Use of ejectors: Efficiency advantages for the control of heat exchangers

Translated from German
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The use of heat exchangers is a standard feature in industry and building automation and control. Depending on the application, we recommend different kinds of control circuit to regulate performance. A little-known alternative involves admixture control via a water ejector. With this method, the heat distribution is hydrodynamic and not electrodynamic as normal. Allow us to present the system.

In frequently used mass flow control circuits – referred to as throttle circuits in trade jargon – the temperature at the inlet of the heat exchanger is always equal to the primary flow temperature of the heating network (figure 1). The circuit is very simple, but has considerable disadvantages when larger temperature differences between the primary and secondary flow are involved. The greater this temperature difference in the respective application, the greater are the disadvantages of this circuit (see table 1). Thus if large capacities, but also very small part loads are to be regulated, an additional smaller control valve is required for good control performance (dotted line in figure 1).

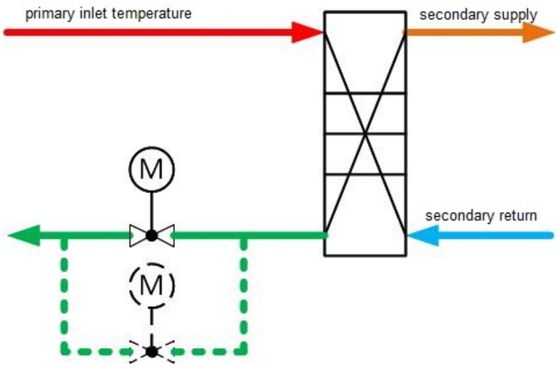


Figure 1 *Mass flow control*

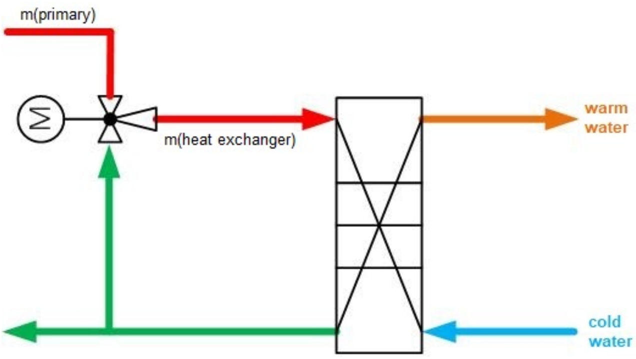


Figure 2 *Admixture control with Jetomat ejector*

As the efficiency and control performance of heat exchangers is also limited at very low flow velocities under partial load, a different solution is advisable for such applications. The water ejectors (Jetomat) from Baelz offer a convenient and efficient solution.

Comparison of volume and admixture control

Property	Volume control	Admixture control
Power range	Any	Any
Partial load performance	Additional control valve for large total capacities and requirements for partial load	No extra expense → Control 0 – 100% stable
Pressure fluctuations in the primary network	Additional differential pressure controller necessary	No extra expense → Control compensates pressure fluctuations
Flow at small load	Mass flow decreases linearly with the capacity, laminar flow possible → No mixing of fluids in the heat exchanger, control tends to oscillate	Admixture guarantees high mass flow with turbulent flow → Consistently homogeneous mixing of fluids
Accumulation of mud	Low mass flow provokes the risk of heavy deposits.	Consistently high mass flow → Only few deposits possible.
Calcification on the secondary side during the heating of drinking water	Inlet temperature high on primary side. Therefore calcification possible.	Variable adjustment of the inlet temperature possible → Substantial reduction of calcification.
Thermal material stress in the heat exchanger	Inlet temperature high on primary side. Thermal stresses unavoidable.	Variable adjustment of the inlet temperature possible → Only low thermal stresses, service life significantly extended.

Table 1 *Comparison*

The water ejector, sometimes also called Jetomat, jet pump or three-way injector valve, provides energy-saving, cost-effective heat distribution by hydrodynamic heat distribution instead of electrodynamic. It circulates the water in the distribution circuit, adapts the circulation flow to the consumer (static heating, ventilation register, heat exchanger, etc.) to the heat demand, controls the temperature and compensates for differential pressure fluctuations. The basic idea of the ejector technology is the utilization of existing differential pressures in water distribution systems. Water ejectors are used to control the supply temperature constantly or according to the outside temperature. In addition, the volume of water to the consumer (static heating, ventilation register, heat exchanger, etc.) is adapted to the heat demand. The differential pressure to overcome the system resistances is built up from the network differential pressure at the inlet of the ejector. The controlled ejector combines a control valve and a pump in one unit. Water ejectors are used to change the supply temperature and the flow quantity, i.e. the heat output is controlled.

Baelz have been manufacturing and using controlled ejectors in building heating stations, ventilation registers, heating distributors and in industry as well as for water heating in building automation and control for around 50 years. The ejector works as a control valve and pump at the same time. It is part of the control circuit. It circulates the water in the distribution circuit, adjusts the circulation volume to the heat requirement, controls temperature and equalizes differential pressure fluctuations. It is thus an elementary part of the control loop.

Advantages of admixture

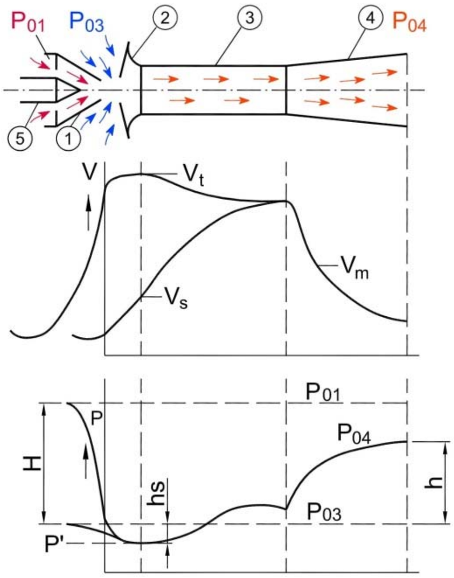
Admixture control improves the quality of the system over mass flow control in all load cases. Owing to increased system complexity resulting from the additional mixing circuit pump required, the option of an admixture circuit is often dismissed for reasons of cost. The use of a controlled water ejector (Jetomat), however, makes admixture possible without extra expense (figure 2 and figure 3). The primary circuit inlet temperature into the heat exchanger can thus be optimally adapted to the boundary conditions of the application.

Figure 3 *Preassembled district heating station with ejector*

Functional principle of the ejector

The figure shows a schematic diagram of a controllable ejector. The jet flow with static pressure P01 is accelerated in the convergent jet nozzle ① and attains its highest velocity V_t upon entering the mixing tube ③, i.e. at the end of the throat ②. The jet flow draws the intake flow along due to the mechanism of turbulent shear stresses resulting from the high velocity. The intake flow with static pressure P03 is accelerated in the throat ② and attains the velocity Vs upon entering the mixing tube ③. Both flows merge in the mixing tube where an exchange of momentum, kinetic energy and thermal energy takes place. The mixed flow has a velocity V_m at the end of the mixing tube ③, which is less than V_t and greater than Vs. The velocity of the mixture decreases to a usable value in the diffusor ④.

The pressures in the jet nozzle ① and in the throat ② decrease in a way which corresponds approximately to that predicted by the Bernoulli equation and attain the lowest value upon entry into the mixing tube ③, the joint pressure P'. The pressure rises in the mixing tube ③ owing to the exchange of momentum mentioned above and in the extension it continues to rise with decreasing velocity.



1. Jet nozzle
2. Throat
3. Mixing tube
4. Diffusor
5. Plug

V, V_t, V_s, V_m - Velocities (drive, intake, mixing flow)
P - Pressure
H - Differential pressure at the inlet of the ejector = P01 - P03
h - Differential pressure at the outlet of the ejector = P04 - P03
P01 - Pressure in the primary network
P03 - System return pressure
P04 - System flow pressure
P' - Pressure behind the nozzle
hs - Differential pressure between P03 and P'

<u>**Example 1**</u> (see table 2)
Fresh water station with low power requirement (e.g. circulation mode)

Heat supply network data:

- Primary flow temperature: up to 130°C in winter and at least 75°C in summer
- Examination of transitional periods at 101°C primary network temperature
- Differential pressure in the network 0.4 bar to 3.0 bar

Secondary circuit: Heating drinking water from 10°C to 60°C

Comparison of mass flow control and admixture control

Initial situation: 55°C circulation temperature in the drinking water system, i.e. approx. 56°C in the return in the primary circuit, no consumption of warm water, thus purely circulation load, this is approx. 3...5% of the total capacity of the water heating system.

Capacity balance: Q [kW] = m [kg/h] • c [J/kg • K] • ΔT [K]

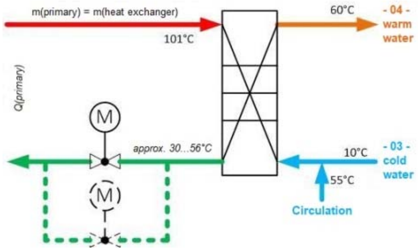
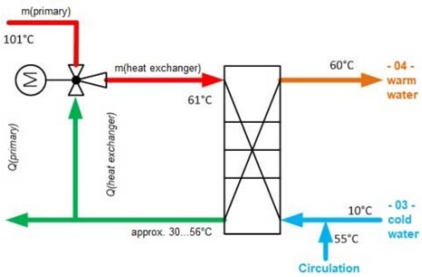
	Volume control	**Admixture control**
Example with temperatures		
Inlet temperature in primary circuit	101°C	101°C
Inlet temperature at heat exchanger	101°C	61°C
Outlet temperature in primary circuit	56°C	56°C
Mass flow in primary circuit [kg/h]	m (primary)	m (primary)
Mass flow through the heat exchanger [kg/h]	m (heat exchanger = m(primary)	m (heat exchanger) = 9 • m (primary)

***Table 2** Volume comparison of water heating in partial load operation*

Q (primary) = m (primary) • specific heat capacity c • (supply temperature - return temperature)

Mass flow control:

Q (primary) = m (primary) • c - (101°C - 56°C)

Admixture control:

Q (heat exchanger) = m (heat exchanger) • c • (61°C - 56°C)

Equation: Q (primary) = Q (heat exchanger)

m (primary) • c • (101°C - 56°C) = m (heat exchanger) • c • (61°C -56°C)

m (primary) • 45°C = m (heat exchanger) • 5°C

m (heat exchanger) = m (primary) • 45/5

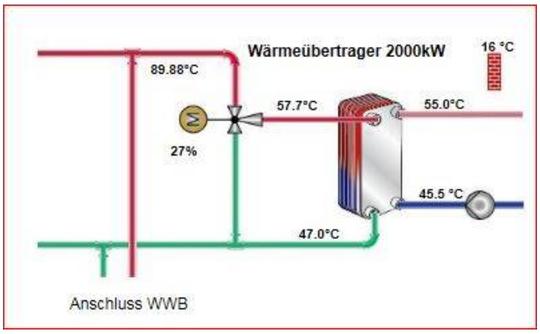
m (heat exchanger) = m (primary) • 9 (see table 2)

Calculation of the mass flow ratio

In this example, the admixing control for domestic hot water achieves 9 times the amount of water at partial load compared to mass flow control. At other temperatures and other load cases, the ratio of the quantity changes, but the advantage of admixing control always is: the smaller the load reduction, the larger the quantity of water through the heat exchanger compared to mass flow control. The resulting advantages are already summarized in table 1 above.

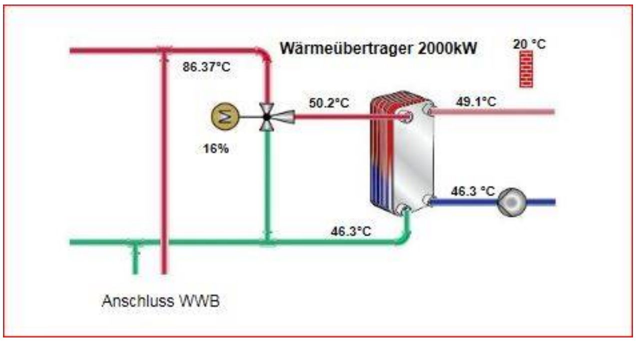
Example 2:
2,000 kW district heating transfer station with 2 different load cases

A) Partial load control at an outside temperature of 16°C



m (primary) • (89.88°C - 47°C) =
m (heat exchanger) • (57.7°C - 47°C)
m (primary) • 42.88°C = m (heat exchanger) • 10.7°C
m (primary) • 42.88/10.7 = m (heat exchanger)
m (primary) • 4 = m (heat exchanger)

B) Partial load control at an outside temperature of 20°C



m (primary) • (86.37°C - 46.3°C) =
m (heat exchanger) • (50.2°C - 46.3°C)
m (primary) • 40.07°C = m (heat exchanger) • 3.9°C m (primary) • 40.07/3.9 = m (heat exchanger)
m (primary) • 10.27 = m (heat exchanger)

In load case A) at an outside temperature of 16°C, 4 times the water flow of a system using mass flow control is circulated by the admixture at 27% stroke of the positioning device (ejector). In load case B) at 20°C outside temperature, 10 times the water flow is moved by the admixture through the heat exchanger.

A constant minimum differential pressure in the supply network is a precondition for admixture using an ejector. Realistic values start at 30...40 kPa. High differential pressures of e.g. 600 kPa (6 bar) are also possible. The components are designed according to the lowest expected differential pressure. Differential pressure fluctuations are stabilized by admixture control with an ejector.

Depending on the dynamics of the process to be controlled, electrical actuators with an actuation speed of 6 to 130 mm/min are used. Digital controllers with connections for up to maximum 4 temperature sensors can be installed in the actuators (230 V or 24 V). The control loop is supplied preconfigured and is ready for immediate operation.

Conclusion

In hundreds of systems, the admixture control has proven its worth for the perfect control of a heat exchanger. There are quite a number of municipal energy suppliers in Germany that prefer this technology, and also company groups in the automotive and pharmaceutical industries have recognized the sustainability of the control with ejectors.

Author

Dipl.-Ing. Marc Gebauer

In demand

IKZ PLANNING EXPERT: What do you need to pay attention to when planning an ejector-based admixture control?

Marc Gebauer: The admixture control is based on the return admixture. A primary network to which differential pressure is applied is necessary for admixture without the use of an additional circulating pump. This differential pressure should be at least twice as high as the hydraulic resistance of the consumer, so that a valve authority greater than 50% is ensured. If used to control heat exchangers, the pressure drop of the heat exchanger can be determined based on the network differential pressure. If used for heating circuit distribution, the main pump is adapted to the pressure drop in the heating circuit, whereby it is not necessarily the worst heating circuit that has to be considered, as mixing systems with ejectors and circulating pump plus control valve are also possible. The focus is on the economic efficiency of the overall system.

IKZ PLANNING EXPERT: A particular characteristic of modern high-efficiency pumps is their low electricity consumption. How does the ejector system compare energy-wise?

Marc Gebauer: This comparison depends on the application. In local heating systems with functionally induced differential pressure, 100% of the electrical energy is saved by the use of ejectors as opposed to circulating pumps. If the networks are separated by heat exchangers or supply is via a hydraulic separator, an electric main pump is necessary. This one main pump supplies the ejectors and has a better overall efficiency than many small wet rotor pumps in the individual control loops.

IKZ PLANNING EXPERT: Let's move from theory to practice: Do you also provide the ejectors as preassembled modules – in other words as complete admixture circuits? **Marc Gebauer:** We offer 90% preassembled modules, individual ejectors can also be supplied to experienced regular customers whose technical expertise we can rely on.

Dipl.-Ing. Marc Gebauer, Regional Manager Sales East, W. Baelz & Sohn GmbH & Co.

IKZ PLANNING EXPERT: Can the preassembled modules be retrofitted into existing systems, or do they typically require special control technology for control of the ejector?

Marc Gebauer: Ejectors are used as part of renewal measures. An existing controller can be used, but to utilize the full capability of the ejectors we recommend using a controller from the manufacturer of the ejectors and connecting this controller to a databus with a superordinate control.

IKZ PLANNING EXPERT: To what extent do you as a manufacturer support building services planners in the layout and configuration of the systems? **Marc Gebauer:** We are pleased to completely design the systems – district heating stations, heating distributors, fresh water stations – and we also give a warranty for the function of the ejector control loops upon receipt of an order. In this way, we hope to break down psychological barriers against trying something "new".