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Elimination of Differential Pressure Regulating Valves

Simplified Hydraulic Balance

The number of control components in many heating systems could be reduced to save energy. Based on an example, the following article explains the disadvantages of systems operated with differential pressure regulating valves and circulation pumps and outlines the advantages of a control with ejectors.

Today differential pressure regulating valves are no longer required for hydraulic balance. It is sufficient to set the design volumetric current rate on the valve of the heating section. The part load behaviour is ensured exactly by a heat output control. This facilitates hydraulic balance and improves the total efficiency of the system as compared to the frequently used differential pressure regulating valves.

A heating system can be divided into three main sections:

- energy generation,
- energy distribution,
- energy consumers.

Heat exchanger stations, boiler units, heat pumps, solar thermal energy, CHP plants, etc. are used to generate and provide energy. Here a large variety is currently available on the market.

Energy distribution includes the pipelines, the circulating pumps and the valves for balancing the heating sections. With regard to energy distribution the range offered is not as large.

The number of different consumer systems is constantly increasing. These range from static heating surfaces with radiators to component activation, underfloor heating, radiant ceiling panels, ventilation systems, etc. and offer various possibilities for space heating and cooling. Until the 1970s, some of the heating systems were gravity systems. The distribution system of the gravity heating system shown in *figure 1* consists only of the piping and shut-off valves.

Today, various additional valves, e.g. control valves, throttling valves and valves for circulating the heating water such as check valves and differential

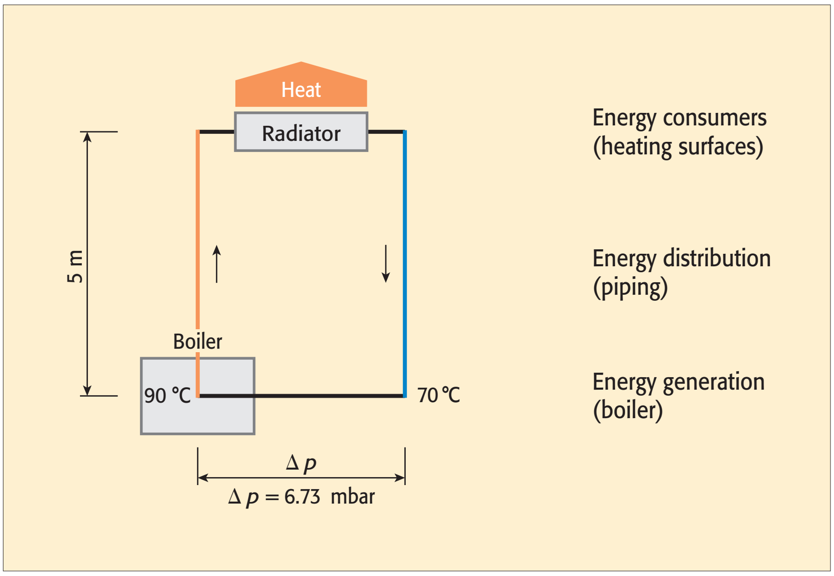

Figure 1. Gravity heating system

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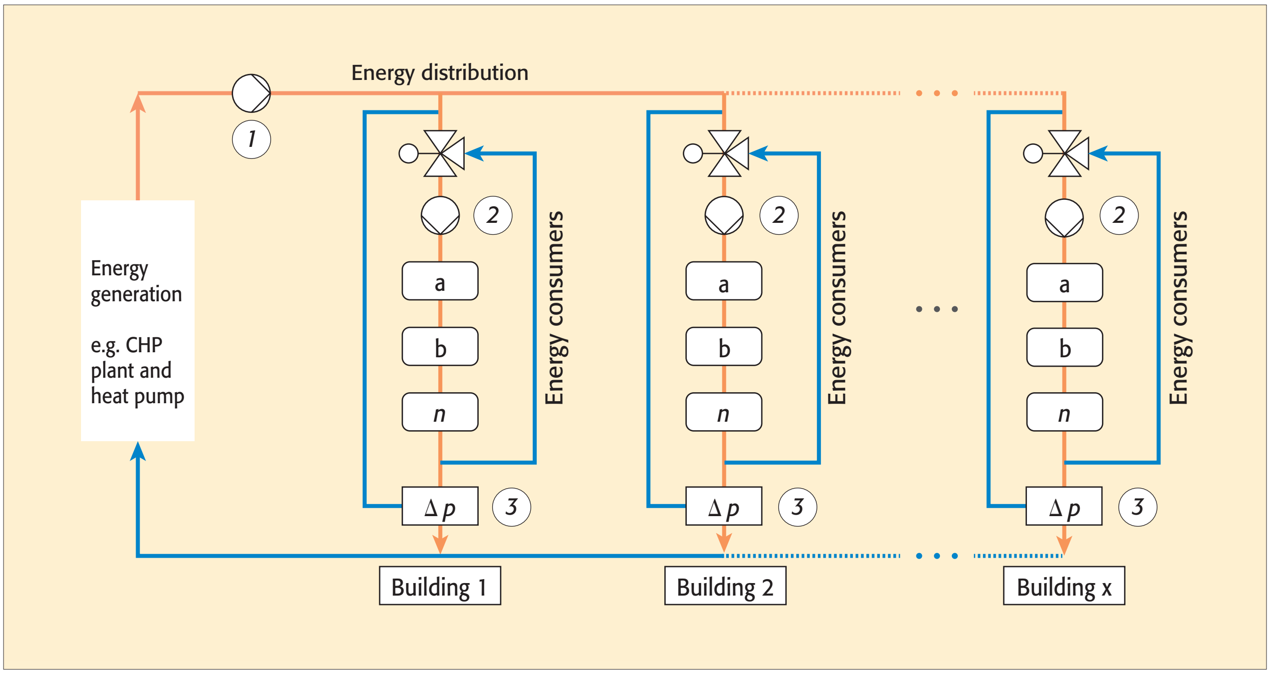

Figure 2. Complete system with inefficient design

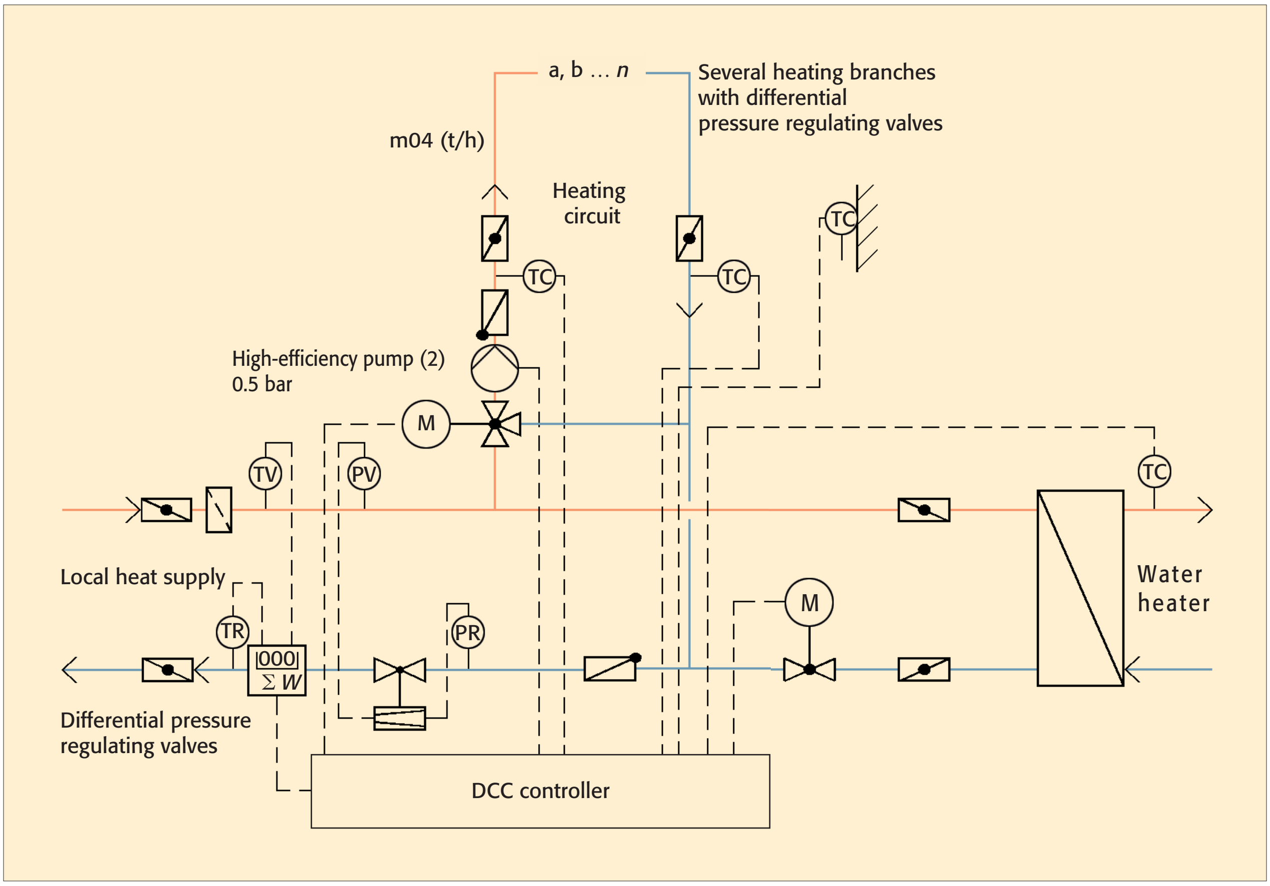

Figure 3. Building heating system installation with inefficient design

pressure regulating valves are installed in distribution systems to control the temperature of the heating circuit. All these involve installation and operating costs. In addition to this fact, operation is frequently difficult due to additional control functions. An installation engineering using ejectors, however, permits considerable savings with regard to valves and electrical energy.

The more thoroughly an investment is planned, the greater the sustainability of the respective measure can become. The possibilities to influence the costs of a measure are best at its start. To a great extent, cost-effective decisions are already made when defining the project and during the first design phase. This is the stage at which the interrelation outlined below should already be included in the considerations. The following example describes the possibility to save energy and to reduce the number of valves required.

Several buildings with a two-pipe heating system and hot water generation are connected to a local heating network. The heat demand of the examined building amounts to approx. 250 kW at a temperature difference of 20 K. Local heating networks were frequently designed as shown in *figure 2* (illustration without hot water generation).

Waste of energy due to differential pressure regulating valves and circulation pumps

A speed-controlled main pump (1) generates the differential pressure required for the entire distribution system in accordance with the design volumetric current. In the house substations of the individual buildings, further electric speed-controlled high-efficiency pumps (2) are used to control the supply temperature by mixing the supply water with the return water. This series connection of the main pump and the circulation pumps in the buildings as well as the parallel connection of the building heating system installations are often balanced using differential pressure regulating valves (3) in the house connection stations. This compensates for the mutual influence of the circulation pumps and ensures a constant differential pressure for the control quality of the control valves (*figure 3*).

Conclusion 1:
The series or parallel connection of circulation pumps may require the use of differential pressure regulating valves or hydraulic separators to decouple the circulation pumps. Differential pressure regulating valves destroy pressure energy and energy is generated again by the circulation pumps in the buildings. This is a waste of energy.

Differential pressure regulating valves compensate for lower pressure drop under part load operation

The sizing of the circulation pump (2) in the heating circuit is based on the maximum volumetric current calculated in accordance with the heating load. Based on the pipe network calculation, the delivery head of the circulation pump should be set so that the maximum pressure difference at the thermostatic valves of the heating surfaces in the branches a, b to *n* is 0.1 bar. In addition to this pressure loss, there is the pressure loss of the pipelines in the branches (0.3 bar), the valves in the branches (0.05 bar) and of the control valve for mixing the supply water with the return water (0.15 bar). The delivery head calculated for the examined building is 0.6 bar. *Figure 4* shows the pipe network and the pump characteristics.

Under part load operation it is essential to consider the lower pressure drop of the pipelines and the valves. If the volumetric current in a heating system under part load operation is e.g. 50%, due to thermostatic valves which close as a result of solar radiation or internal heat sources, the pressure drop is reduced to 25% of the design case as shown in *figure 4*. The pressure drop in the static section of the pipe network required for the part load water volume is approx. 0.15 bar. When using a speed-controlled high-efficiency pump with a set constant differential pressure regulation, a pressure of 0.6 bar is generated at each operating point. The excess differential pressure with regard to the pipe network characteristic is 0.45 bar. With the proportionally controlled pump, the excess differential pressure is still approx. 0.3 bar. This excessive differential pressure must be reduced to prevent flow noises at the thermostatic valves. In this inefficient but common system design, this is ensured by the installation of additional differential pressure regulating valves.

Conclusion 2:
The lower pressure drop in the pipe network of a heating system under part load operation is the reason for the use of millions of differential pressure regulating valves or in other words: differential pressure regulating valves compensate for the deviation of the delivery head of the speed-controlled high-efficiency pump from the pipe network characteristic. Differential pressure regulating valves thus destroy the pressure energy generated by a high-efficiency pump under part load operation.

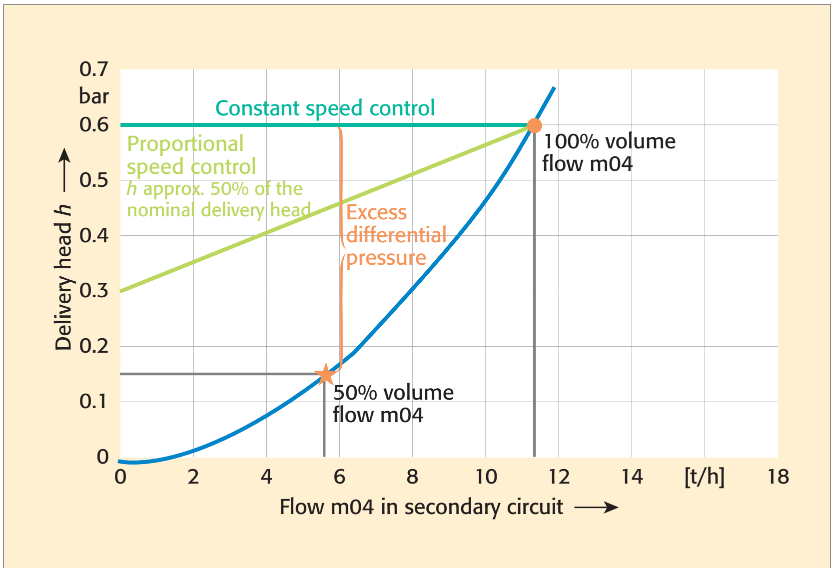

Figure 4. Pipe network characteristic (blue) and pump characteristics (green)

No interrelationship between supply temperature and flow control

With this system design, there is no interrelation between the temperature control via the mixing control valve and the speed control of the high-efficiency pump. The supply temperature of the heating is influenced by the outdoor

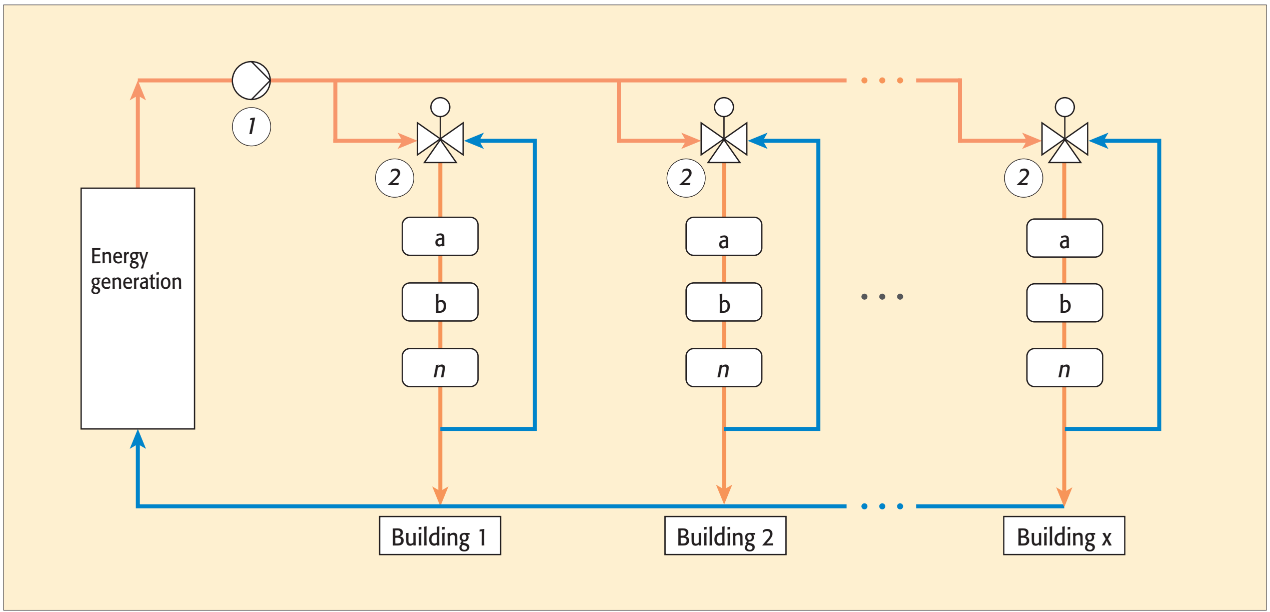

Figure 5. Control with ejectors

temperature. If the supply temperature rises as the supply water is mixed with return water, which, as a result of the lower energy output caused by high outdoor temperatures, has not sufficiently cooled down, the proportion of supply water from the primary section is reduced by adjusting the stroke of the control valve. Although less heat is required, the total water volume circulated will not change simultaneously. The circulation pump is controlled by the internal speed control and will only react if the differential pressure of the system changes. The temperature control is independent from the volume control of the circulation pump. This raises the question what should be ensured by the heating circuit. Is it about controlling the supply temperature or controlling the heat to be transferred into the heating circuit to obtain a desired room temperature? The following applies:

Q [kW] = V [m^3/h] · c_w [1.16] · dT [°C]

With the conventional technology which uses circulation pumps and a mixing control valve, the circulation volume V [m^3/h] and the supply temperature dT [°C] are each installed as individual control loops. In practice this is demonstrated by a heating system with night setback. The heat capacity is to be reduced at night. The supply temperature is lowered. The thermostatic valves on the radiators open as the set room temperature is no longer reached. The main pump increases the speed and delivers 100% water volume. This problem is known to some extent and is partly solved by the implementation of additional control functions. Either some type of single-room control is installed via controlled actuators on the thermostatic valves and the pump speed is reduced via the increasing differential pressure in the network, or the pump is controlled by an additional signal.

Conclusion 3:
Additional control technology compensates for the missing interrelationship between supply temperature and flow control.

Efficient system design

A heating system should be designed with the objective of combining a simple system design, similar to a gravity heating system as shown in *figure 1*, with today's requirements with regard to temperature and pipe network in line with a sustainable technology. The results regarding the inefficient design in Conclusions 1, 2 and 3 provide a basis for reflection and are intended to bring about changes in this technology in order to design an efficient overall system.

System without differential pressure regulating valves

In this example, the use of a single main pump (1) is sufficient and the control valves in the heating circuits are replaced with controllable ejectors (2) – control valves with injector effect (*figure 5*). The system design is changed from a »multiple pump« system to a »single pump« system. *Figure 5* shows the system design of an efficient overall system.

To conclusion 1:
With this system design, no differential pressure regulating valves are required to decouple the circulation pumps.

Control with ejectors

The system design of a control system with ejectors is shown in *figure 6*. The ejector control uses the network differential pressure H to circulate the heating water across the radiators. This control type also compensates for differential pressure fluctuations in the local heating network. The water volume on the secondary side corresponds to the demand of the heat consumers under any load condition. Therefore there is no excess water volume and thus no excess differential pressure. Differential pressure regulating valves are consequently not required. The ejector control permits circulation of a water volume in accordance with the pipe network characteristic shown in *figure 7*.

To conclusion 2:

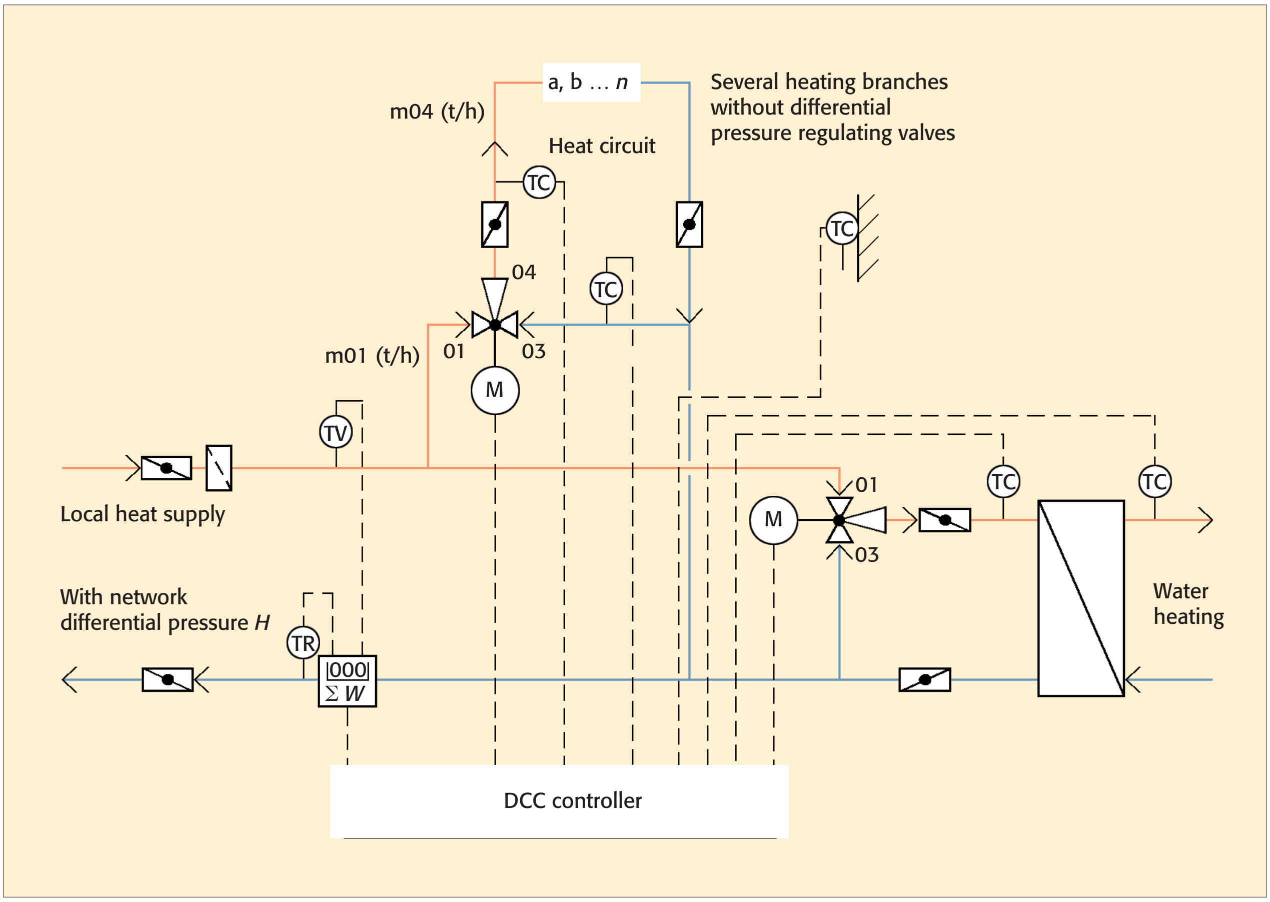

Figure 6. Building heating system installation with sustainable design

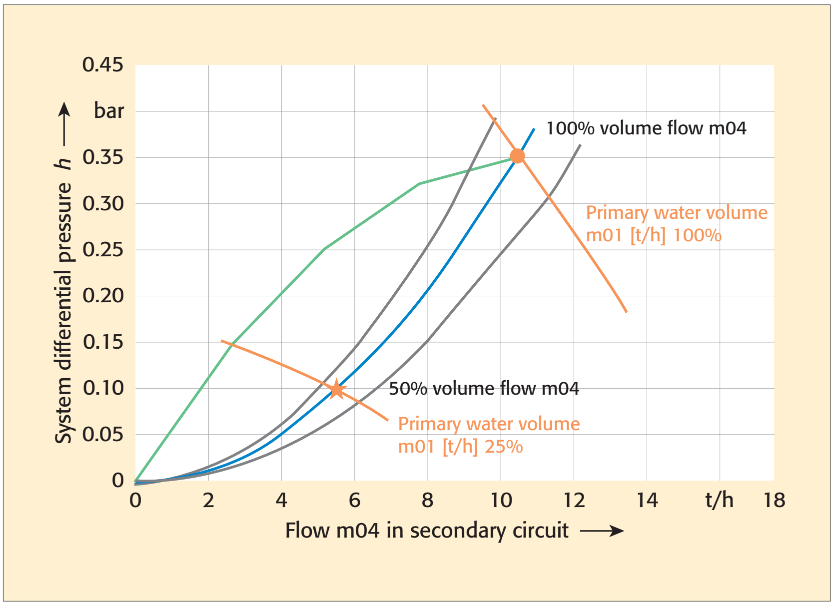

Figure 7. Pipe network characteristic curve when using a controllable ejector

Control with an ejector compensates for the lower pressure drop in the pipe network of a heating system under part load operation.

Heat capacity control

The pipe network characteristic changes depending on the deactivated branches or a reduced heat capacity of radiators by partly closed thermostatic valves. The two black curves each correspond to a ±25% change in pressure drop (*figure 7*). The orange curves represent the primary water volume m01 per load case. This proportion of the total water volume m04 supplies the pressure energy from the network differential pressure *H* for circulating the water volume via the consumer with the pressure loss *h*. Analogous to an electric circulation pump, the primary water volume can be regarded as the speed. The more the total water volume m04 is reduced, the less primary water m01 (corresponds to a reduction of the speed of a circulation pump) is used. The green line shows the operating limit of the calculated ejector.

The ejector as a control valve has several functions (*figure 8*). Temperature and water volume are varied depending on the load. Each adjustment of the valve stroke of the ejector influences the temperature dT [°C] and the circulation volume V [m^3/h]. This means that the supplied heat output

$$Q\,[\mathrm{kW}] = V\,[\mathrm{m^3/h}] \cdot c_w\,[1.16] \cdot \mathrm{d}T\,[°\mathrm{C}]$$

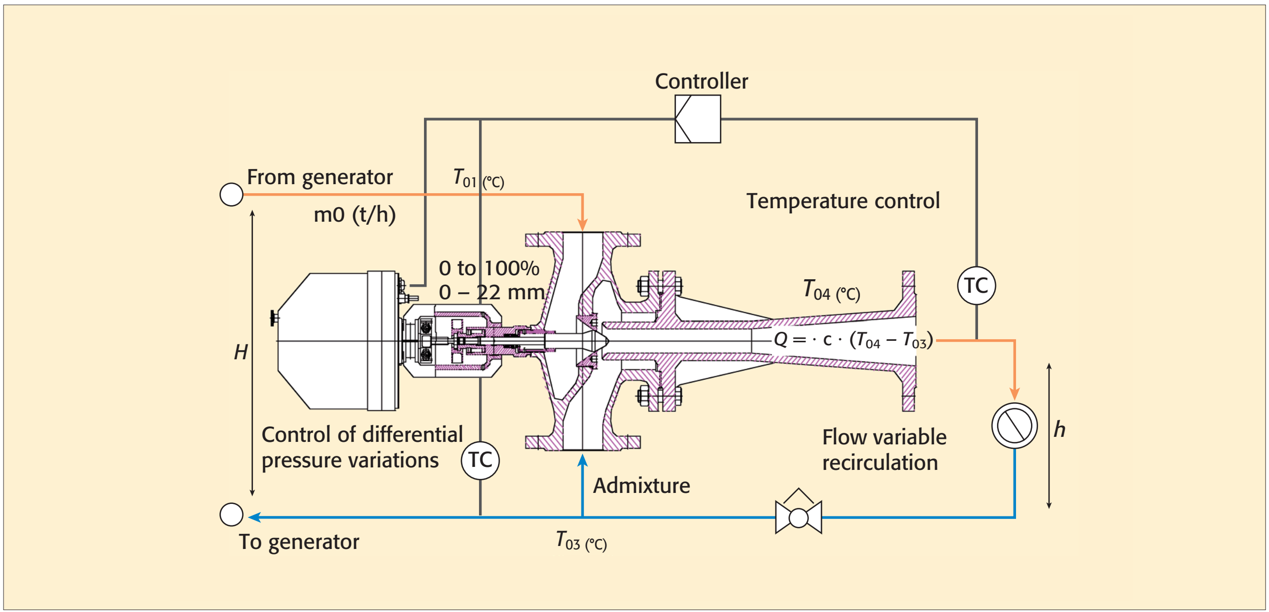

Figure 8. Functional diagram of the ejector system

can be controlled with a single valve of the control loop.

In the event of a night setback, for example, the lower supply temperature is achieved by restricting the primary water volume m01. The mixing ratio of primary water m01 and return water changes continuously. The proportion of the return water volume increases from e.g. 10% in the design case up to 200% during part load operation. The reduction of the total water volume m04 across the heating surfaces ensures appropriate cooling of the return water. Ejector systems are known for their low return temperatures.

To conclusion 3:
Control with an ejector is a heat capacity control.

Savings

Energy savings can be accurately determined by a simple comparison of the pumps calculated for each variant. The reduction of the electrical energy requirements during the operating time when using ejector technology ensures CO_2 emissions savings (see also www.baelz.de/en/company/baelz-brands/baelz-hydrodynamicr/).

In Berlin, this ejector technology has been in operation for many years in approx. 300 residential buildings. On the example of the renovation of a hospital, [1] compares the economic efficiency of the building technology with circulation pumps before the renovation and ejectors after the renovation.

Hydraulic balancing of a system with ejectors is simplified by the elimination of differential pressure regulating valves and circulation pumps. A mutual influence of these control components can no longer occur. The required flow measurement and regulating valves are set to the design point and the water volume for part load operation is ensured by the ejector control. The system design is similar to that of a gravity heating system due to the elimination of circulation pumps and differential pressure regulating valves. Compared to the complex technology shown in *figure 2* and *figure 3*, sustainability has much improved.

Summary

Thorough consideration of different variants at the right time results in:

- a less complex valve technology (investment),
- the reduction of electrical energy requirements (operating costs),
- simplified hydraulic balancing (commissioning costs),
- elimination of flow noise (user satisfaction),
- cooling of the return flow (use of regenerative energy) and
- an improvement of the sustainability (Green Building).

References

[1] Kilpper, R.; Bälz, U.: Heizungssanierung mit regelbaren Strahlpumpen (Renovation of heating systems with controllable ejectors). In: Moderne Gebäudetechnik (2010) 7-8. (Modern building technology (2010) 7-8).

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