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Hydraulic balance in a district cooling system

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Hydraulic balance in a district cooling system

During the last two decades, the number of established district cooling systems has increased rapidly.

This may be caused by the fact that today`s district cooling systems are:

- More economically attractive
- More environmentally friendly
- More efficient

This means that today, much more than earlier, district cooling can meet the demand for air conditioning systems and other applications where cooling is needed. Important preconditions of a district cooling systems` success are a well functioning distribution net, system type and the right choice of consumer systems. The choice of control equipment for hydraulic balancing of the water flow in the network and consumer systems is very important, as well as the temperature control.

District cooling systems typically operate with considerably lower temperature differences than the traditionally known district heating systems. Typical temperature differences (ΔT) for district heating systems are 40-50°C, whereas the differences in district cooling systems are 6-10°C.

As the capacities in district cooling systems are very often high, it means that the systems will circulate a much larger flow of water than the traditional district heating systems. Therefore, a change of ΔT in a district cooling system will result in a much higher rate of change in circulated water flow in the distribution network for a district cooling system. This, again, will cause an increasing need for a pump effect and a lower efficiency of the systems. Figure 1 shows how the pressure drop in the pipe network increases in relation to the change in typical district cooling systems ΔT, compared to a typical district heating system. This shows that even small changes in district cooling systems` ΔT can cost a lot in pump effect, or, if the pump capacity is insufficient, in energy supply.

In looking for the right system application, it is therefore important to focus on systems with a high ΔT and keep this ΔT as a minimum under all operational conditions.

In this article, recommendations will be given for:

- Choice of the right concept for high ΔT and high efficiency
- Temperature control of the systems
- Hydraulic balancing of the systems
- Choice of balancing valves
- Settings of the control equipment

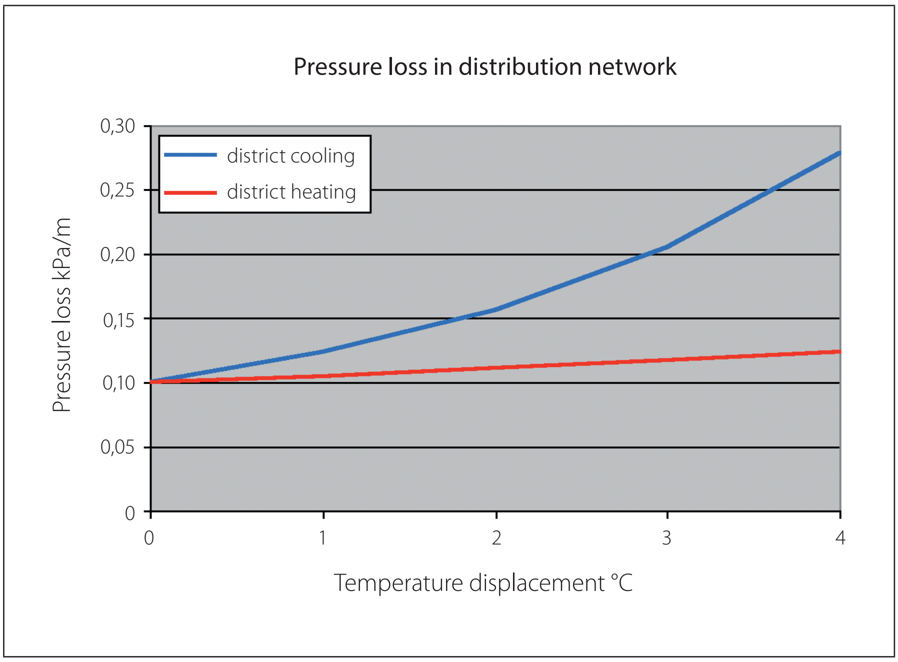

FIGURE 1: Pressure loss kPa/m related to decreasing ΔT

System type

A district cooling system can be split into:

Distribution system:

- Constant flow system
- Variable flow system

Substation type:

- Directly connected systems
- Indirectly connected systems

House systems:

- System with or without mixing loops

Constant flow systems

Distribution system

The main purpose of a district cooling network is to deliver the sufficient capacity needed for the consumer; nothing more. This can be achieved by establishing a hydraulic balance as a well-designed network.

A district cooling system is in hydraulic balance when the water flow to the individual part of the systems has exactly the volume necessary to maintain the required or designed water flow at the current load.

The consequence of a non-existing hydraulic balance in a district cooling system can be a high rate circulation in the system or a lack of supply to the system.

Constant flow systems
In a constant flow system, the circulated water flow is independent of the consumption. To maintain a constant water flow in the network, a diverting valve is used in each substation, diverting the supply water either to the consumer or to the return pipe.

The consequences of choosing a constant flow system are:

- Hydraulic balance in the system
- Low ΔT in the distribution network at low consumption
- High velocity of the water stream in the pipe network (meaning low water temperature at the consumer)
- High return temperature, i.e. high heat transfer from the ambience to the return pipe
- High rate of circulated water in the network = high pumping costs

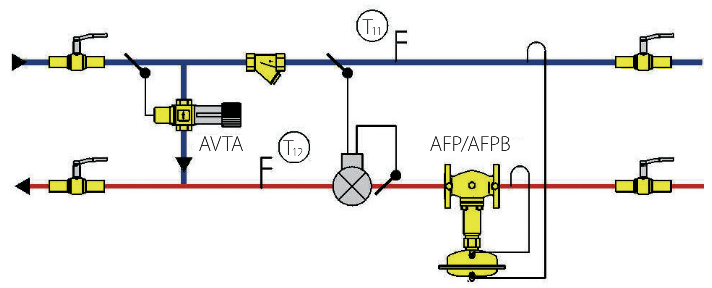

***FIGURE 2:** By-pass in a district cooling system where a normally closed self-acting controller is chosen in a by-pass to keep the right temperature at the inlet of the building.*

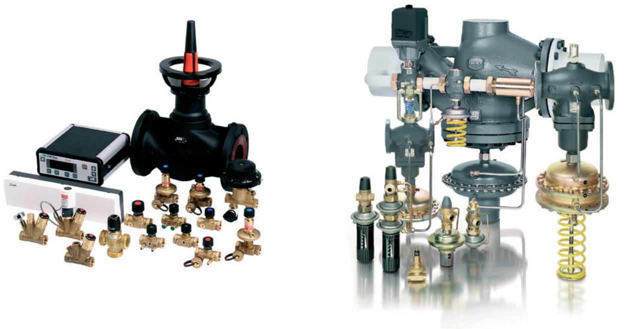

***FIGURE 3:** Balancing valves, flow limiters and flow controllers, which can be used in district cooling systems to maintain a hydraulic balance.*

Variable flow system
In a variable flow system, the circulated water flow depends on the consumption in the system. The control valves in these type of systems are 2-way valves. Here the water flow depends on the consumption at the consumers. The consequence is therefore a lower circulated water flow and a higher return temperature.

Taking into consideration the advantages and disadvantages, one thing is clear – if a hydraulic balance and low supply temperature are established in a variable flow system, then a variable flow system is to be preferred as network type in a district cooling system.

As the velocity of the flow stream in a variable flow system is low at low consumption, there is a risk that the water in the supply pipe will be heated too much from the ambient temperature before it enters the substation.

A solution for solving this problem is to mount a normally closed thermostatic valve of the type AVTA in a bypass line right after the entrance in the building (see figures 2, 8 and 9.

Hydraulic balance

Establishing a hydraulic balance in a system is a matter of adapting the system's water flow to the max. consumption. Equipment for this purpose can be the following:

- Manual balancing valves
- Differential pressure controllers
- Combined differential pressure control and flow limitation
- Combined differential pressure and flow control

Manual balancing valves
Manual valves are mainly used to restrict the water flow in a branch at a given differential pressure. As soon as the water flow in a manual balancing valve decreases, the restricting effect in it will be reduced drastically. These types of valves are therefore useful and mostly applied in systems with small variations in the water flow.

The manual balancing valves with temperature controllers have a few disadvantages – varying capacity in the loop, unstable differential pressure across the temperature control valve and, consequently, unstable temperature control.

The manual balancing valves are very often used in systems with mixing loops to balance the secondary water (see figures 4 and 6).

Differential pressure controllers
The control function of a differential pressure controller is to keep a constant differential pressure in a control loop independent of the water flow in the system. This function reduces the risk of instable temperature control, because the differential pressure across the

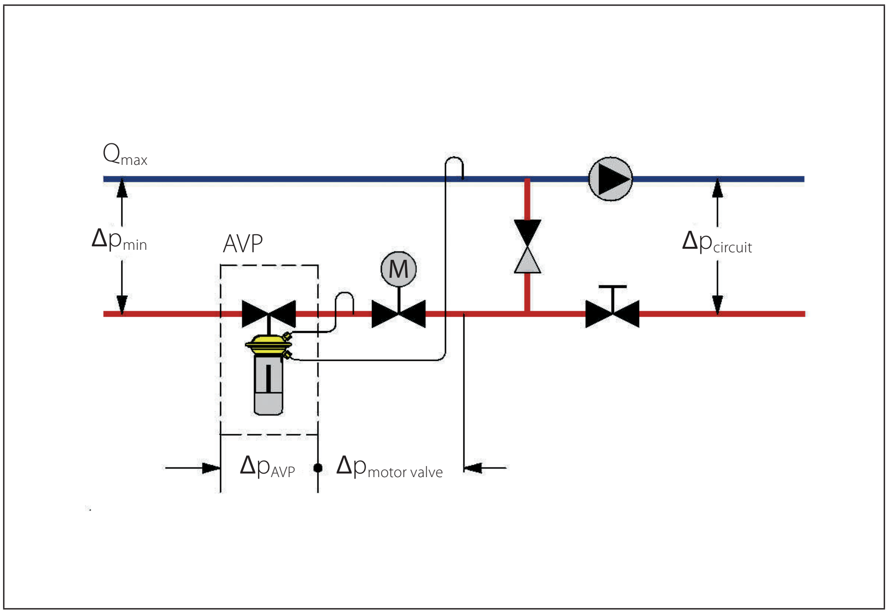

FIGURE 4: Differentail pressure control of a mixing loop in a district cooling system.

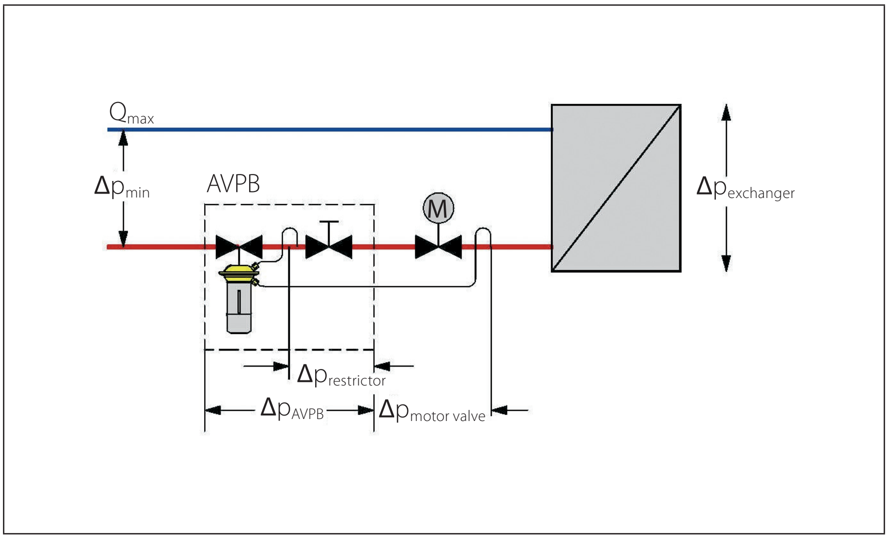

FIGURE 5: Differential pressure control and flow limitation of a heat exchanger system in a district-cooling network.

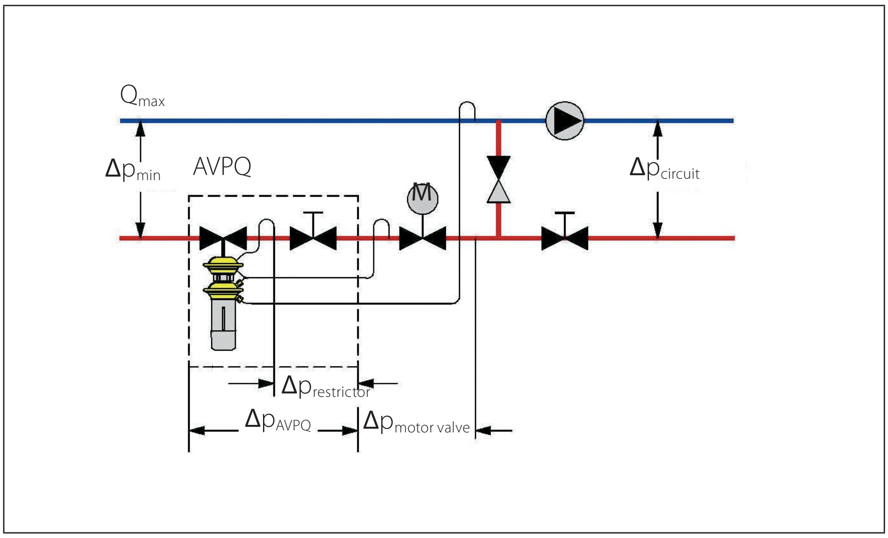

FIGURE 6: Combined differential pressure and flow control of a mixing loop in a district cooling system.

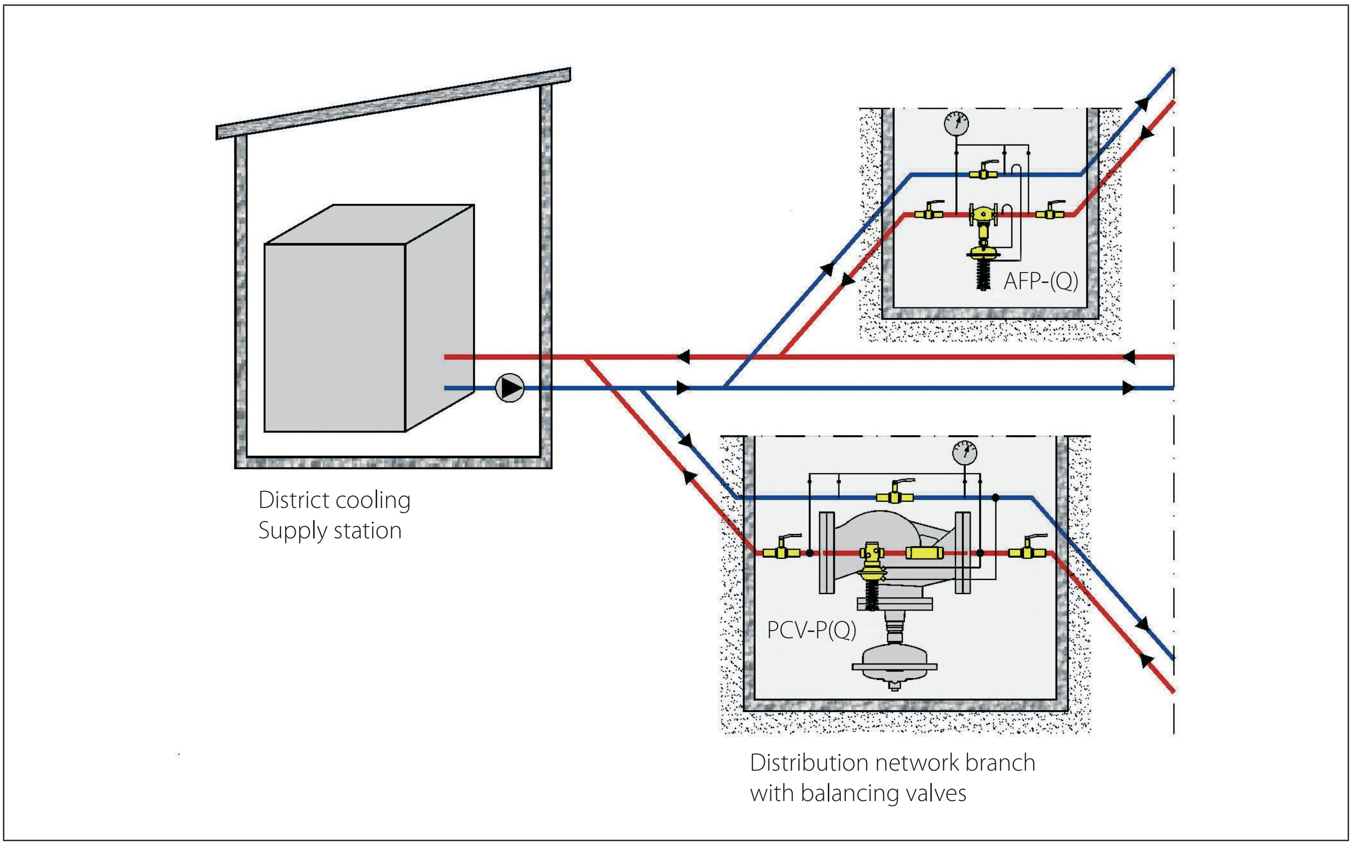

FIGURE 7: Hydraulic balancing valves in a district cooling network.

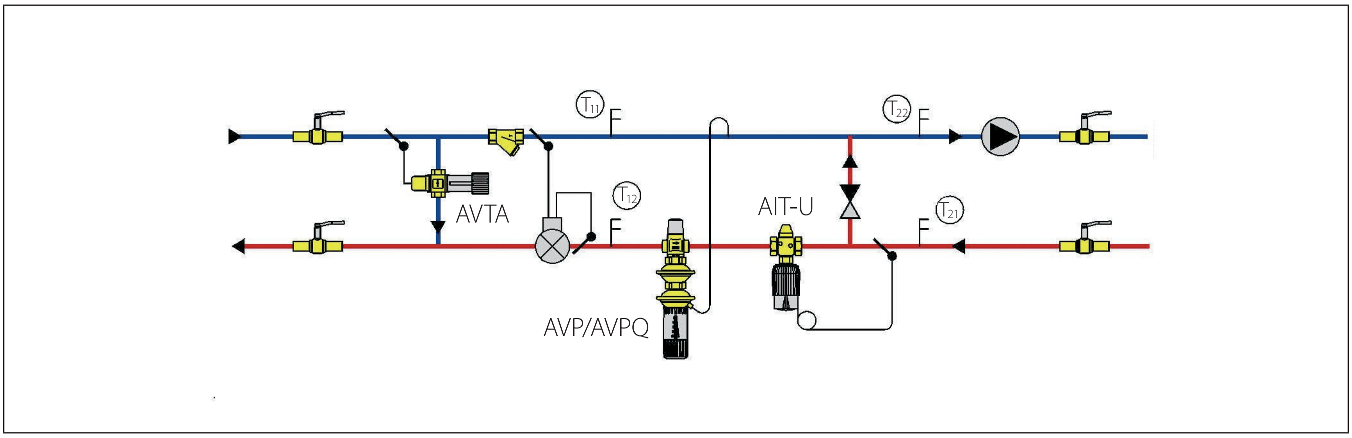

FIGURE 8: Self-acting control of a district cooling substation.

temperature control valve will be more or less constant during all flow variations.

In a mixing loop (as shown in figure 4), the set pressure of the differential pressure controller will be the calculated differential pressure across the motorized control valve ΔP motor valve. If the return water flow is mixed up in the mixing loop at max. load, the ΔP circuit can be restricted with the manually balancing valve.

Combination valves
In systems where the capacity is limited, or where the tariff of district cooling is based on the allocated capacity, a type of flow limitation or flow control in combination with a differential pressure controller might be preferred.

Combined differential pressure control and flow limitation.
A combined differential pressure controller and flow limiter consists of a differential pressure controller with an integrated restrictor on top of the valve. A differential pressure controller with an integrated restrictor controls the differential pressure across a number of units in a loop where the restrictor is in series (see figure 5). The flow limitation (the ΔP restrictor) is then set by means of the restrictor on top of the control valve. As the flow limitation in this controller is based on all restrictions in the loop, this type of flow controller is often used in a loop, in which the differential pressure across all equipment, is known. Typically these systems consist of a heat exchanger and a control valve (see fig. 5). It is only used in systems where the flow limitation is the allocated capacity for the whole loop.

Combined differential pressure and flow control
A combined differential pressure controller and flow controller has two diaphragm elements. The lower element is for the control of the differential pressure in a system loop. The element near to the controller has the function of controlling and limiting the water flow in the system independent of the differential pressure controller function. Like the flow limiter, the controller has a restrictor integrated in the valve. In this way, a differential pressure controller controls a differential pressure in a control loop. The flow control is based on the differential pressure across the restrictor and its setting.

The controlled flow is then set with the restrictor on top of the control valve.

Combination valves of this type can typically be used in systems where the restriction in the total loop is unknown and where the capacity is limited to a level lower than the designed capacity for the whole loop. Typical for this controller are directly connected systems with and without mixing loop (see fig. 6), or systems in which the flow limitation is set for more loops or branches in the total system – i.e. systems in which the total restriction is difficult to determine.

System adjusting

The precondition for a well functioning district cooling system is a balanced water flow. The system can be split up in three groups that are balanced individually. The groups are the following:

- Distribution networks
- House substations
- In-house systems

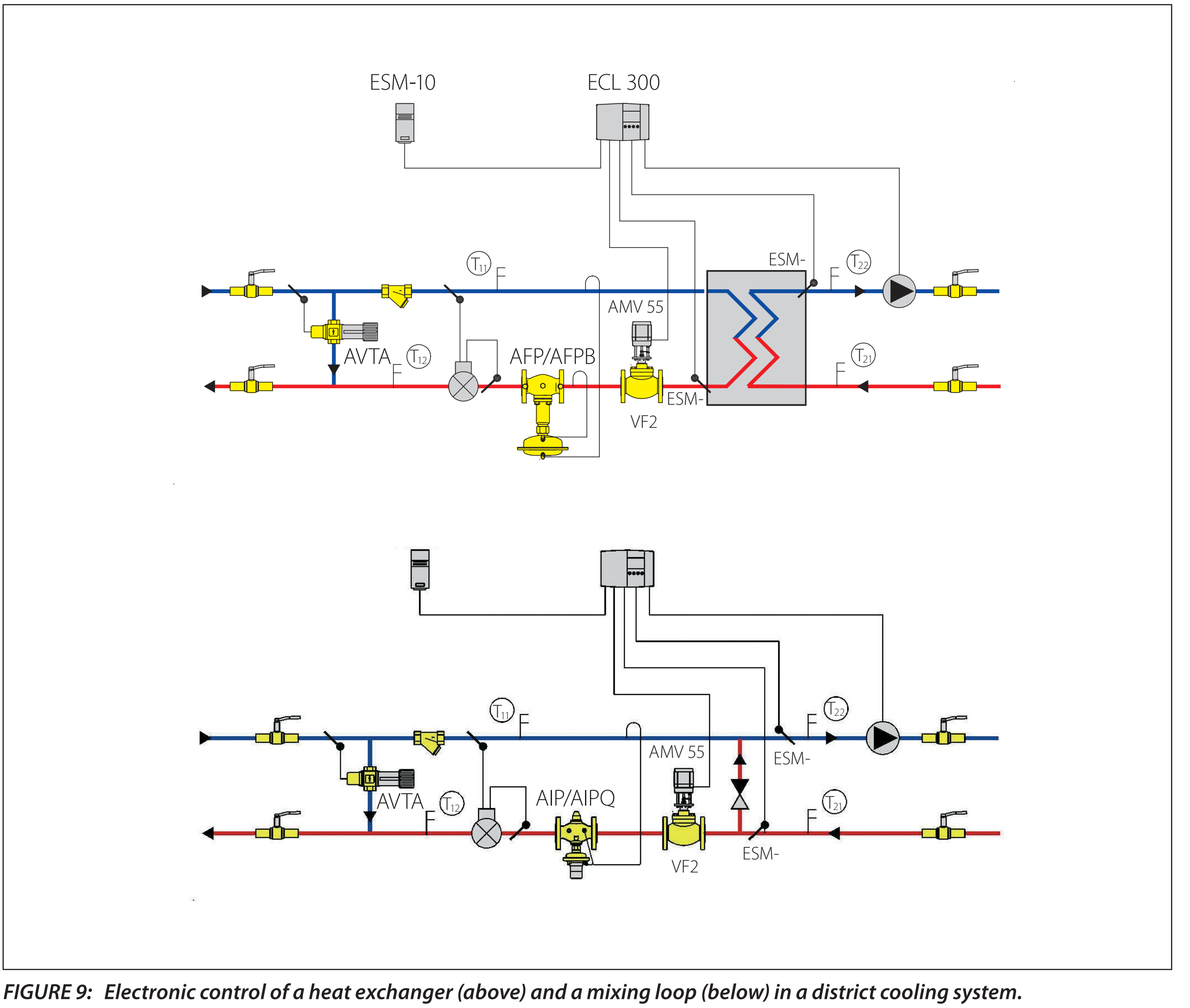

***FIGURE 9:** Electronic control of a heat exchanger (above) and a mixing loop (below) in a district cooling system.*

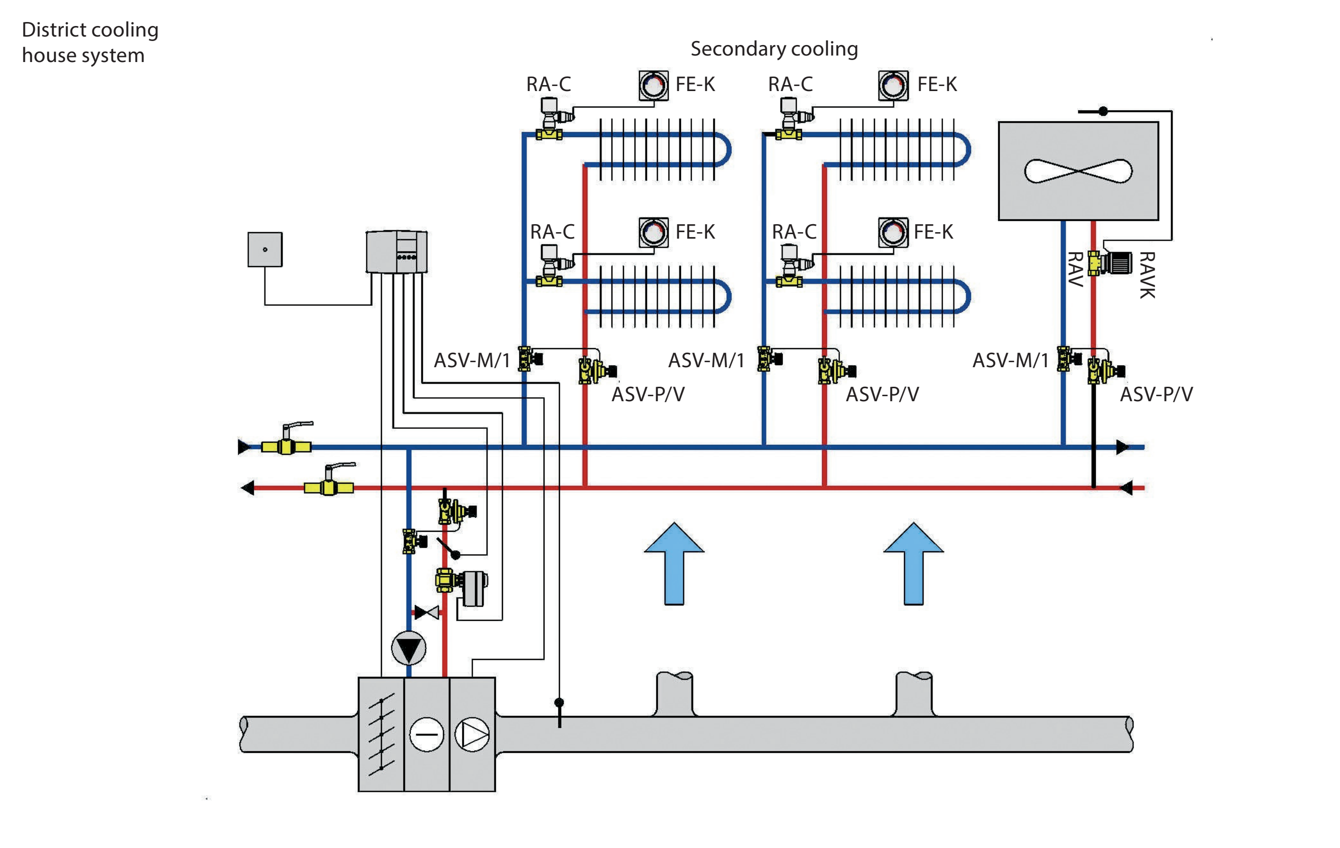

FIGURE 10: A house system with air-conditioning systems.

Distribution networks

In order to make sure that all consumers have sufficient capacity and the necessary water flow in the pipe network, the system has to be carefully balanced.

A good solution to this problem could be the use of a differential pressure or flow controller (see figure 7).

The flow controller will be a good solution in case of smaller systems, where the delivered capacities in the individual branches are known. Differential pressure controllers and the limitation of the flow in the system can be set according to the calculated pressure loss in the pipe network.

In branches with high water flow, pilot controlled valves can be used as balancing valves. In pilot controlled valves, small differential pressure controllers or flow controllers are used as control valve for the main diaphragm valve.

The advantages of pilot controlled valves are – first of all – the price level of the valve, as well as its wide rangeability. This means that a stable controlled pressure can be expected even with very small water flows.

House substations

House substations can be directly connected or connected with a heat exchanger between the primary and secondary net.

The directly connected system can be completed with and without a mixing loop. In a mixing loop, the supply temperature to the individual systems in the house can be controlled.

The advantage of directly connected systems is the high efficiency (a high differential temperature ΔT) in the system – there is no temperature loss in the heat exchanger.

When using heat exchangers in the system, a lower system pressure can be established in the secondary net, which is an advantage, too. Furthermore, these two systems can run different types of media because they are hydraulically separated.

Control of smaller systems

Temperature control
Smaller systems with mixing loops very often have self-acting thermostatic valves for temperature control of the set return temperature in the house system. The sensor of the thermostatic valve is placed in the return to control the return temperature, and will make sure that a high return temperature is achieved. If the return temperature is not maintained, the thermostatic valve will start to close and the return water will then be bypassed into the supply water and increase the supply temperature to the house systems.

Differential pressure or flow control
If a capacity control is preferred, a combined differential pressure and flow controller will be the right solution (see figure 8). The differential pressure controller has to be set in such a way that no flow will run in the bypass when the designed or the set return temperature is achieved. This can easily be checked on a thermometer in the supply line. If T11 and T show the same temperature, then no flow will run in the bypass line.

Control of bigger systems

Because of the demand for more control functions in bigger systems, electronic temperature controllers are often selected. In that case, a weather compensator with an integrated return temperature limitation function will be the preferred option.

The supply temperature can then be controlled according to the outdoor temperature. This will increase the level of comfort. However, a high return temperature is of high priority. Therefore, the controller has to have a return temperature limitation function to keep the water temperature on a sufficient level. The return temperature limitation can be weather compensated so that a higher return temperature can be accepted at high load of the system.

Differential pressure or flow control
The criteria of selecting flow control/ limitation or just differential

pressure control are the same as in small systems. However, if the system has a heat exchanger and capacity control is demanded, a combined differential pressure controller and flow limiter can be used (see figure 9).

In a system with a mixing loop, the differential pressure controller has to be set in such a way that no water mixes up in the secondary supply line at max. capacity.

The procedure for the setting is the following:

- Set the differential pressure on the differential pressure controller, or set the flow limiter according to max. water flow in the line.
- Adjust the water flow in the secondary main line so that no flow will run in the mixing loop (T11 = T22).

This water flow can be adjusted with a manual balancing valve or with an adjustable circulation pump.

House systems

Together with the temperature controllers, a hydraulic balancing of the house system will ensure a high rate of ΔT in the system. For this purpose, self-acting balancing valves are preferred – apart from their balancing function, they also have an impact on the temperature control. Thus, a stable and precise temperature control can be achieved in the air conditioning systems. The choice of balancing valves depends of the type of systems.

In central systems, like air conditioning and air handling systems where a motorized control valve controls the supply temperature, a traditional differential pressure controller can be used (see figure 10).

The differential pressure controller is set in the same way as the electronically controlled substations. This means that there is a max. flow at fully open motorized control valve and no flow in the bypass line under this condition. In decentred air handling units such as induction units, the choice of balancing valve type depends on the control valves for the units.

If the control valves have a pre-setting function, a traditional differential pressure control function can be chosen. If not, a differential pressure controller in combination with a flow limitation function is a better solution.

Conclusion

As stated in this article, a high system ΔT is a very important factor in obtaining a high system efficiency. Another positive impact of a high ΔT is that sufficient capacity can be delivered to the consumers.

Maintaining a hydraulic balance all over the system including the secondary net is of high importance. Here, self-acting controllers play an important role because of the constant differential pressure under all conditions. This also improves the temperature control.

A correct choice of application, including control equipment, also has a big influence on the temperature conditions in the system and improves the comfort as well.

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