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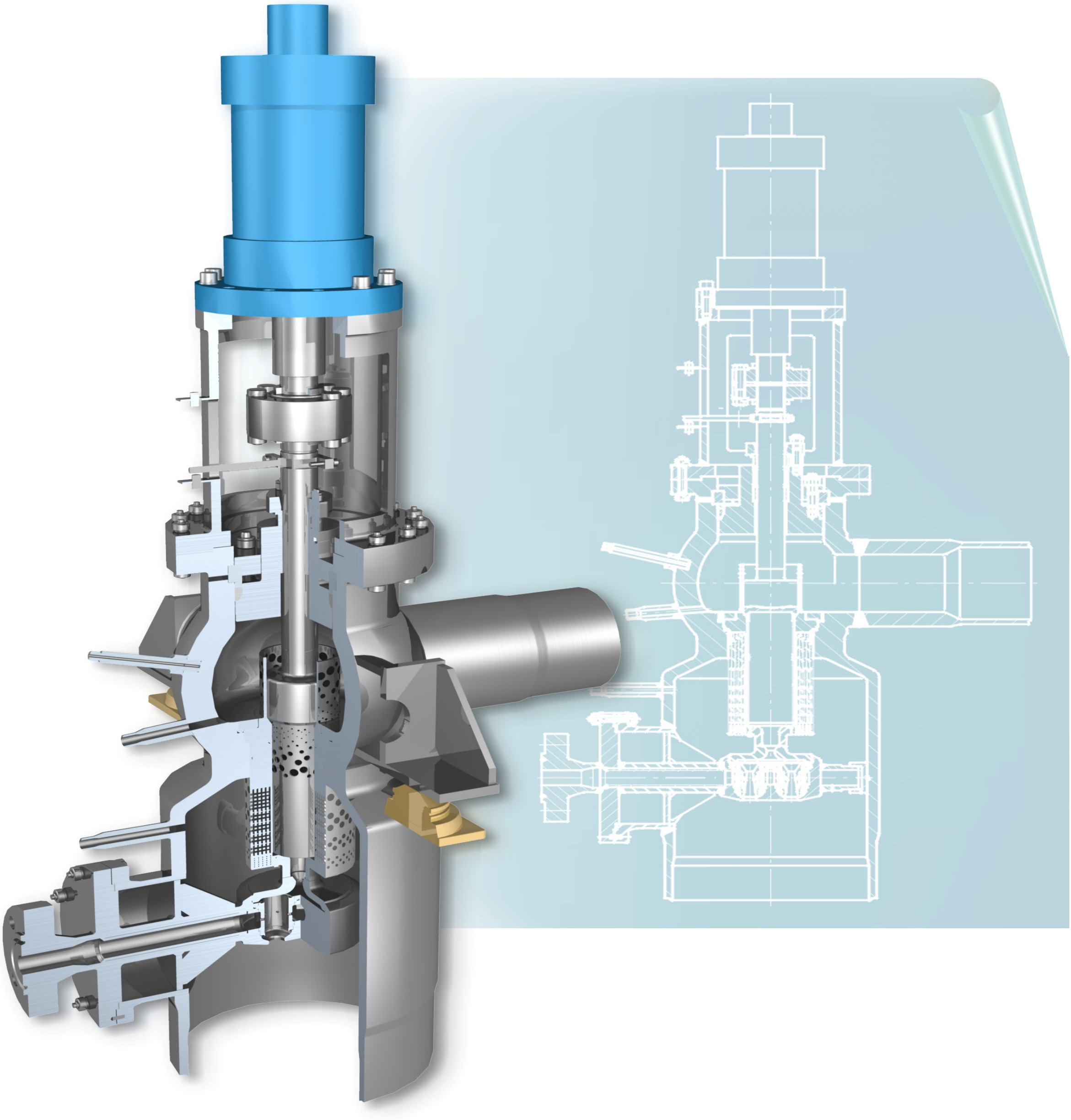

Bypass valves in thermal power stations

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Field of application for bypass valves

In thermal power stations, the whole process of generating energy revolves around the turbine. At the turbine, the kinetic energy of the incoming gas/steam medium is first converted into rotational energy and subsequently, in the generator, into electrical power. Effectively protecting these complex components from mechanical damage is a key concern of power station operators - from both technical and economic perspectives. For this reason, a bypass valve is installed at every turbine stage.

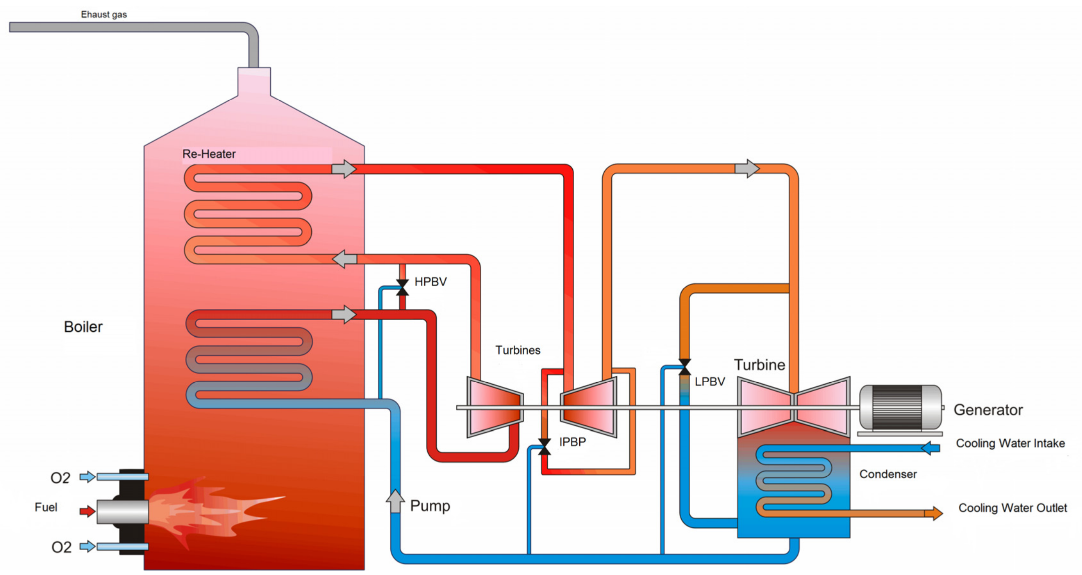


Figure 1: The use of bypass valves in thermal power stations

Basic principles

If the turbine has to shed load - be it due to fluctuation in current take-off or to a technical failure - the bypass valve diverts the medium to an alternative system and thus protects the main system. Depending on the turbine stage in the high, medium and low-pressure region, and according to the parameters of the down-stream system, the bypass valve may have to reduce pressure and temperature. During start-up and shutdown, the bypass valve also protects the turbine by evening out irregularities such as fluctuations in the system´s temperature and/or pressure. Moreover, the gas circulation can be maintained at the desired setting, and the boiler does not have to be tripped, thus saving time and fuel.

The basic construction of steam circuits is in principle similar in all types of thermal power stations, be they powered by fossil-fuel (coal, gas, oil), nuclear, combined cycle, biomass or even solar. However, the design of the bypass valve is contingent on the system`s specific operating conditions and in particular on the precise characteristics of the pipe system, necessitating a made-to-measure solution (to meet the individual requirements of each system). Thus in practice, differences in the safety concepts of different countries and operating companies result in a multitude of design variations. This is reflected, for example, in the stipulated direction of flow, the type of actuating drive, and the method of de-superheating.

Requirements for Power Station Operations

Irrespective of the system‘s exact specifications, experience shows that bypass valves must fulfil the following basic requirements[1]:

- rapid transfer of the steam medium (< 1 sec.)
- safe and rapid desuperheating of steam
- excellent control accuracy
- reliable functionality
- durability
- low noise emissions
- maintenance-friendly design for reduced down-time

The following chapter presents means of meeting these technical requirements, and describes which particularly problematic areas require solutions. Emphasis is placed on decompression and noise management, as well as on comparing the various options for de-superheating. The article concludes, in the final chapter, with a look ahead to new developments in the field of turbine bypass valves for high-temperature (> 620□) operating conditions.

Technical Properties

A common factor among all bypass valves is that they separate the various pressure systems in a power station. Thus, for example, the high-pressure bypass valve is a connector between a high-pressure system and a medium-pressure system, and is hence built in parallel with the high-pressure turbine stage.

In principle, the transition between two adjacent pressure systems via a bypass valve represents the coupling of two systems with widely divergent pressure and temperature differentials. This coupling has to take place in a closely controlled manner, because otherwise the pressure difference results in high velocities and this in turn causes unacceptable noise as well as damage to the valve‘s internals. In addition, aspects of the safety concept are implemented via the coupling, with the aim of protecting the pipe system from undue pressure.

[1] Logar, Depold, Gobrecht (2002).

Safety Concepts

The valve acting as a transition between two pressure systems should be designed to automatically shift itself to a safe position in the event of a failure, such as a power failure. In this way the valve should relieve or lock the system requiring protection. This so-called fail-safe position is achieved using the force of the through-flowing medium alone.

Safety concepts vary from plant to plant and from country to country. In steam conditioning stations the medium usually flows via the control cone, thus exerting pressure on the cone in the direction of closure. This feature can be used in a safety concept to protect the adjacent system from pressure accumulation, and in this case, the valve is closed in the fail-safe position. For high-pressure bypass valves, which constitutes a particular type of steam conditioning station, the safety concept often requires that the fail-safe position be open, and that this be achieved both by the medium flowing under the cone and additionally by a spring-operated opening mechanism. In this case, the steam flows under the cone.
Some safety codes may alternatively (or in addition) require, as a back up, the maintenance in an accumulator of a secure provision of the actuating medium (air or oil) in the commensurate pressure range.

Pressure Reduction and Noise Management

In by-pass valves, pressure reduction and steam decompression are achieved using pressure stages. Since this process has a direct bearing on noise emissions, both topics are interrelated and should be considered together. Moreover, both topics are closely related to the concept of flow velocity, v.

Principles of pressure reduction

In by-pass valves, pressure reduction and steam decompression are achieved using pressure stages. Since this process has a direct impact on noise emissions, both topics are interrelated and should be considered together. Moreover, both topics are closely related to the concept of flow velocity, v.

Considering two steam-containing systems characterised by pressures p1 and p2 and by temperatures T1 and T2, whereby p1>>p2, and assuming the two systems are connected, then the steam medium, in search of thermodynamic equilibrium, will flow from the system with greater pressure p1 to the system with lower pressure p2.

Both the mass flow and the speed of the flowing steam depend on the density of the medium - as a function of pressure and temperature - and on the smallest cross-sectional area A of the connector. Figure 2 depicts such a system.

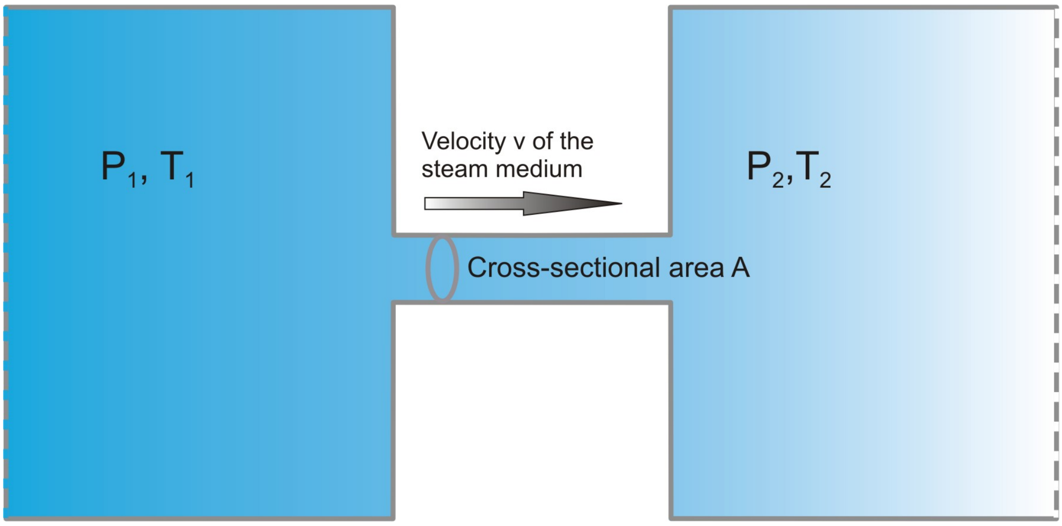


Figure 2: Pressure equalisation between two connected systems

The medium flows through the connector from system 1 to system 2 at speed v. In compliance with the law of conservation of mass, the continuity equation states that:

$$\rho_1 \cdot v_1 \cdot A_1 = \rho_2 \cdot v_2 \cdot A_2 = \dot{m} \left[\frac{Kg}{s}\right] \quad \text{whereby} \quad \rho_{1/2} = f(P_{1/2}, T_{1/2})$$

Figure 3 gives a schematic representation of the relationship between velocity and flow stream for incompressible media. A constant flow stream moving from a larger cross-sectional area (A1) adapts to a smaller cross-sectional area (A2) by increasing its velocity.

However, liquid and gas media behave differently in this respect, despite the continuity equation above being valid for both types of media. The following takes a closer look at the behaviour specifically of steam, taken as an approximation for an ideal gas. Depending on the pressure differential between two systems, the pressure decrease may be sub-critical ($p2/p1 > 0{,}546$), critical ($p2/p1 = 0{,}546$) or super-critical ($p2/p1 < 0{,}546$).

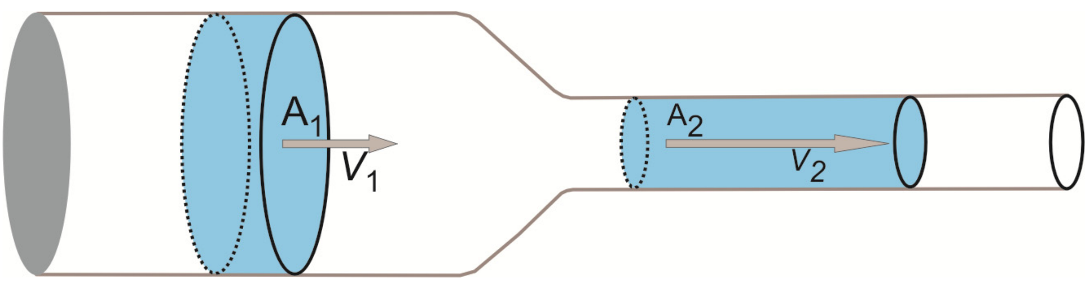


Figure 3: Velocity and flow stream

A pressurised container with, for example, p1 = 10 bar, has an aperture with diameter d. Through this aperture the medium flows to the surrounding area of lower pressure (with, for example, p2 = 1 bar), whereby the rate of flow is determined by diameter d. Even though the pressure drop is super-critical, the decompression at the narrowest cross section can be critical at most. This means that for steam, pressure can be reduced at most, in a single step, by the pressure reduction factor of 0,546.

In our example, a so-called free jet is generated, since the medium exits the container into normal atmospheric pressure (1 bar). The flow velocity at the narrowest point thereby approaches the speed of sound. The medium is only able to completely expand behind this point, and it follows an aerodynamic path with recurrent zones of compression, corresponding to Figure 4.

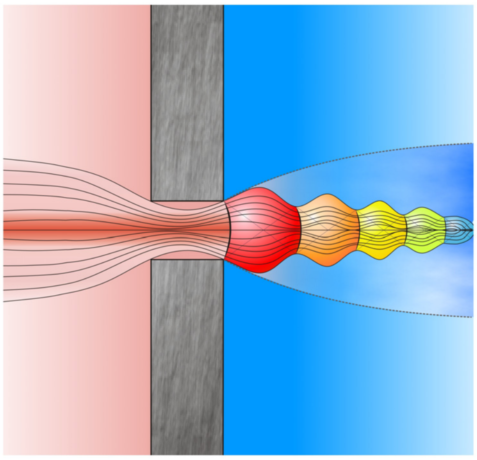


Figure 4: Schematic diagram of a free jet

Super-critical decompression causes noise emissions, vibrations and abrasive wear. For this reason, super-critical stages should be avoided during the process of decompression. This can be achieved by using so-called pressure stages, each with their individual expansion chamber characterised by intermediate pressure. Moreover, the medium should be subjected to a change of direction to partially dissipate its kinetic energy and thus reduce its speed.

Sub-critical reduction of a system‘s pressure from 10 bar to 1 bar can be achieved using four pressure stages, as depicted in Figure 5.

A practical example to illustrate pressure reduction:

A bypass valve functions as a connector between a high-pressure system with the parameters p1 = 125 bar, T1 = 560°C and an intermediate pressure system with p2 = 32 bar and T2 = 340-400 °C.

To achieve a sub-critical decompression a minimum of four pressure stages would be necessary. The technical implementation of a pressure stage may consist, for example, of a perforated disc or bush which forces the steam to change direction of flow. Expansion chambers are connected between each pressure stage to allow for the necessary decompression.

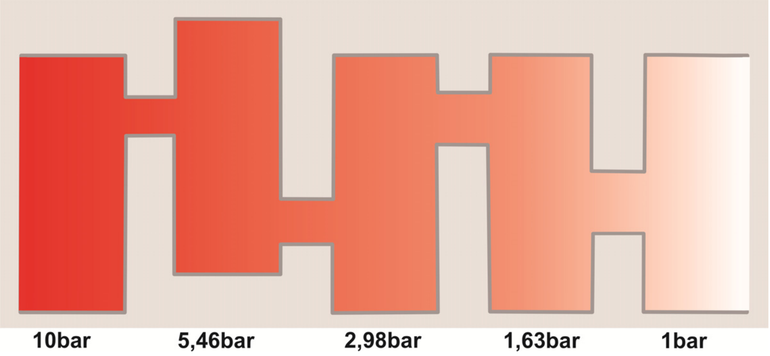


Figure 5: Pressure reduction by four stages

Careful calibration among the unobstructed areas of the various pressure stages is essential for achieving the desired decompression. This means that precisely the correct unobstructed area must be manipulated to correspond to the expansion eventuating upon the decompression of the medium. In the above example, we would use six rather than four pressure reduction stages, thus raising the decompression factor from 0.63 to 0.79. This has a significant effect on the noise emissions of the bypass valve, as the higher factor makes for a particularly quiet valve. The reason for this is that the higher the ratio of the pressures between the two pressure stages Pn+1/Pn, the lower the flow speed from one stage to the next.

Table 1 gives the parameters of the described decompression process, whereby values are provided for the unobstructed area, temperature, heat content and mass flow at the *n*th stage. Flow stream and heat content are conserved quantities, hence this flow restriction is termed an isenthalpic process. In accordance with the laws of thermodynamics, the temperature of the steam decreases with decreasing pressure while the specific volume increases.

Reducing Stage	**Free Space**	**Pressure Reduction**	**Temperature$_{Stage}$**	**Enthalpy**	**Mass Flow**
n	**A [cm$^{2]}$**	**p_{Stage} [bar(a)]**	**T [°C]**	**HD [kJ/kg]**	**ṁ [t/h]**
	83	125,0	560,0	3502	280
1	105	125x0,79 = 98,8	549,7	3502	280
2	132	98,8x0,79 = 78,0	541,2	3502	280
3	167	78,0x0,79 = 61,6	534,3	3502	280
4	212	61,6x0,79 = 48,7	528,6	3502	280
5	291	48,7x0,79 = 38,5	524,1	3502	280
6	273	38,5x0,79 = 32,0	521,1	3502	280

Table 1: Pressure reduction by six stages

Technically, pressure reduction is often implemented via a series of perforated discs or cylinders. The perforated face thus constitutes the narrowest cross-sectional area, which, in multi-stage decompression, increases from stage to stage. The respective increases in cross-sectional area are carefully matched with each other to effect the desired pressure reduction.

Through-flow or pressure can thus be controlled by increasing or decreasing the cross-sectional area, for example by means of a spindle stroke. The exact configuration of the bored holes plays a key role in ensuring precise controllability. The bored holes‘ diameter is kept to a minimum to avoid the formation of free jets.

There are basically two main types of pressure reduction:

Full multi-stage controllability together with pressure reduction across the complete stroke range

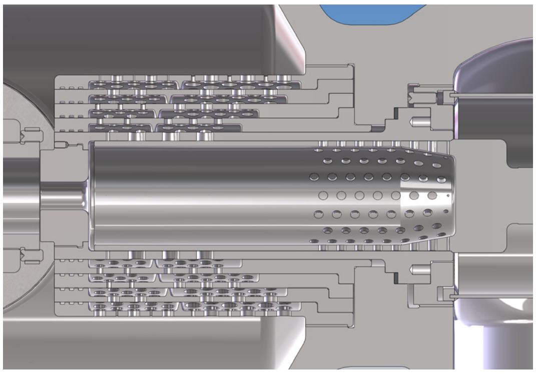
In the first case, a combination of perforated cylinders are aligned such that depending on the degree to which the unobstructed cross-sectional area of the first stage has been opened - which in turn depends on the stroke setting - all subsequent cross-sectional areas of the other stages are opened. This allows for sub-critical decompression across the full load range and across all stages (Fig. 6).

Multi-stage pressure reduction with single-stage controllability

In the second case, through-put is controlled by the spindle itself as the first pressure stage. All other pressure stages are, as perforated cylinders or discs, always completely open and firmly affixed. They are not adjustable upon opening the unobstructed cross-sectional area at the first stage (the stroke) (Fig. 7).

In consequence, when the spindle is fully opened the faces are optimally aligned, but under medium load conditions the cross-sectional area is only reduced at the first stage, hence the majority of the decompression takes place at this first stage.

This can lead to higher medium velocity and thus to greater noise emissions.For this reason, the Type 1 valve is preferable in systems frequently operated at intermediate load. However, Type 2 valves offers a considerable cost advantage. A cost-benefit analysis may help to determine which type of valve best meets the requirements of the system based on load conditions.



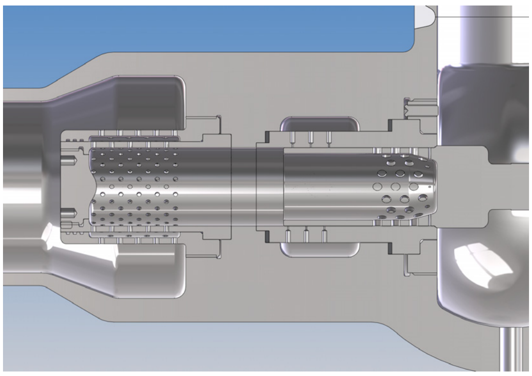


Figure 6 (left): Controlled decompression system composed of perforated spindle, seat bushing with perforated cylinder and four further perforated cylinders. Visible in the perforated cylinders are the individual chambers which limit the decompression of the medium to the appropriate partial load range (important for partial strokes).

Figure 7 (right): Multi-stage decompression system (single-stage controllable) composed of perforated spindle, seat bushing and 2 perforated cylinders. No chambers for partial loads are required in the perforated cylinders.

Desuperheating

When bypassing the turbine it may be necessary not only to decompress but also to cool the superheated steam, in order to meet the requirements downstream of the turbine. To clarify this procedure, power plant operations are displayed in Fig. 8 as a temperature-entropy diagram. As a consequence of the mechanical work transferred from the steam to the turbine, both the temperature and the pressure of the steam medium are reduced, according to the laws of thermodynamics. In the temperature-entropy diagram, this is displayed as the decompression in the turbine with the concomitant performance of mechanical work (3->4 and 5->6).

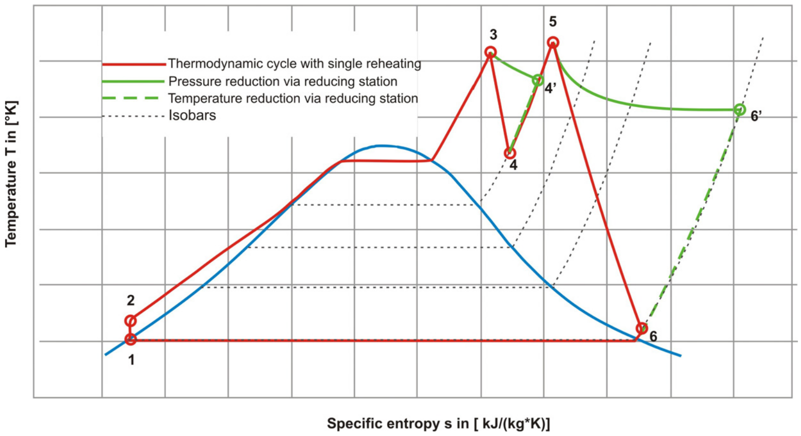


Figure 8: Temperature-entropy diagram of typical cycle of a power station with single reheating[2]

1->2 Pressure build-up (pump)
2->3 Heating, evaporation, superheating
3->4 Expansion in a high-pressure turbine, with performance of mechanical work
3->4‘ Decompression, with bypass valve in use, via high-pressure bypass valve instead of via turbine
4‘->4 Desuperheating, with high-pressure bypass valve in use
4->5 Isobar reheating
5->6 Expansion in the medium-pressure turbine with performance of mechanical work
5->6‘ Decompression, with bypass valve in use, via medium-pressure bypass valve instead of via turbine
6‘->6 Desuperheating, with medium-pressure bypass valve in use
6->1 Condensation

Decompression via a reducing station proceeds adiabatically in the temperature-entropy diagram, in other words without loss of heat and without the performance of mechanical work. Nonetheless, decompression in an actual valve is accompanied by a certain reduction in the temperature of the steam (known as the isenthalpic process), although this temperature reduction is less than if the steam had performed mechanical work on the turbine. In Fig. 8, this alternative pathway via the bypass valve is indicated by the green line.

[2] Strauß et al. (2009), pp. 81ff.

Technically, the cooling of the steam is achieved using cooling water which is dispersed into ultra-fine droplets by various methods during the injection process. Heat is transferred to the droplets from the steam, and in ideal circumstances the droplets are evaporated quickly and completely. In this way, the desired temperature reduction is achieved as a factor of the water quantity deployed (evaporation enthalpy). The quantity of injection water can be controlled by measuring the temperature of the exiting steam. In addition, so-called enthalpy controllers are used to calculate - via an enthalpy budget and using the measured parameters of the steam at the inflow (pressure, temperature and mass flow) and the desired parameters of the steam at the outflow - the required quantity of water, and to control the injection valve so that the required water flow is delivered.

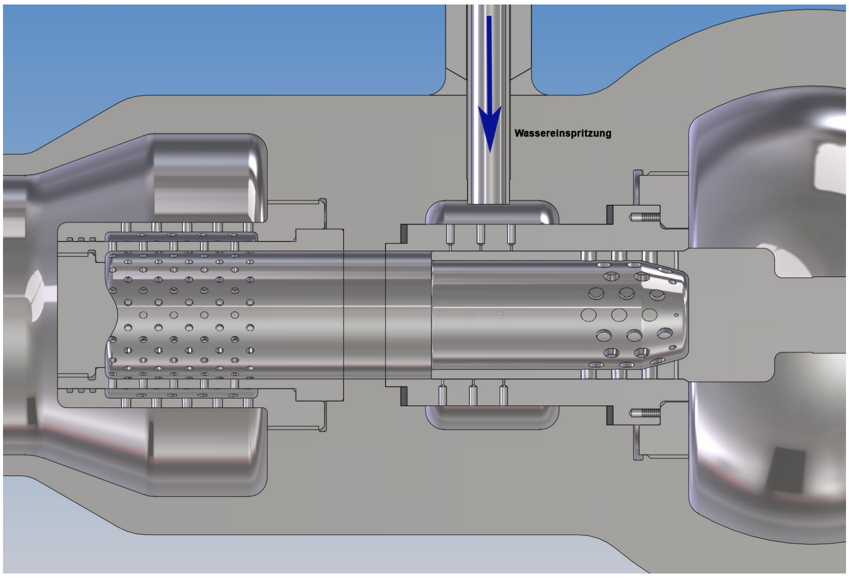


Fig. 9: The integrated water injection is denoted by the blue arrow

The time needed to evaporate the individual droplets is governed essentially by the available surface area of the droplets and by the possible heat transfer.

Heat transfer can be described in general as:

$$Q = A \cdot \alpha \cdot (T_D - T_W) \cdot \Delta t \quad [J]$$

Q: is the quantity of transferred heat [J]
α: is the heat transfer coefficient [W/(m²*K)]
A: is the observed area of contact [m²]
T_D, T_W: are the respective temperature of steam and water [K]
Δt: is the observed time interval [s]

Maximising the surface area of the droplets (A) relative to their mass is achieved by minimising their size. Maximising the heat transfer (α) is achieved by maximising the speed of the droplets relative to the steam. To be sure, the formula evaluates that the coldest possible water temperature has the greatest cooling effect, but in fact the evaporation enthalpy of the water makes the greater contribution to heat transfer. Indeed, colder water has a negative impact on the dispersal of the droplets due to the temperature-dependent nature of their surface tension. Colder droplets also take longer to evaporate and when they collide with the inside of the piping system they can cause increased tension. A further disadvantage is increased tension at the injection nozzle, where steam and water first converge. To avoid these effects the water temperature for desuperheating should be > 120 °C (T_W > 120 °C).

In bypass valves, one of three different techniques is normally used to inject cooling water for desuperheating:

1. Integrated injection

2. Downstream pressurised atomisation

3. Downstream desuperheating assisted by motive steam.

Integrated injection

With integrated injection in a multi-stage decompression, water is normally injected into the seat bushing underneath the seat after the first, the second and certainly before the last pressure stage (cf. Fig. 9). During this decompression, the greatest velocity occurs at the point of injection. Further pressure stages follow after water and steam have mixed at this point. Upon passing through the numerous borings of the perforated bush, the velocity of the medium increases again. The resulting decompression causes steam and water to intermingle such that upon their discharge into the pipe system they have become a homogenous mixture of superheated steam, free from water droplets.

The **advantages** of integrated injection are the extremely rapid evaporation, which allows for a short outflow zone downstream of the valve. It also protects the components of the downstream pipe system from abrasion by water droplets and from damage due to thermal shocks. Moreover, this technique enables precise and rapid controllability, in particular of the temperature. Its economic advantages relative to other injection techniques constitute a further argument in its favour.

The **disadvantages** of integrated injection arise from the greater stresses impacting on the inner parts of the valve. Water droplets striking these parts cause greater abrasion and necessitate a higher replacement rate. Due to the abrasive qualities of the water and also to the thermal stresses causes by colder droplets in a hot steam medium, integrated injection is better suited to time-limited requirements. Examples include starting and shutting down as well as bypass operations while trip of turbine plants.

For continuous duty operations or those which require alternating loads, as for example demanded by combined-cycle plants, the following injection systems are more suitable.

Downstream pressurised atomisation

With downstream pressurised atomisation, water is introduced as centrally as possible into the steam medium of the pipe system, and downstream of the decompression. The special injection mechanism is characterised, for instance, by the use of hollow-cone or spring-loaded nozzles.

With **hollow-cone nozzles**, the water is brought into a spinning motion by the rifled construction of the nozzle. Applying a centrifugal force to the water, the nozzle sprays a circular jet of fine droplets. In general, the greater the pressure differential between the injected cooling water and the steam medium, the smaller the diameter of the droplets (for pressure differentials of 3 - 40 bar between water and steam).

With **spring-loaded nozzles**, a slit opening is regulated by water pressure and flow rate. A spring is deployed to allow an optimal atomisation face for pressure differentials between 0.8 and 35 bar.

Advantages of pressurised atomisation include that the internal valve components do not come into contact with water droplets, which considerably extends the valve`s service life. Moreover, the modular nature of the valve allows for the local containment and exchange of wearing parts. All in all, pressurised atomisation jets are characterised by lower manufacturing costs compared to motive steam nozzles.

Disadvantages of pressurised atomisation result from its range of operations being restricted to cooling temperatures of less than 50 °C above saturation temperature. In addition, a flow rate falling below 20 % of maximum flow capacity is not advisable with pressurised atomisation nozzles, as in both cases the proportion of completely evaporated water is reduced. Water remaining in the pipe system can cause stresses, and may even cause water hammering. Furthermore, the water required for cooling is then only partially available.

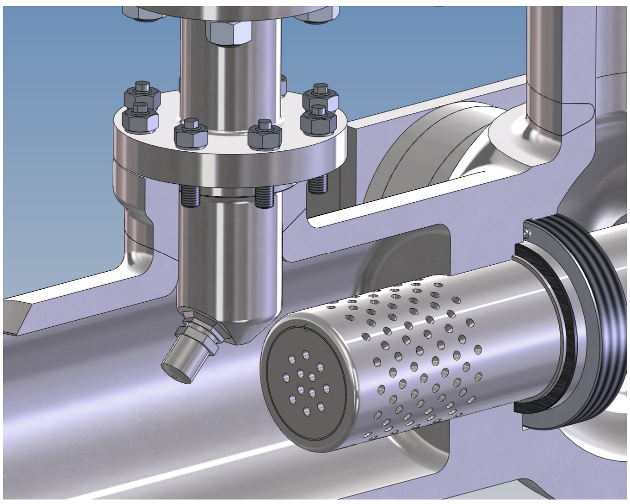


Figure 10: Downstream pressurized atomization

Downstream desuperheating assisted by motive steam

With the motive steam nozzle, the atomisation of the water is effected at high pressure by means of separately fed motive steam. The motive steam is led at high speed into the nozzle at the point of injection, immediately rupturing the injected water into minute droplets. The motive steam nozzle is often located directly downstream of a decompression stage. This optimal geometric relationship allows the motive steam for the feed to be taken from the high-pressure side and injected at very high relative speeds between the water droplets and the steam.

Advantages of the motive steam nozzle include the particularly efficient evaporation of the injected water, with short evaporation distances and hence good conditions for measuring the temperature. Internal valve components do not come into contact with the injected water, because the motive steam-assisted cooling is located downstream of the decompression stage. These components, as well as the pipe system, are thus protected from stresses. A further important advantage is being able to run less then 5 % of maximal load without compromising the evaporation of the injected water. Moreover, the medium can be cooled very close to the temperature of saturated steam (c. 1 - 5 °C above superheating).

Disadvantages of the motive steam nozzle include it being relatively difficult to deal with large amounts of injection water.
For all three techniques, moreover, it is important to consider the length of uninterrupted pipe required for evaporation. In other words, no further built-in components should be installed in the pipe in the immediate downstream vicinity of the injection nozzle.
Even if the pipe length required for evaporation with motive steam-assisted cooling is considerably shorter than that required for pressurised atomisation cooling, it is nonetheless longer than that required for integrated injection. Lastly, the steam-assisted solution is more cost-intensive than the other techniques mentioned.

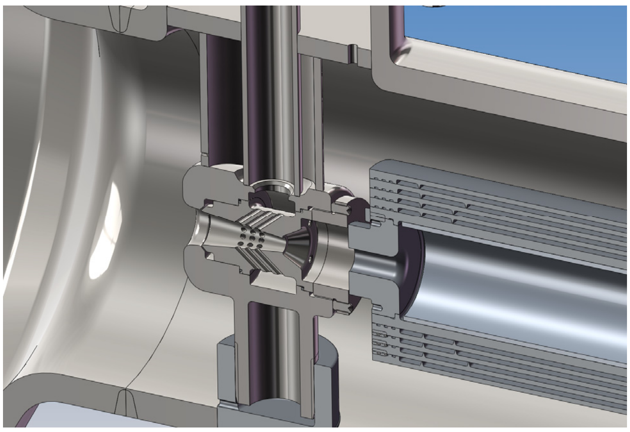


Figure 11: Motive steam injection in a BOMAFA bypass valve

Other technical issues

Over and above the functions of pressure regulation and temperature reduction, some further technical issues relating to the design of bypass valves should be outlined. These issues include the tightness of the seat, the use of packing material at high temperature ranges, and the response time of the actuators.

Tightness of the seat

Many types of adjustment control exist, whereby there are in some instances strict leakage requirements particularly with regard to the tightness of the seat.

The seat has to ensure that the medium cannot leak into the area downstream of a valve. This is not the place to present all known concepts for seat tightness, but the basics are sketched out below.

The most reliable method of ensuring the housing remains impermeable is to fit a gate valve or a double disc gate valve upstream of the bypass valve. It is however often more economic to use a combined gate and control valve. In general it is important to note that in the long term, a control valve can only to a limited extent fulfil the duties of a gate valve. High velocities in the seating area can exert major stresses. It is important to bear in mind that the actual seating area (the sealing face) for a seating diameter of, for example, 136 mm, measures only 6.5 cm^2. This corresponds to square with sides of just over 2.5 cm. With a pressure differential of c. 50 bar this corresponds to a force of 32 kN or to a mass of c. 3,2 tonnes. In addition, in high temperature applications it is necessary to take account of temperature
es reaching 600 °C.

It is therefore right to concluded that high-tensile materials are required for engineering the valve`s seating and spindle. Thus for temperatures up to 400 °C materials such 1.4057 (X 17 CrNi 16-2) are used, and for temperatures up to 600 °C materials such as 1.4923 (X 22 CrMoV 12-1) find deployment. In even higher temperature applications material 1.4910 (X 6 CrNiMoN 17 12 2) may be used.

Another issue for large-dimension bypass valves are the forces required to actuate the spindle. In particular at high pressures and with large seating diameters, formidable forces may be required to open the spindle. To reduce these forces, certain modifications may be made to the spindle. Upstream of the spindle a pressure-relief chamber is added, and this is sealed using packing material on the high-pressure side.

In this way, the side of the spindle facing the pressure and the side of the spindle facing away from the pressure are both pressurised equally and therefore balance each other out. This does considerably reduce the force required to actuate the spindle, but on the other hand also places exacting demands on the packing material at the spindle head. Moreover, this solution may, in the longer term, cause increasing leakage in the bypass valve. An alternative method involves making the seal using a pressure ring in which the relief borings are sealed by a so-called prestroke taper when in the closed position (Fig. 12).

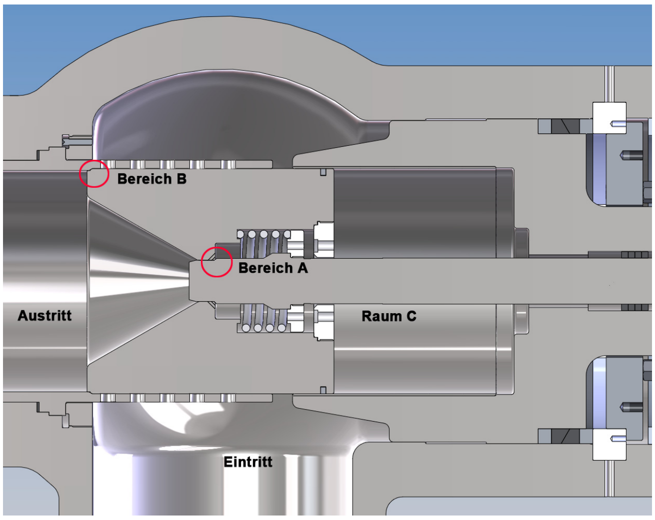


Fig. 12: Load relieving the spindle using a prestroke taper

Packing material at high temperature ranges

The spindle`s packing is an important component of bypass valves. Packing may be made from graphite, special alloys or composite materials. Currently, packing is standardly deployed at up to 500 °C. At temperatures above this, the following issues must be considered:

Although graphite can remain stable even above 700 °C, it has been observed that when exposed to oxygen in the air at temperatures above 500 °C it may pass into a gaseous state and therefore lose its sealing properties. For this reason, at temperatures above 500 °C, it is important to ensure that either the surface of the packing is shielded from oxygen in the air or that the packing area is separately cooled below this critical temperature. In practise, however, the packing is usually designed to be positioned within the valve such that the medium has already cooled below the critical temperature before it comes into contact with the packing.

The sealing and wear properties of spindles subject to surface treatments (e.g. nitriding, boriding) is the subject of ongoing research. For both conventional and high-temperature applications, numerous research questions revolve around improving spindle packing material and seals.

Actuator response times

The bypass valve has the capacity to quickly divert up to 110 % of the system`s steam. This allows the turbine, if necessary, to be immediately relieved (turbine trip) and thus protected from damage with no loss of steam, as described above. To facilitate this rapid reaction of the bypass valve, a high-performance mechanism is required to both close the steam`s path to the turbine and open the bypass. To this end the bypass valve is equipped with either pneumatic or hydraulic actuators. Pneumatic actuators have a response time measurable in seconds while for hydraulic actuators this is tenths of seconds.

The look ahead: bypass valves for modern thermal power stations

The main focus of efforts to improve the design of future power stations is on optimising the combustion process. The aim is to use less fuel to generate more electric power. For existing power stations, the aim is to enhance performance and simultaneously increase efficiency and thereby reduce CO_2 emissions.

Although there is currently a rise in the proportion of electric power generated from renewable sources of energy, most power is still generated at conventional power stations running on oil, natural gas or anthracite, or at nuclear power stations. For the foreseeable future, then, fossil fuels are likely to make a major contribution to power generation, and the challenge is to render this power generation less harmful to the environment and more economic.

The single most important measure needed to reduce CO_2 emissions per kilowatt hour for fossil fuel power stations is to increase combustion efficiency; this is also one of the most complex challenges in power station technology. In theory, the upper limit of this efficiency is governed by the second law of thermodynamics as expressed in Carnot‘s theorem. In practise, the as yet unavoidable effects of heat loss, friction etc. mean this limit has far but been reached.

In this context the main focus of attention is on the development of power station processes and of their respective components. Approaches include using multiple reheat cycles, increasing turbine efficiency, reducing the power station`s own power requirement, and waste heat recovery.

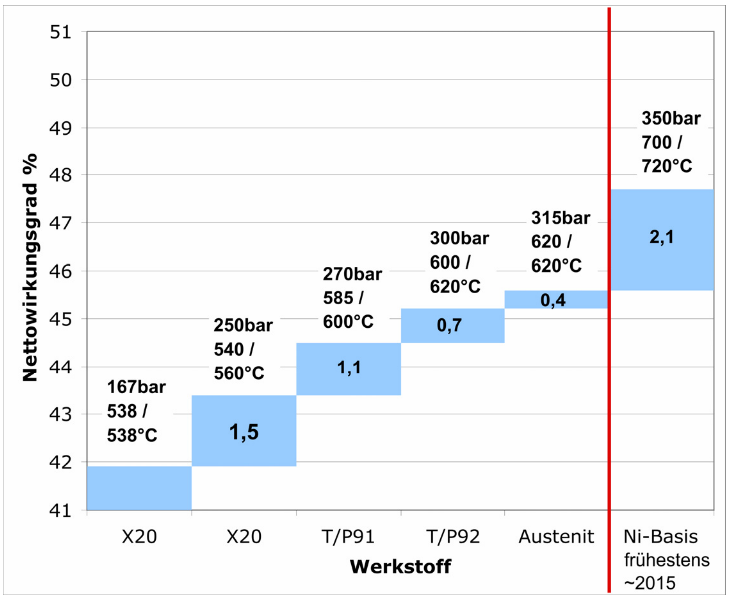


Fig. 11: Material development as a factor of efficiency[3].

The most effective improvements of both the efficiency and performance of power stations are however contingent on higher operating temperatures and pressures. This means increasing demands on the materials used. Fig. 11 shows the relationship between efficiency, operational parameters and the required materials.

These days the material P 92 (ASTM A335 P92) is often used for valves in 1,000 MW power stations, as it is allows steam temperatures of up to 620 °C. At even higher temperatures, with supercritical steam states of 700 °C and 300 bar, nickel-based alloys become necessary. Here, as stated above, there is considerable need for further research, and the EU is funding research projects and the establishment of new research institutions. The goal is to reach efficiency rates of up to 53 % by 2020.

Promising results are already being delivered by combined-cycle gas turbine power stations, where efficiency rates of 62 % are being targeted. Necessary steps to achieve this target include developing hard-wearing materials for gas turbine blades with a high nickel content and single-crystal structure, and special coatings for the turbine blades to protect against corrosion.

Overall it is evident that unresolved questions abound in the fields of power station technology, energy generation and, relatedly, in the field of bypass valves. Creative ideas paired with long-standing experience are needed to meet the energy requirements of tomorrow`s growing world.

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