permament operational reliabaility of the entire heating/cooling system

The diagrams serve only to illustrate the connections. They must be adapted and specified according to local conditions.

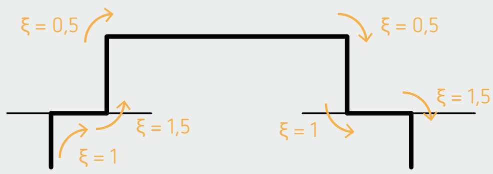

Heating-/cooling ceiling combined heating-/cooling elements
other heating circuits
Cooling flow
Heating flow
Cooling return
Heating return
Sinus Compact hydraulic separator
hydraulically decouples the generator circuit and the consumer
Sinus Compact manifold
Exdirt V
dirt and sludge separator for vertical pipework
TI
PI
FZ
Reflex
diaphragm expansion vessel for single protection* of the heating or cooling generators
PIS
LIS
Fillset
with integrated water meter for monitoring the make-up quantity
System separator according to DIN 1988-100 or DIN EN 1717 (BA), with integrated dirt trap
Fillsoft II
treatment of the make-up water by softening or desalination
Variomat
pressurisation, degasing and make-up in one system
state of the art and customer-friendly control unit
*also serves as control vessel volume for Variomat

Dimensioning of a transfer pipe during master-slave operation

Key data

Prerequisite:
Defined or max. pressure increase in the transfer pipe Δp_{tot} of max. ≤ 0.1 bar*.

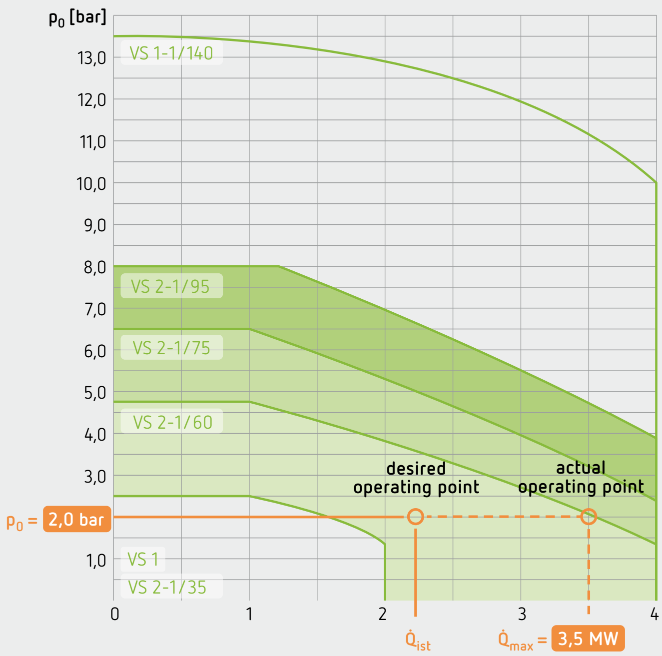
* Target value for the pressure maintenance working range to avoid interval operation during volume displacement



Schematic routing of transfer pipe including expansion pipes

1. Determination of the possible total heating capacity for the pressure maintenance system

Determine based on the system characteristic curve from the diagram below



Guideline

1. Determine desired operating point via total heating capacity* and p_0
2. Determine the actual operating point along the system characteristic curve:

$\dot{Q}_{max}$ = **3.5 MW**

The desired operating point may not correspond to the actual operating point!

*Total heating capacity of the heating/cold water system

2a. Rough dimensioning of the transfer pipe

From Table 1

Transfer and expansion pipe Balancing section	$\dot{Q}_{max}$ Max. possible total heating capacity for heating case [MW]			
25 m (15 elbows)	≤ 2.5	≤ 4.0	≤ 6.0	≤ 10.0
40 m (25 elbows)	≤ 1.8	≤ 3.5	≤ 4.8	≤ 8.5
60 m (40 elbows)	≤ 1.5	≤ 3.0	≤ 4.0	≤ 7.0
Transfer pipe size	DN 25	DN 32	DN 40	DN 50

Transfer pipe length including expansion pipe circuit A / circuit B	l =	40 m	Density of the medium	ρ =	988 kg/m³
Number of elbows	n =	25 pcs	Pressure loss per unit length caused by friction in a DN 32 straight steel pipe	R =	145 Pa/m
Minimum operating pressure	p_0 =	2.0 bar			
Total heating capacity	$\dot{Q}_{act}$ =	2.2 MW			

Calculation example

2b. Accurate dimensioning based on differentiated pressure loss calculation

for mass displacement via a transfer pipe

Calculation / derivation	Example
Total pressure loss for volume flow mass displacement section	
$\Delta p_{tot} = \Delta p_{ExIA} + \Delta p_{ExIB} + \Delta p_{BI}$	= XX + XX + XX = ≤ 0.1 bar
Δp_{ExIA} = Pressure loss in the expansion pipe of pressure maintenance circuit A Δp_{ExIB} = Pressure loss in the expansion pipe of pressure maintenance circuit B Δp_{BI} = Pressure loss in transfer pipe section	
Total of the individual resistance coefficients	
$\Sigma\xi = 5 + n \times 0.5$	= 5 + 25 pcs × 0.5 = 17.5
Derivation of the volume flow from the max. possible heating capacity for determination of the flow velocity w	
$\dot{V} = \dot{Q}_{max} \times 0.68 \frac{l}{kW \times h} \times \frac{h}{3{,}600\ s}$	$= 3{,}500\ kW \times 0.68 \frac{l}{kW \times h} \times \frac{m^3}{1000\ l}$ = 2.38 m³/h
$w = \frac{\dot{V}}{A_P}$	$= \frac{2.38\ m^3/h \times 4}{3{,}600\ s/h \times (0.0359\ m)^2 \times \pi}$ = 0.67 m/s
A_P = Inner pipe cross-section	
Pressure loss caused by individual resistances	
$Z = \Sigma\xi \times \frac{w^2}{2} \times \rho$	$= 17.5 \times \frac{(0.67\ m/s)^2}{2} \times 988\ kg/m^3$ = 3,880 Pa*
Note: Expansion pipes and transfer pipes should be dimensioned together.	* 1 Pa = 1 kg/(m × s²)
Total pressure loss for volume flow mass displacement section	
$\Delta p_{tot} = R \times l + Z$	= 145 Pa/m × 40 m + 3,880 Pa = 9,680 Pa → 0.0968 bar

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