

# System Catalog 1

**Solenoid valves** | Process and control valves | Pneumatics  
Sensors | MicroFluidics | MFC and proportional valves



The smart choice of Fluid Control Systems



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## A quite “everyday” technology



Technology from Bürkert, particularly solenoid valve technology, is not only encountered in industrial installations in an extremely wide variety of sectors, it can also be found literally on the street: inside many useful devices and apparatuses that make our daily life easier. For example, at each and every service station. Gas pump nozzles respond precisely down to the cent with Bürkert solenoid valve technology. Tire

inflation pressure is checked and oil extractions carried out using our technology, as are car-wash operations with their various programs and, last but not least, Bürkert solenoid valve technology ensures filling of the main tanks and reliable operation of the sprinkler system. Even the cup of coffee we buy from a vending machine is not an exception: Bürkert technology takes care of the dosing. It is no won-

der that our engineers are just a bit proud of the fact that their ideas are so welcome in everyday applications.

### **Evolution of core competence**

Our company has never outsourced the further development of solenoid valve technology, not even sub-areas of this technology. After all, it is with



solenoid valve technology in particular that Bürkert has achieved its position as market leader in fluidics. It is one of the main pillars of our company success, and one which first and foremost represents an advantage for our customers: the ongoing, practically-oriented expansion of our competence as a pioneer in the industry is as good as a guarantee for groundbreaking innovations. The market confirms this. Bürkert

is one of the top addresses worldwide for future-orientated solenoid valve technology.

### **Process-integrated, systematic solutions**

Bürkert systematically follows the principle of maximum customer benefit when developing efficient solenoid valve technology. Regardless of whether you require a single component or

a complex system solution, we always focus on optimum process reliability, efficiency and economy. Two essential parameters for future-proof solenoid valve technology are maximum repeat accuracy and minimum downtimes. This is where Bürkert brings its strengths to the fore, strengths based on decades of experience gained by a pioneer in the industry. We are motivated anew every day by our goal of passing on this experience to our customers and advancing their success. The result is systematic solutions offering an optimum combination of technical and economic benefit for every process.

### **Efficient technology for your application**

When it comes to shutting off, releasing, dosing, distributing or mixing gases and fluids, solenoid valves are the most frequently used control elements. The sum of the applications mentioned above corresponds to a wealth of specialized and diversified solutions which have one thing in common. We make choosing the right component or the appropriate system as simple as possible. Since we consistently observe the market, we are most likely already familiar with your requirements. And should your needs be new to us, our engineers will meet the challenge with great motivation.

# 1. Solenoid systems for solenoid valves

## 1.1.

### Basics

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix gases and fluids. They are confronted with many different requirements in your application areas, e.g.

- fast and safe switching
- high reliability
- long service life
- good medium compatibility of the materials used
- low control power
- compact design.

Besides the plunger-type actuator which is used most frequently, pivoted-armature actuators and rocker actuators are also used.

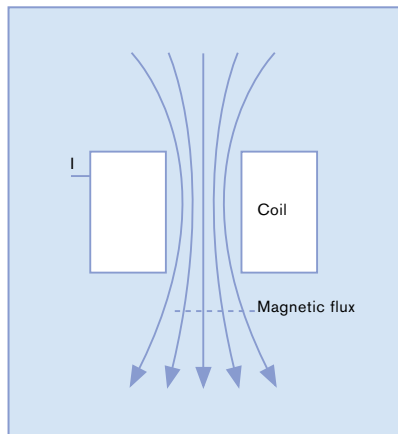
## 1.2.

### The basic operating principle of a solenoid

While the actuation system, mechanical construction and the function as a whole do indeed differ, fundamental elements of the actuator are identical on virtually all actuation principles. The core of a solenoid consists of an electrical magnet, which is also referred to as a solenoid coil.

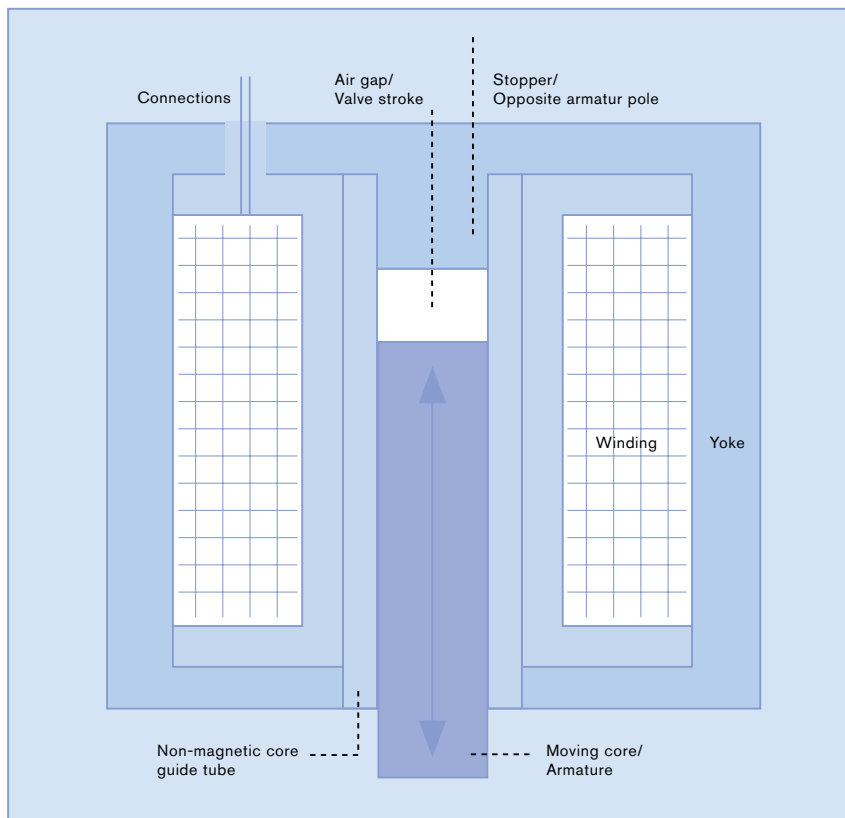
If an electric current flows through an electrical conductor, e.g. an enameled copper wire, this wire also generates a magnetic field. This magnetic field can be amplified by focusing the electrical conductors in the form of a coil. In addition to the number of windings and the amperage, the iron circuit around the solenoid coil also has a substantial impact on the resultant magnetic forces. Normally, the polarity does not need to be noted.

In the following, we will explain the mechanical construction of a solenoid actuator using the example of a plunger-type actuator.



Magnetic flux with electrical actuation of a coil





**Functional principle of a solenoid with plunger-type armature**

### 1.3.1. Solenoid coils for direct current

The coil design is relatively simple for DC coils. Depending on the required operating voltage, the electrical power results from the electrical resistance of the windings and the relevant voltage applied. On coils without integrated electronic components, the electrical resistance can be measured and the power can be calculated as follows:

$$P = \frac{U^2}{R}$$

P = Active power

U = Operating voltage

R = Coil resistance

Neither eddy-current losses nor hysteresis losses occur on DC solenoids, so that the iron circuit can be designed as solid, whereby preference is given to iron grades with a low coercive field strength or low remanence in order to achieve low pull-off strengths. If defined return conditions are required, it is frequently essential to incorporate an air gap which causes shearing of the iron circuit and thus a reduction of remanence. One essential advantage of the DC solenoid is the delayed, gentle pick-up of the armature due to the degressive current rise and the silent holding function of the solenoid armature.

The magnetic field generated by the solenoid coil causes a force of attraction on the magnetic core located at the center, which is also frequently referred to as the plunger. The magnetic core is held by the coil for as long as current flows through the coil. If the flow of electric current is interrupted, a compression spring repels the core again and moves it back to its initial position.

Stringent requirements are demanded on the core material used:

- good magnetization properties
- low magnetic memory effect
- high wear resistance
- high chemical resistance to aggressive media
- good mechanical workability.

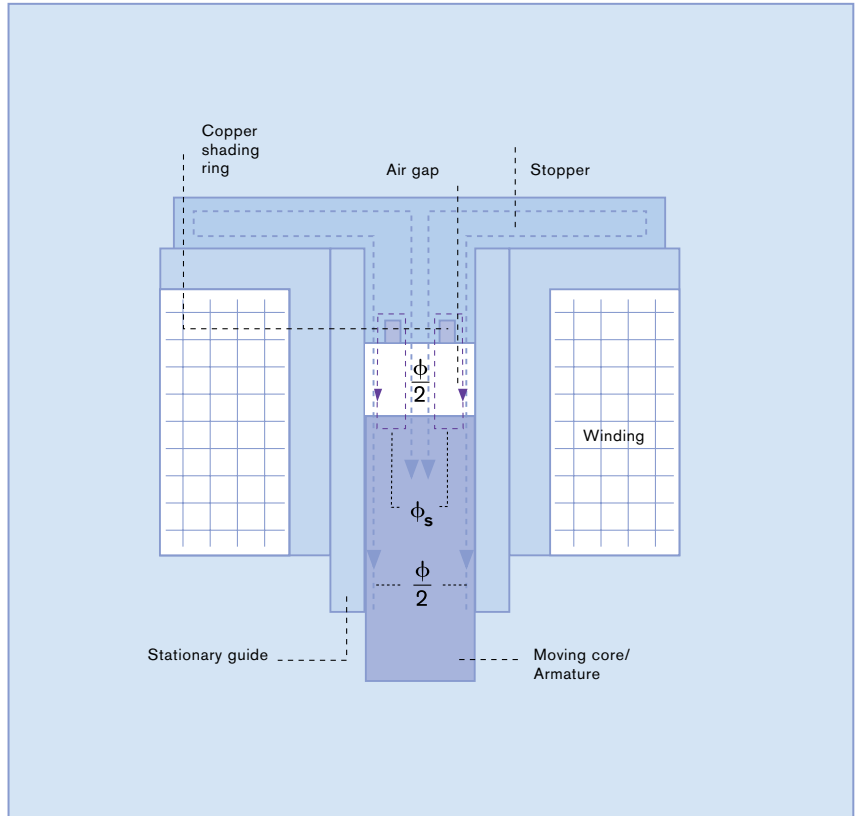
A seal which is connected permanently to the core thus causes a solenoid valve to open and close.

### 1.3. Solenoid coils for direct current and alternating current

Specific translatory armature movements can be executed with these two coil types, depending on the design. In addition, there are also specifically preferred applications and operating limits due to the physical laws for these two types. For example, DC coils are given preference in field bus technology.

### 1.3.2. Solenoid coils for alternating current

On AC coils, the current is determined not only by the ohmic resistance of the windings, but also by the inductive resistance (reactance). The inductive resistance is significantly influenced by the position of the solenoid core. If the solenoid core has dropped out, the inductive resistance is lower and the coil current is higher. The current is thus higher in the pick-up phase than the coil current in the holding phase. As compared to a DC coil, coil resistance is far lower with the same voltage value being applied. Consequently, a coil should never be operated without a solenoid core when operating with AC voltage. Otherwise, there is a risk of the coil overheating and burning out after a few minutes.



Functional principle of an AC solenoid

The inductive resistance is also dependent on the mains frequency. This is, for example, higher at 60 Hz than at 50 Hz. If a solenoid coil designed for 50 Hz is operated with 60 Hz, the magnetic force of attraction on the core will be lower. The loss of force is 10-30% depending on design and size. With direct-acting solenoid valves, this means restrictions in the pressure range for practical applications.

If a coil designed for 60 Hz is operated with 50 Hz, this results in an increased power consumption with a higher coil temperature. The coil could be damaged under such extreme operating conditions.

One other special factor is the need for an electrically conductive ring (shading ring) in the stopper of the solenoid coil. If an AC solenoid was to be operated without the shading ring, the armature itself would constantly oscillate at the oscillation frequency of 2 x mains frequency (50 Hz or 60 Hz), even with very slight forces of the return spring when energized since, with each zero crossover of the sinusoidal mains voltage, the holding force which represents a sinusoidal-quadratic curve drops practically to zero twice per period. Since this means that the force of the return spring increases above

the holding force twice per period, the core would be lifted and attracted again twice per period. Such a very loud oscillation takes the form of a very unpleasant hum.

If a correctly dimensioned shading ring is now fitted in the working gap, conventionally in the stationary opposite armature pole, a voltage is induced by the primary flux  $\phi_p$  in the shading ring in the energized state of the armature, and this voltage generates a current which is phase-offset by angle  $\varphi$  in the shading ring. This phase-offset current now generates a secondary flux  $\phi_s$  in the shading ring, which is phase-offset with respect to the primary flux  $\phi_p$  by angle  $\varphi$ . This additional, phase-offset secondary flux  $\phi_s$  now produces a quite different resultant force with which the minimum force and, thus, the holding force no longer drops to zero. The minimum holding force achieved in this way can be used for spring design and, along with the lifting force characteristic, represents the most important parameter when designing direct-acting solenoid valves.

Stringent requirements in regards to evenness, flatness and peak-to-valley height are made on the pole faces of opposite armature (stopper) and core in order to achieve a hum-free holding force which is as high as possible.

Larger air gaps between the poles very substantially reduce the holding force of the core since the magnetic conductivity of air is substantially poorer than that of iron.

In practice, even a dirt deposit could cause hum and have major consequences for the coil and solenoid core. It may be necessary to use a DC coil with a series-connected rectifier when operating with AC voltage.

## 1.4.

### Stroke-force behavior of DC and AC solenoids

The pick-up forces acting on the core are very greatly influenced by the core stroke (air gap). The greater the stroke, the lower the pick-up forces will be. This interrelationship is referred to as stroke-force.

In addition to the spring force for returning the core, fluidic forces, triggered by the medium pressure, also act in opposition to the pick-up force of the solenoid coil.

The stroke-force behavior of DC coils differs with respect to AC coils with the same electrical active power by virtue of the fact that the magnetic holding forces of the DC coil are higher with the solenoid core energized. However, the pick-up forces with the solenoid core dropped out are generally lower. Referring to the functions of the valve, this means that, in many cases, higher pressures can be switched with AC voltage. Often, this DC coil deficit can be compensated for with a special design of the solenoid core and stopper geometry (profiled armature).

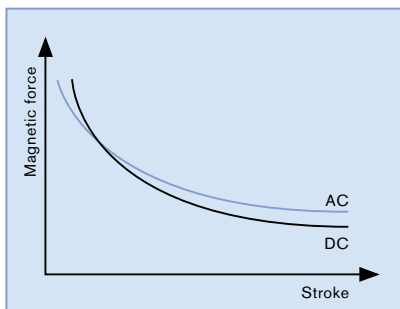
There are also other different characteristics in addition to the differing stroke-force behavior:

#### DC solenoid

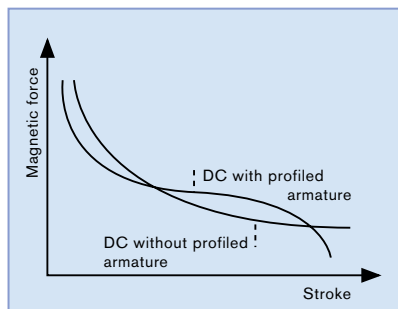
- Quieter
- Less wear of solenoid core
- High solenoid holding force
- Same pick-up and holding power
- No shading ring required.

#### AC solenoid

- Tendency to hum
- Risk of burn-out of the solenoid coil if solenoid core is jammed
- Faster switching speed (dependent on phase angle).



Stroke-force characteristic curve for DC and AC coils



Stroke-force characteristic curve for coils with and without profiled armature

## 1.5.

### Coil design and self-heating

Each coil is wound individually with differing wire diameters and number of windings, depending on its overall size, existing winding volume, nominal voltage and required power rating. In order to achieve optimum efficiency, the existing winding volume is utilized to the maximum extent. That means that coils of the same overall size frequently vary only by virtue of the use of different wire diameters and number of windings. However, it is only in a few cases that solenoid coils can also be operated with other voltages.

The electrical power of a coil is converted virtually 100% to thermal energy. This means that the coil may heat up very greatly in continuous operation, which in turn means that the maximum power rating of a coil will essentially depend on the maximum tolerable temperature of a coil which may not be exceeded on a sustained basis, depending on the mode of operation (continuous operation or only short-time duty), without damaging the coil. The encapsulation materials and the largest possible coil surface area ensure good heat dissipation and radiation from the surface.

In addition to the self-heating of the coil, application-specific factors or operating data also have a major influence on the achievable overall temperature of the coil:

- Ambient temperature
- Medium temperature
- Medium type (fluid or gaseous)
- Heat radiation capacity (encapsulation)
- Heat flow inside the coil and to the medium
- Continuous operation or reduced duty.

With continuous operation and normal ambient temperature (20 °C) of a solenoid valve, temperatures on the surface of 80-90 °C or even higher may be achieved.

The maximum operating data (ambient temperature and medium temperature, etc.) is thus specified under "Technical Data" in the relevant data sheets for the valve types. If two or more operating data items are in the limit range in the relevant application, the user should seek technical advice in order to achieve optimum service life for the equipment.

## **1.6.**

### **Special coils**

#### **1.6.1. Solenoid coils with high-performance electronics**

The highest electrical power is required by the coil of a solenoid valve when the core needs to be picked up. As can be seen from the stroke-force curves, the coil has the lowest force of attraction on the solenoid core at this point. A much lower power is required to hold the core. For such cases, Bürkert has developed solenoid coils with high-performance electronics. These electronics cause the coil to be operated with a much higher power for a brief period until the coil has picked up the solenoid core. After a period of approx. 500 ms, an electronic circuit switches over to a far lower holding power that does not overload the coil even in continuous operation. This means, for example, that much higher pressures can be switched with the same coil size than is the case with standard coils. Other applications are solenoid systems with a long valve stroke.

If using valves with high-performance coils, note that the valve must be connected to an adequately rated power supply. In addition, the valve may not switch too frequently since, otherwise, the coil would be overheated as the

result of excessive coil heating. A maximum of six switching operations per minute is considered as the guideline value.

A distinction is made between two systems:

#### **1. Solenoid coils with integrated electronics**

This coil consists of a pick-up winding and a holding winding which is designed with corresponding winding parameters for the required power. This circuitry must be connected in series with a rectifier, to enable the valve to be operated with universal current.

Advantage:

No additional electronics required

Disadvantage:

special coil, more complex, expensive production, 3 wires.

#### **2. Solenoid coil with external electronics**

A standard coil with a higher power rating is used on this system. Externally mounted circuitry results in synchronized control of approx. 1 kHz of the coil with a specific pulse duty factor after an overexcitation time of approx. 500 ms. Here as well, the valve can be operated with universal current.

Advantage:

More favorable, use of standard coils possible

Disadvantage:

Additional control circuitry required

#### **1.6.2. Impulse coils**

Impulse coils require only a brief current pulse applied to the pick-up winding for switching. The solenoid core is energized in this period and held by integrated permanent magnets. A second release winding integrated in the coil results in an opposed force and the core drops out again. No electrical power is required for holding the relevant switch position. Bürkert offers impulse coils designed as plunger-type and pivoted-armature coils. These coils, also referred to as "zero-watt coils", are used in specific applications.

Typical applications:

- Control from battery supply
- Undesired coil heating or no heat applied to the medium
- Holding the switch position even in the event of power failure
- Switching systems with pulse control.

### 1.6.3. Explosion-proof coils

The mechanical construction and coil design of explosion-proof coils are similar to those of DC coils. Corresponding measures, for example, pressurized enclosure or potting of electrical components, are used to ensure that explosive sparks cannot escape to the outside and thus trigger an explosion, even in the event of damage. The coil systems are generally operated with direct current by means of a generally press-fitted bridge-connected rectifier in the coil. Bürkert offers a wide variety of different coil systems which can be combined with many different fluid modules on the basis of a modular principle.

See the "Approvals" section for further information on explosion protection.

Meaning of the type of protection (IP code)

Digit	1st digit – Protection against ingress of foreign bodies	2nd digit – Protection against ingress of water
0	No protection	No protection
1	Foreign bodies > 50 mm	Water incident, perpendicular
2	Foreign bodies > 12 mm	Water incident at an angle (75...90°)
3	Foreign bodies > 2.5 mm	Spray water
4	Foreign bodies > 1.0 mm	Splashwater
5	Dust-protected	Jet-proof
6	Dust-tight	Heavy seas
7		Immersion
8		Submersion

## 1.7. Type of protection and electrical connection

The encapsulation materials of the solenoid coils, comprising sheathed polyamide or epoxy resin, protect the electrical system against harmful influences such as dust, dirt and moisture. These encapsulation materials, which feature a high chemical resistance, provide adequate protection in most cases, even against aggressive environments. Taken together, the encapsulated coil itself and the electrical connection form one unit. This means that not only the coil, but also the professional electrical connection represents an important criterion for the type of protection. The most frequent electrical connection is an appliance plug socket in accordance with DIN 43650, types A, B and C.

### 1.7.1. Type of protection for electrical equipment

Pursuant to EN 60529, the IP (Insulation Protection) type of protection is defined for the protection of electrically live components of electrical devices against ingress of solid or liquid foreign bodies. The identification comprises 2 digits and, if applicable, an additional letter. The first digit identifies the protection against ingress of solids and the second digit identifies the protection against ingress of water or moisture.

Many solenoid systems are designed for IP65 type of protection in the version with cable connection or appliance plug socket. It is thus dust-tight, protected against splashwater and complies with the requirements of most operating conditions.

## 2. Functional principals

The tasks of the valves or actuators are shutting off/releasing, dosing, distributing or mixing fluids and gases.

The requirements applicable to valves are very diverse, including:

- fast and safe switching
- low leakage losses in closed position
- low control power
- use for differing flow rates (nominal size) and pressures (nominal pressures)
- use for neutral and/or aggressive fluids and gases
- differing mechanical construction in the fluid section/valve, in the actuator (type of energy/principle) and in control
- small overall size
- long service life
- ambient conditions.

Application areas
Process engineer./chemical engineer.
Plant engineer./mechanical engineer.
The semiconductor industry
Water treatment
Environmental technology
Medical engineering
Equipm. construct./Analysis techn.

The special operating conditions for valves mean that there is a wide variety of variants which are matched to specific tasks. Over the course of time, manufacturers have developed names and terms whose logic is not always understandable, but which have nevertheless become incorporated into the everyday jargon in the sector. Terms focusing on the function of the valve (on/off, proportional) are blended with names characterizing a design or design element (e.g. plunger-type valve, pivoted-armature valve, rocker valve, diaphragm valve or angle-seat valve, etc.).

Bürkert solenoid valves are intended for operation with neutral, aggressive and special fluids, even under arduous operating conditions. They serve to shut off, distribute, mix or dose cold and hot fluids (fluids such as water, oils, fuels, solvents and saline solutions etc., gases and steam...).



**2.1.**

**Fluidic circuit symbols, designation of the circuit function and their meaning**

	<p><b>WW A</b> 2/2-way valve; normally closed</p>		<p><b>WW A</b> Servo-assisted 2/2-way valve; normally closed, pilot channel inside</p>
	<p><b>WW B</b> 2/2-way valve; normally open</p>		<p><b>WW B</b> Servo-assisted 2/2-way valve; normally open, pilot channel inside</p>
	<p><b>WW C</b> 3/2-way valve; normally closed, outlet A relieved</p>		<p><b>WW C</b> Servo-assisted 3/2-way valve; outlet A normally relieved, pilot channel inside</p>
	<p><b>WW D</b> 3/2-way valve; outlet B normally pressurized</p>		<p><b>WW D</b> 3/2-way valve; outlet B normally pressurized, pilot channel inside</p>
	<p><b>WW E</b> 3/2-way mixer valve; normally pressure port P2 connected to outlet A, P1 closed</p>		
	<p><b>WW F</b> 3/2-way distributor valve; normally pressure port P connected to outlet B</p>		
	<p><b>WW T</b> 3/2-way valve; universally usable</p>		

WW = Circuit function

## 2.2.

### Direct-acting solenoid valves: plungers

General characteristics:

- Rugged design
- Good value for money
- Universal field of application
- Broad nominal diameter range
- AC, DC and UC variants available
- Friction leads to restricted service life without lubrication
- Restricted pressure range results from media separation
- On 3/2-way version, one port points upwards
- Circuit function B (normally open), available for many versions
- Also available as explosion-proof version
- With push-over coil.

#### 2.2.1. 2/2-way plunger-type solenoid valves

Direct-acting 2/2-way plunger-type solenoid valves (e.g. Bürkert Types 6011 and 6013), also referred to as through-way valves, are shut-off valves with two ports: one inlet P and one outlet A, see Figure 1: Inlet P is connected to the pressurized fluid or gas. In the de-energized state, the core spring, assisted by the fluid pressure, forces the solenoid core (plunger) with the valve seal onto the valve seat; passage to outlet A is thus shut-off. If voltage is applied, the solenoid core with the valve seal is pulled into the coil as the result of the magnetic force and the valve opens; the passage is unobstructed again.

Characteristics:

- Flow direction normally above seat
- The maximum pressure depends on the nominal diameter and power consumption of the coil
- Weak springs in use, i.e. low back-pressure tightness (dependent on spring force and nominal diameter).

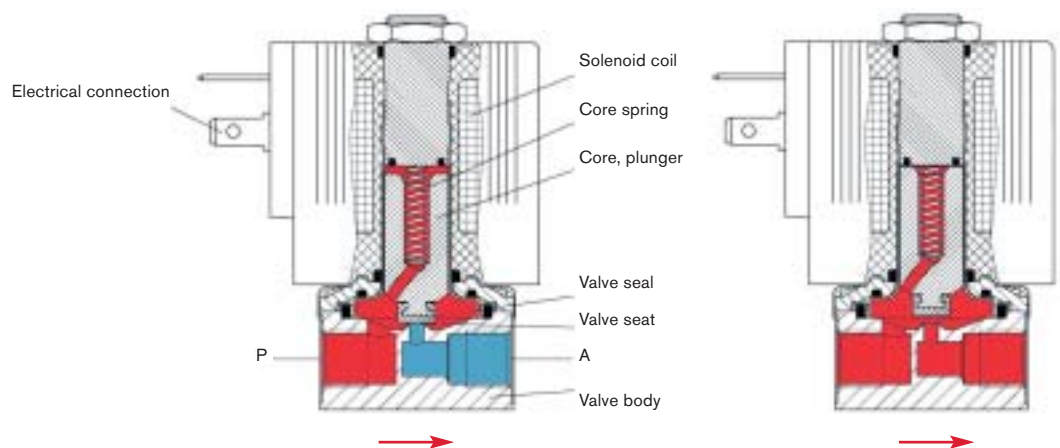


Figure 1:  
Direct-acting 2/2-way plunger-type solenoid valve,  
shown closed at left and open at right

**2.2.2. 3/2-way plunger-type solenoid valves**

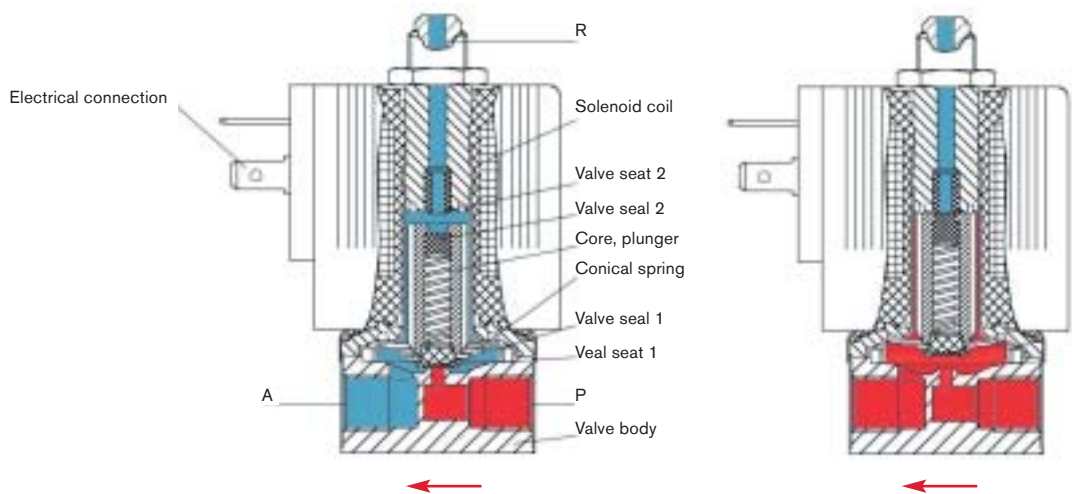
Direct-acting 3/2-way plunger-type solenoid valves (e.g. Bürkert Types 6012 and 6014) have three ports and two valve seats. Alternately, one valve seat is always open or closed.

The circuit function of the valve depends on how the ports are “assigned”, i.e. how they are connected to the fluid system. In circuit function C (NC), port P (see Figure 2) is connected to the supply which ducts pressurized fluid; port A forms the outlet and port R is the return or venting port. In the de-energized state, a conical spring forces the core (plunger) onto the valve seat 1 and blocks off supply P. Outlet A is connected to return R. After energization, the core is pulled into the so-

lennoid coil, whereby valve seat 2 is sealed off via the spring-mounted valve seat 2. The return R is thus shut-off. As the plunger moves upwards, valve seat 1 is also opened and the fluid can flow from P to A. In circuit function D (NO), the return R is normally shut-off.

Characteristics:

- in WW C (NC) flow direction below valve seat 1
- in WW D (NO) pressure inlet on upper valve seat (in diagram, port R, from the top)
- Maximum pressure is dependent on the spring force and the nominal diameter (not power consumption of the coil)
- High spring forces in WW C and weak spring force in WW D
- In the case of WW C (NC), the operating pressure is not limited by the pick-up force of the coil, but by the closing force of the conical spring.



**Figure 2:**  
**Direct-acting 3/2-way solenoid valve,**  
**inlet P closed, outlet A vented to R (left),**  
**inlet P open to outlet A (right)**

### 2.2.3. Direct-acting solenoid valves: pivoted-armature valves

Pivoted-armature valves are used with a 3/2-way function and in a 2/2-way version. On the 3/2-way Bürkert pivoted-armature valve (e.g. Type 0330, see Figure 3), all three ports are accommodated in the valve body and an isolating diaphragm prevents fluid from entering the solenoid system's armature chamber. The pivoted-armature valves are equipped with a manual override function (standard) and can also be optionally equipped with a visual position indicator or an electrical feedback indicator.

#### Advantages:

- Excellent reliability
- All three fluid ports in one plane
- Media separation on standard design
- Long service life
- AC, DC and UC versions available
- Visual or electrical position feedback optionally available
- Also available as explosion-proof version
- Conditionally suitable for aggressive media as well

#### Potential disadvantages:

- Replacement part exchange difficult
- Cost-intensive

### 2.2.4. Direct-acting solenoid valves: 3/2-way rocker valve

The Bürkert rocker solenoid valve (Bürkert Types 6104 and 6106) is designed for operation with compressed air; all three ports are also accommodated in the valve body. The valve is also frequently used as a pilot valve for pneumatic valves. A rocker with sealing seats alternately closes valve seats 1 for the air supply (fluid port P) and 2 for venting (fluid port R) of the outlet channel (fluid port A) (see Figure 4), in a similar manner to the pivoted-armature valve. Solenoid valves with rocker technology are available with or without isolating diaphragm.

#### Advantages:

- Low mass of moving parts
- 3 fluid ports in one plane
- Media-separated version available
- Economical
- Very long service life
- Compact design
- Low coil power
- High coil system efficiency
- Also available as explosion-proof version (intrinsically safe).

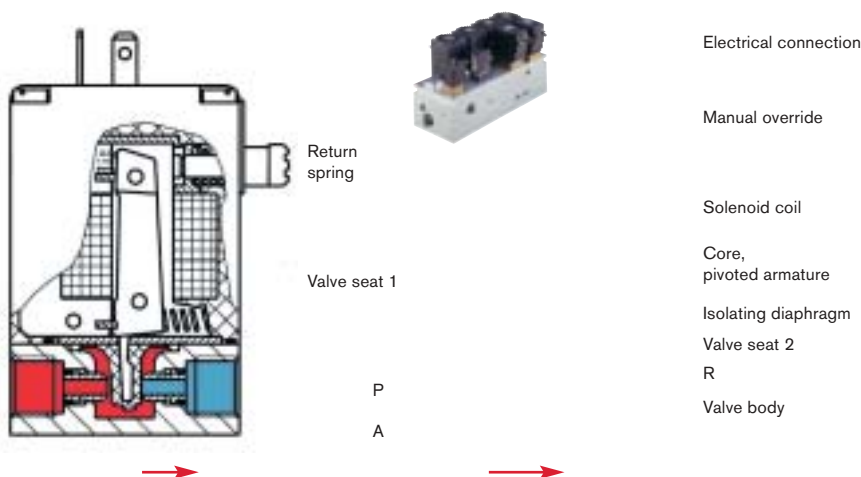
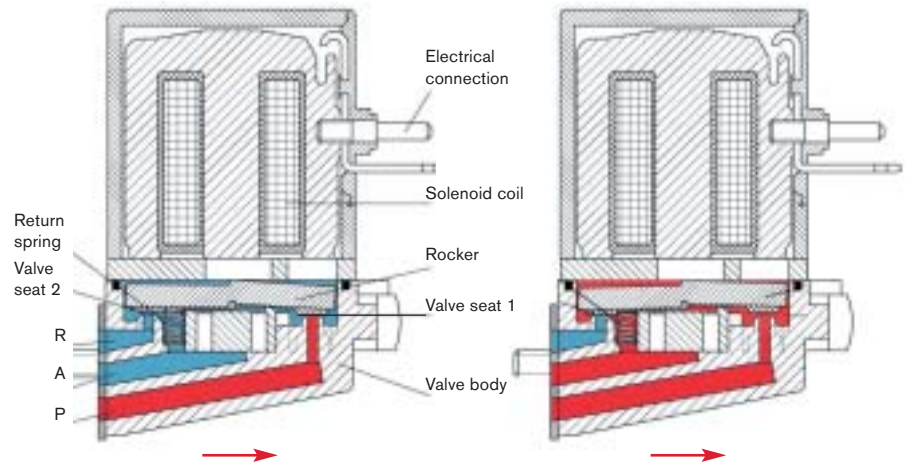


Figure 3: Bürkert pivoted-armature solenoid valve

Potential disadvantages:

- Only DC version, or for AC with series-connected rectifier (in coil or appliance plug)
- Media separation reduces maximum pressure range
- Low input pressure (max. 10 bar)



**Figure 4:**  
**Rocker valve**

<b>2.2.5. Characteristics and possible applications of various solenoid actuators for solenoid valves</b>			
	<b>Plunger</b>	<b>Pivoted armature</b>	<b>Rocker</b>
Media separation in actuator	No	Standard with media separation.	Available with and without media separation.
Wear behavior/ service life	Moderate to high wear susceptibility of the solenoid core due to the friction in the core guide tube, depending on field of application.	Low wear since there is no sliding friction in the armature.	Very low wear and long service life (special version without isolating diaphragm).
Universality and possible applications	Very robust solenoid coils available in various sizes and with various power ratings. Can be used for AC/DC/UC.	Very tried and tested actuation principle. Only one coil size available. Can be used for AC/DC/UC.	Small, compact actuation system, particularly as pilot valve or for low flow rates. Can be used only for DC, or also for UC with series-connected rectifier.
Typical media	Neutral gaseous and fluid, non-abrasive media, e.g. - Water (demineralized water, only conditional) - Air - Oils - Industrial gases	Neutral gaseous and fluid, media, conditionally also aggressive and abrasive, depending on use/usability and resistance of the isolating diaphragm material, e.g. - Water (including demineralized water) - Oils, Acids and lyes - Ultrapure media	Without media separation: neutral gases, e.g. air  With media separation: also aggressive gases and fluids of low viscosity

### **2.3.**

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#### **Servo-assisted solenoid valves**

At high system pressures and with large nominal diameters, it would also be necessary to have higher magnetic forces and electrical control power values in direct-acting solenoid valves. The larger solenoid coils required for this would increase the overall weight and overall size. Consequently, servo-assisted valves are used.

In the case of servo-assisted solenoid valves, a main valve is controlled by a solenoid-operated pilot valve with smaller flow cross-sections and lower electrical control power. This control can comprise either a 2/2-way pilot valve or a 3/2-way pilot valve. The main valve uses a diaphragm or a piston as a moving closure element for opening and closing the fluid path.

The Bürkert valve range also includes servo-assisted solenoid valves on which the armature of the pilot valve is linked to the piston or diaphragm of the main valve (forced valve lifting). On these valves (e.g. Bürkert Types 6213 and 290), a minimum pressure differential is not required. Depending on the design, a low pressure differential is required to open the full cross-section. This principle is used primarily with 2/2-way valves, both normally closed and normally open. The valve can be operated in only one flow direction. The back-pressure tightness is very low.

**2.3.1. Servo-assisted 2/2-way solenoid valves with diaphragm**

In this case, a plunger-type solenoid is used as the pilot valve. The main valve seat is opened and closed by means of a diaphragm. With this, closing is performed both by the force of the compression spring and by the medium pressure.

The fluid chamber above the diaphragm is relieved when the pilot opens. The medium pressure beneath the diaphragm lifts the diaphragm and opens the valve. If the pilot valve is closed,

the medium pressure builds up again above the diaphragm through a restrictor port in the diaphragm or through a bypass channel. The system closes as the result of the higher area ratio (above the diaphragm).

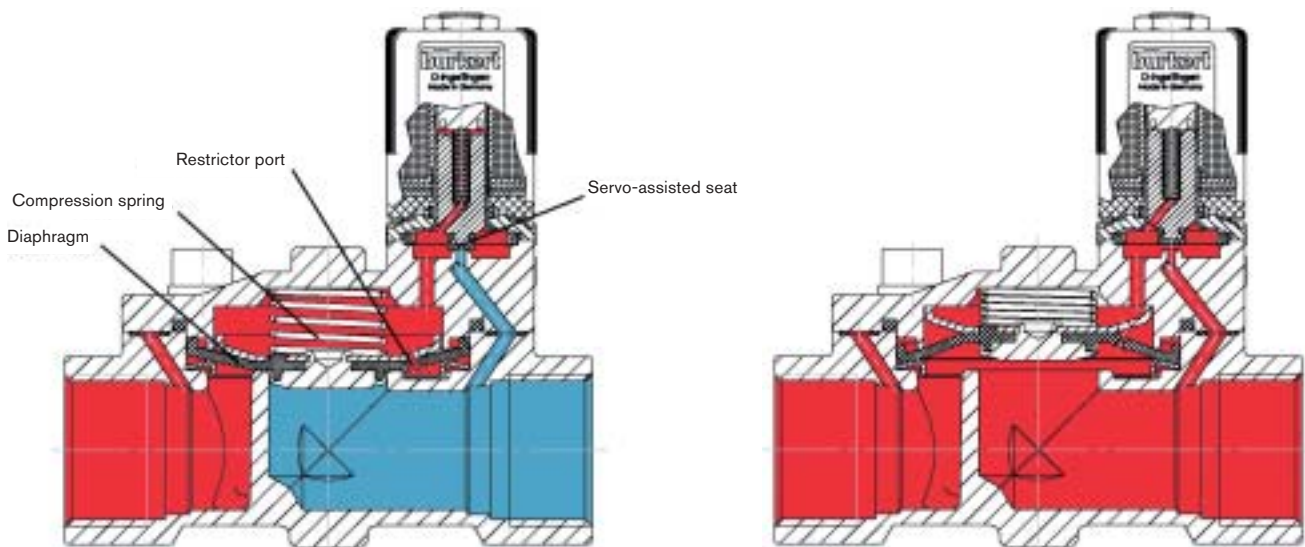
The chief application area of servo-assisted diaphragm solenoid valves with large nominal diameters (approx. DN 10 ... 65 mm) relates to neutral but also aggressive, fluid and gaseous media. Bürkert units based on this principle include, for example, Types 5281, 6211, 6228 and 0142.

**Advantages:**

- Economical mechanical construction
- Low electrical power consumption
- Good closing-impact damping
- Low pressure differential required.

**Disadvantages:**

- Sensitive to dirty media
- Not suitable for medium temperatures > 120 °C
- Restricted service life if gaseous media are used.



**Figure 5:**  
**Servo-assisted 2/2-way solenoid valve, normally closed, with diaphragm.**  
**Shown closed at left and open at right**

### 2.3.2. Servo-assisted solenoid valves with piston

A plunger-type solenoid is used as the pilot valve with this principle as well, but the main valve function is implemented by a piston. The function of this valve (e.g. Types 5404 and 6221) results from the fact that fluid is also able to flow from the supply P through a control bore in the piston or bypass channel of the main valve. If the chamber above the piston is closed off with the pilot valve de-energized, the fluid system pressure builds up there as well and the piston, which simultaneously forms the valve seal, closes the valve seat in the main valve.

It is assumed that the fluid pressure can be discharged in outlet A. For as long as a pressure differential exists between the inlet port and the outlet port, the main valve remains closed as the result of the closing forces above the piston. After activating the pilot valve, the pressure in the chamber above the piston is able to drop. The force acting on the lower side of the piston as the result of the fluid system pressure is greater than that on the upper side of the piston, it lifts the piston and opens the main valve. Servo-assisted solenoid valves operating on the basis of this design require a minimum pressure differential for correct opening and closing. Solenoid valves with a coupling (forced valve lifting) between the solenoid core and piston (e.g. Type 407) require no pressure

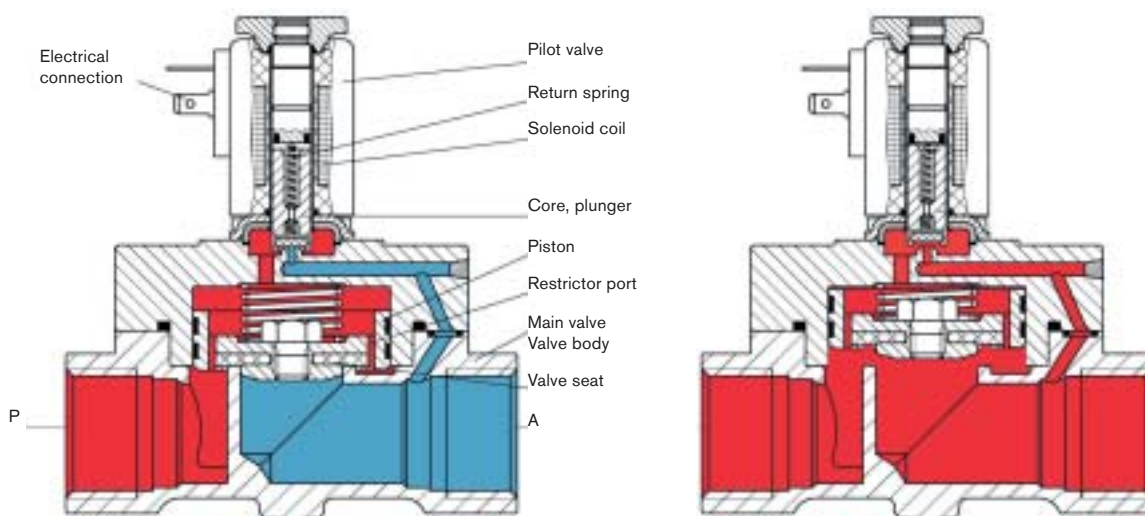
differential for switching. Servo-assisted piston-operated valves are used chiefly in applications with high pressures, gaseous media and steam up to 180 °C.

Advantages:

- More robust than servo-assisted solenoid valves with diaphragm
- Higher pressure range
- Suitable for gases and steam.

Disadvantages:

- More expensive than servo-assisted solenoid valves with diaphragm
- Less damping of closing impact
- Require higher pressure differential for opening.



**Figure 6:**  
**Servo-assisted 2/2-way solenoid valve, normally closed, with piston.**  
**Shown closed at left and open at right**



**2.3.3. Force pilot operated solenoid valves**

Force pilot operated solenoid valves essentially differ from the normal servo-assisted solenoid valves by means of a coupling, either of the piston or of the diaphragm, to the solenoid core. This coupling may either be direct or comprise a spring.

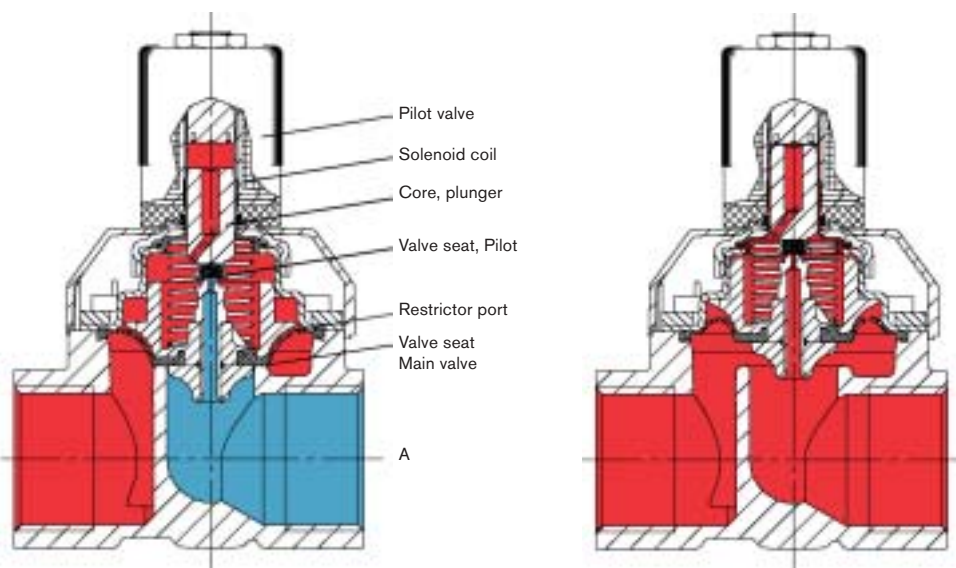
The function is a combination of direct-acting and servo-assisted. In the case of low pressure differentials, the direct-acting function of the system predominates, and the servo-assisted function of the system predominates at higher pressure differentials.

Advantage:

- Opens without pressure differential, can also be used in circuits or at low pressures
- Good closing-impact damping
- Good price-performance ratio
- Universal usability.

Disadvantage:

- Sensitive to dirty media due to small diameters of the control bore in the diaphragm
- Only normally closed function available
- Coils with a higher power rating are required for larger nominal diameters.



**Figure 7:** Servo-assisted 2/2-way solenoid valve, force pilot operated, normally closed, with diaphragm. Shown closed at left and open at right

### 2.3.4. Servo-assisted solenoid valves with 3/2-way pilot

A pivoted-armature or rocker valve with isolating diaphragm is used as the pilot valve. The essential difference with respect to the 2-way pilot is that a medium does not flow through the pilot in an open switch position and thus there is a much slighter risk of clogged control bores due to dirty media. In addition, a diaphragm protects the solenoid armature against harmful influences.

The chief field of application of this functional principle (e.g.: Type 142 and Type 5282) therefore obviously relates to both dirty media and aggressive media.

#### Advantages:

- No small control bores in the diaphragm and thus less sensitive to dirty media
- Solenoid chamber protected by isolating diaphragm
- Only a small quantity of medium flows through the pilot valve for opening or closing
- No medium flow through the pilot valve in open condition! This is a crucial advantage over valves with 2-way pilot.

- Response times adjustable with adjusting screws
- NC and NO function, possible simply by turning the pilot
- Extremely high functional reliability
- Also available as explosion-proof version.

#### Potential disadvantages:

- Cost-intensive
- Cannot be used in all circuits, since the system requires pressure differential for opening.

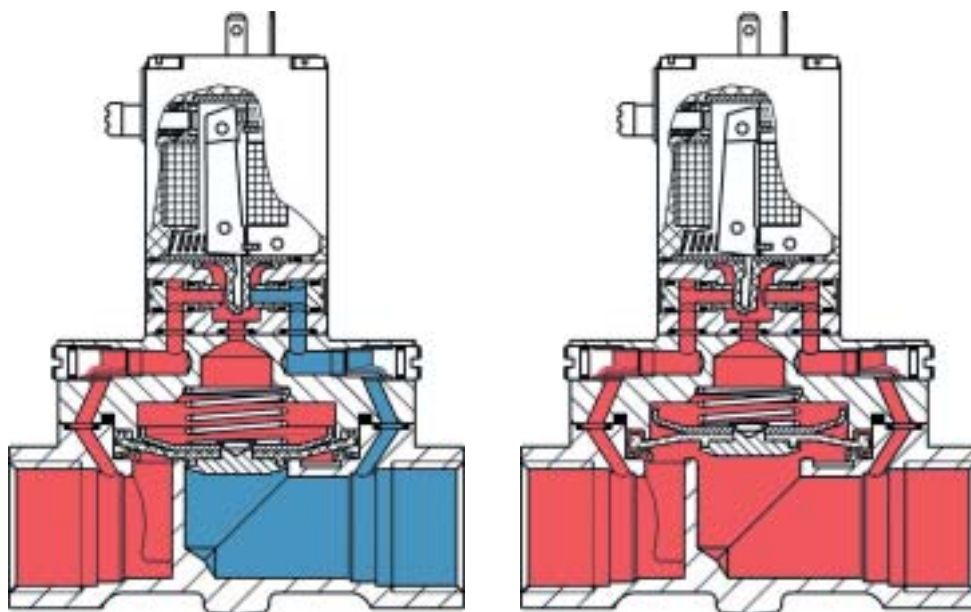


Figure 8:  
Media-separated servo-assisted solenoid valve with diaphragm and 3/2-way pilot solenoid

# 3. Basics of dynamic fluid mechanics

## 3.1. Flow behavior of solenoid valves for fluidics

### 3.1.1. Differences with respect to application areas

In fluidics, solenoid valves are chiefly used as pilot valves. These can either open or close a line (ON/OFF valves) or switch over a material stream from one line to another. These are tasks of binary control engineering. Valves which are able to constantly vary their opening cross-section are required for closed-loop control-engineering tasks (continuous-action valves, control valves / proportional valves).

When selecting solenoid pilot valves for fluidics, the main interest is whether the required fluid quantity is able to flow through the valve at the given pressure differential, i.e. whether the valve features an adequately large cross-section and an adequate switching capacity. In the case of control valves, the shape of the valve characteristic curves (opening, flow and operating characteristic curve) is also of importance.

## 3.2. Flow behavior and $k_v$ value of fluids

### 3.2.1. Volume flow and mass flow

With fluids, the volume flow through a valve or fitting can generally be calculated on the basis of the following formula.

$$\dot{V} = \alpha \cdot A \sqrt{\frac{2 \cdot \Delta p}{\rho}} = A \sqrt{\frac{2 \cdot \Delta p}{\zeta \cdot \rho}}$$

where  $\alpha = \frac{1}{\sqrt{\zeta}}$

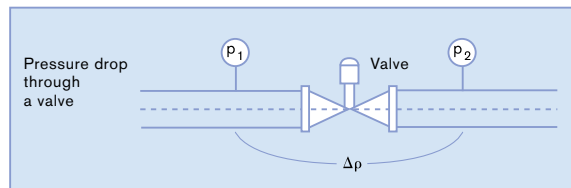
Equation 1

Where:

- $\alpha$  Flow coefficient
- A: Cross-section
- $\Delta p$ : Pressure drop through valve (pressure loss)
- $\rho$ : Density of the fluid
- $\zeta$ : Loss index or resistance index

The following applies

$$\Delta p = p_1 - p_2$$



The mass flow can be obtained with

$$\dot{M} = \rho \cdot \dot{V}$$

$$\dot{M} = \alpha \cdot A \sqrt{2 \cdot \rho \cdot \Delta p} = A \sqrt{\frac{2 \cdot \rho \cdot \Delta p}{\zeta}}$$

Equation 2

### 3.2.2. $k_v$ value

The  $k_v$  value, which is defined as follows, has been introduced to describe the flow behavior of valves:

- The  $k_v$  value is the volume flow  $\dot{V}$  (in  $\text{m}^3/\text{h}$ ) of water ( $\rho_0=1\text{kg}/\text{dm}^3$ ) at a temperature between 5 and 40 °C at a pressure drop (permanent pressure loss) at the valve of  $\Delta p_0=100\text{ kPa}$ .

From this equation, we can then deduce the following for the  $k_v$  value:

$$k_v = \alpha \cdot A \sqrt{\frac{2 \cdot \Delta p_0}{\rho_0}}$$

Equation 3

For a valve, the  $k_v$  value can be determined experimentally on the basis of the assumptions contained in the definition ( $\rho_0$  und  $\Delta p_0$ ). It thus represents a parameter for characterizing a valve. Thus, the  $k_v$  value can initially be used as a measure of the quality of the flow-dynamics design of valves. If, for example, we compare several valves with the same nominal diameter, the valve with the highest  $k_v$  value is the best-designed valve from a flow dynamics perspective.

Since the  $k_v$  value designates a volume flow ( $\text{m}^3/\text{h}$ ), the frequently encountered designations “flow-rate coefficient” or “valve coefficient” are misleading since they presuppose that  $k_v$  is non-dimensional.

### 3.2.3. $c_v$ value and $Q_{Nn}$ value

In countries using the Imperial system, the  $c_v$  value is used as the flow parameter instead of the  $k_v$  value.

- The  $c_v$  value is the volume flow (in US gallons/minute) of water at a temperature of 60 °F with a pressure loss of 1 psi through the valve.

Where:

1 US gallon/minute = 0.227  $\text{m}^3/\text{h}$  and  
1 psi = 0.069 bar (psi: pounds per square inch).

The  $Q_{Nn}$  value, which is defined as follows, is another flow parameter used for valves in pneumatics. The  $Q_{Nn}$  value is the volume flow (in liters/minute) of air at a temperature of +20 °C and at an input pressure of 6 bar and a pressure drop through the valve of 1 bar.

The following conversion factors apply for converting  $k_v$  to  $c_v$  and  $Q_{Nn}$ :

$$k_v = 0.86 c_v$$

$$k_v = 1078 Q_{Nn}$$

### 3.2.4. Interrelationship between volume flow and kv value

If we divide equation 3 by equation 1 and reformulate accordingly, we obtain the following for the volume flow:

$$\dot{V} = k_v \sqrt{\frac{\rho_0 \cdot \Delta p}{\rho \cdot \Delta p_0}}$$

Equation 4

The volume flow of any fluid with the corresponding density (with any pressure drop  $\Delta p$ ) can be calculated with equation 4 for a valve with a given  $k_v$  value. If we reformulate equation 4 accordingly, it is possible to calculate the pressure loss  $\Delta p$  at any volume flow values and with any fluids.

On the other hand, the required  $k_v$  value can be determined at a given volume flow of any medium and at a given permitted pressure loss, thus allowing us to establish a suitable valve type.

If we substitute the values for  $\rho_0$  and  $\Delta p_0$  in equation 4 and if  $\dot{M} = \dot{\rho}V$ , it is possible to state the following everyday formulae for fluids:

Volume flow

$$\dot{V} = 100 k_v \sqrt{\frac{\Delta p}{\rho}}$$

Mass flow

$$\dot{M} = 100 k_v \sqrt{\rho \Delta p}$$

## 3.3.

### Flow behavior with gases

#### 3.3.1. Mass flow and volume flow with gases

The relationships stated for fluids can also be applied to gases provided the differences resulting from compressibility and the special aspects of sub-critical and super-critical outflow applicable to gases are allowed for.

In the case of fluids, both the volume flow  $V$  and the mass flow  $M$  can be stated as a function of the pressure drop  $\Delta p = p_1 - p_2$  through the valve, i.e. as a function of the pressure differential (equations 1 to 4). By contrast, in the case of gases, there is a dependence on the ratio of the pressure  $p_2$  and  $p_1$ , which can be expressed by the outflow function  $\psi$ . Thus, the following initially applies to mass flow:

$$\dot{M} = \alpha \cdot A \cdot \psi \sqrt{2 \cdot \rho_1 \cdot p_1}$$

Equation 5

Where:

- $\alpha$ : Flow coefficient
- $\psi$ : Outflow function (function of pressure ratio  $p_2/p_1$ )
- $A$ : Cross-section
- $\rho_1$ : Density of the gas upstream of the valve
- $p_1$ : Pressure of the gas upstream of the valve

Everyday formulae for fluids, meaning of symbols	
$k_v$	Defined volume flow of water in m <sup>3</sup> /h
$\dot{V}$	Volume flow in m <sup>3</sup> /h
$\dot{M}$	Mass flow in kg/h
$p_1$	Absolute pressure at valve inlet in MPa
$p_2$	Absolute pressure at valve outlet in MPa
$\Delta p$	Pressure drop through valve in MPa
$\rho$	Density in kg/m <sup>3</sup>

Table 1

Specific values of certain media			
Type of gas	$\kappa$ (Konstante)	$\left(\frac{p_2}{p_1}\right)_{crit}$	$\psi_{max}$
Diatomic gases, e.g. N <sub>2</sub> , O <sub>2</sub> , and CO	1.400	0.528	0.484
Air	1.402	0.53	0.49
Triatom. gases, e.g. CO <sub>2</sub> ; superheat. steam	1.300	0.546	0.473
Sattdampf	1.135	0.577	0.45

Table 2

A corresponding relationship can also be stated for the volume flow.

### 3.3.2. Outflow function $\psi$ and critical pressure ratio

Figure 9 shows  $\psi$  as a function of the pressure ratio  $p_2/p_1$ . In addition,  $\psi$  is slightly dependent on the adiabatic exponent  $\kappa$  which must be entered as a parameter.  $\kappa$  is a constant for a specific ideal gas (see Table 2).

#### Outflow function $\psi$

If we reduce the pressure ratio  $p_2/p_1$  starting from value 1, i.e. reduce  $p_2$  with constant pressure  $p_1$ ,  $\psi$  and thus  $M$ , initially rises. Starting at a specific pressure ratio which is referred to as the "critical pressure ratio", the outflow function  $\psi$  and thus also the mass flow remain constant ( $\psi_{max}$  and  $M_{max}$ ). The critical pressure ratio is calculated as follows:

$$\left(\frac{p_2}{p_1}\right)_{krit} = \left(\frac{2}{\kappa + 1}\right)^{\frac{\kappa}{\kappa - 1}}$$

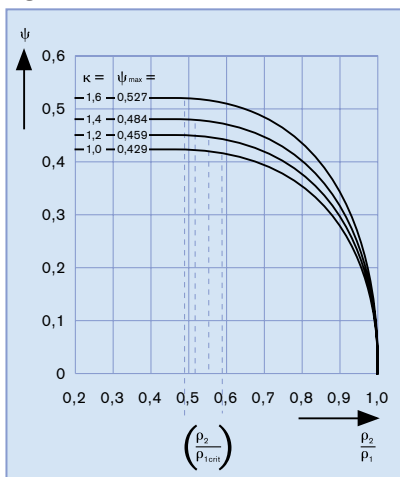
Equation 6

In addition to the adiabatic exponent  $\psi$ , Table 2 shows the critical pressure ratios and values of  $\psi_{max}$  for certain gases.  $\psi_{max}$  may assume values between 0.5 and 0.6 for popular media. The critical pressure ratios lie approximately between 0.45 and 0.55. For practical tasks, it suffices to use a critical pressure ratio of

$$\left(\frac{p_2}{p_1}\right)_{crit} \approx 0,5$$

$$(p_2 = 1/2p_1).$$

Figure 9



### 3.3.3. Sub-critical and super-critical outflow

On the basis of this ratio, a distinction is made in regards to the outflow behavior of gases in valves between a sub-critical outflow and a super-critical outflow:

$$\frac{p_2}{p_1} > \left(\frac{p_2}{p_1}\right)_{crit}$$

= Sub-critical outflow,

$$\frac{p_2}{p_1} \leq \left(\frac{p_2}{p_1}\right)_{crit}$$

= Super-critical outflow.

The differences between sub-critical and super-critical outflows are shown

While, in the case of sub-critical outflow, the mass flow can be calculated on the basis of equation 5, in the case of super-critical outflow, this equation can be specified more precisely as follows:

$$\dot{M} = \alpha \cdot A \cdot \psi_{max} \sqrt{2 \cdot \rho_1 \cdot p_1}$$

Equation 7

By way of approximation, we can use a value of 0.5 for  $\psi_{max}$ .

If we divide equation 5 or equation 7 by equation 1, which describes the  $k_v$  value, and reformulate accordingly, we obtain the following relationships for calculating the mass flow of gases from the  $k_v$  value:

$$\dot{M} = k_v \cdot \psi \sqrt{\frac{\rho_0 \cdot \rho_1 \cdot p_1}{\Delta p_0}}$$

Equation 8

for sub-critical outflow

$$\dot{M} = k_v \cdot \psi_{\max} \sqrt{\frac{\rho_0 \cdot \rho_1 \cdot p_1}{\Delta p_0}}$$

Equation 9

for super-critical outflow.

Thus, using equations 8 and 9, it is also possible to calculate the mass flow values or volume flow values of gases from the  $k_v$  values.

### 3.3.4. Everyday formulae for mass flow and volume flow with gases

From a practical standpoint, various correction factors which, among other things, are also intended to allow for flow of viscous fluids have been introduced in the formulae for mass flow and volume flow in the case of gases.

Meaning of symbols:

- $k_v$ : Defined volume flow in  $m^3/h$
- $V$ : Volume flow of gases in  $m^3/h$  (at 0.1 MPa and 20 °C)
- $M$ : Mass flow in  $kg/h$
- $p_1$ : Absolute pressure at valve inlet in MPa
- $p_2$ : Absolute pressure at valve outlet in MPa
- $\Delta p$ : Pressure drop through valve in MPa
- $\rho$ : Density of gases in  $kg/m^3$  (at 0.1 MPa and 20 °C);  $v_2$  specific volume at  $p_2$  in  $m^3/kg$
- $v_k$ : Specific volume at  $p_1/2$  in  $m^3/kg$ ;
- $T$ : Absolute temperature at valve inlet in K.

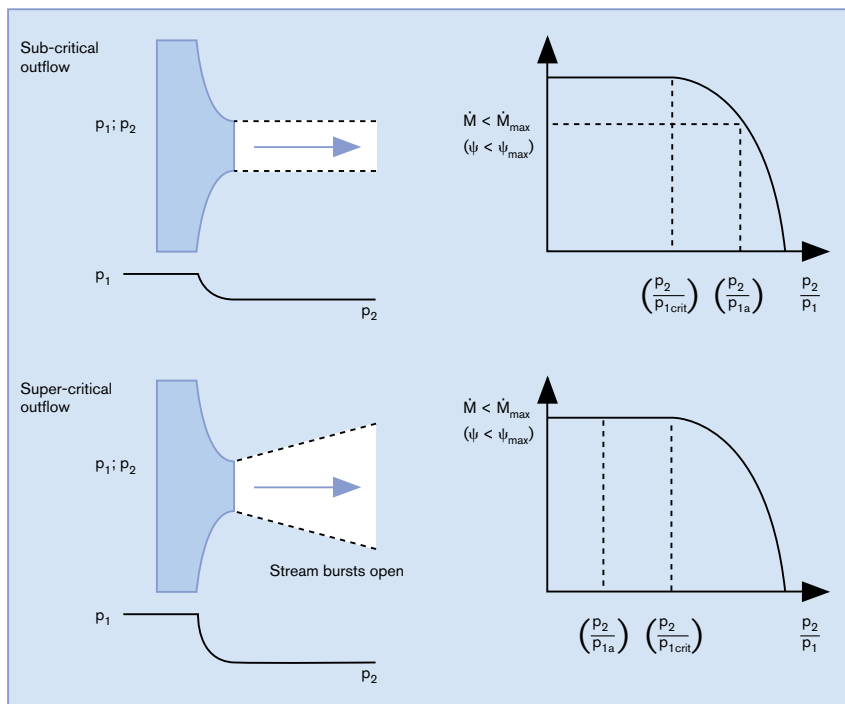


Figure 10: Sub-critical behavior and super-critical outflow

Everyday formulae for gases and steam		
	Gases	Steam
	Mass flow	Mass flow
sub-critical	$\dot{M} = 5140 k_v \sqrt{\frac{\rho \Delta p p_2}{T}}$	$\dot{M} = 100 k_v \sqrt{\frac{\Delta p}{v_2}}$
super-critical	$\dot{M} = 2750 k_v p_1 \sqrt{\frac{\rho}{T}}$	$\dot{M} = 100 k_v \sqrt{\frac{p_1}{2v_k}}$

### 3.4.

## Opening and closing operations in pipes with fluids

### 3.4.1. Origination and propagation of pressure waves

If the velocity of a fluid stream in a pipe changes as the result of opening or closing a valve, it results in a conversion of the kinetic energy of the fluid into a pressure wave which is propagated from the valve at the propagation speed "a" of the flow medium against the flow direction (Figure 11), until reaching the tank or vessel outlet (deflection point) where it is reflected again, etc. This results in pressure undershoots and overshoots which are referred to as suction surges and pressure surges or "water hammer phenomena".

In the case of compressible fluids, the propagation speed "a" of pressure and velocity changes is equal to the speed of sound a in the medium in question.

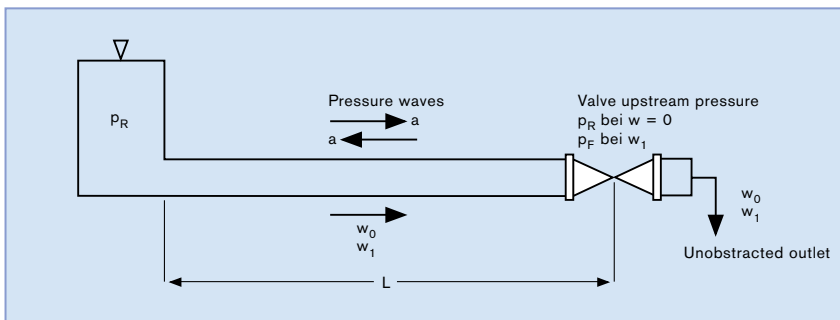


Figure 11: Basic mechanical construction of a simple pipe run system

Speed of sound "a" for fluids in thick-walled, rigid pipes:

$$a = \sqrt{\frac{E}{\rho}} \text{ [m/s]}$$

Where:

- E: Modulus of elasticity of the medium in N/m<sup>2</sup>
- ρ: Density of the medium.

Speed of sound "a" for fluids in thin-walled, flexible pipes:

$$a = \sqrt{\frac{E_F}{\rho} \cdot \frac{1}{1 + \frac{D \cdot E_F}{S \cdot E_R}}} \text{ [m/s]}$$

Equation 10

Where:

- D: Pipe diameter
- S: Wall thickness
- E<sub>F</sub>: Modulus of elasticity of the fluid
- E<sub>R</sub>: Modulus of elasticity of the pipe material.

The following approximate values can be assumed for the speed of propagation or speed of sound in water:

Thick-walled metal pipes: a ≈ 1300 m/s

Thin-walled pipes: a ≈ 1000 m/s.



### 3.4.2. Opening and closing times of solenoid valves (response times)

The magnitude of the suction or pressure surges also depends on the opening or closing times of the valves. Opening time  $t_{op}$  of solenoid valves is determined by the time which elapses up to the build-up of the magnetic field after switching on the coil voltage and by the mass inertia of the valve piston with the solenoid core. Closing time  $t_{cl}$  depends on the magnetic inertia of the solenoid system, the mechanical inertia and the spring force on the core or armature, as well as on fluidic influences, such as the type of medium (fluid or gaseous) and viscosity.

In the following two sections focusing on the origination of suction and pressure surges, we initially assume that the solenoid valves open and close at time  $t = 0$ . On the basis of this, an estimate is provided in each case as to how the definitive opening and closing times affect the magnitude of the suction and pressure surges.

### 3.4.3. Origination of suction surges with fluids

If a shut-off line which is pressurized at pressure  $\Delta p$  (idle pressure  $p_R$  in Figure 11) is suddenly opened at one end, in time  $t_{op}=0$ , the fluid discharges at the following velocity after opening:

$$w_0 = \frac{\Delta p}{a \cdot \rho}$$

Where:

- $w_0$  : Velocity after opening of the valve in time  $t=0$
- $\Delta p$ : Pressure before opening
- $\rho$ : Density of the fluid
- $a$ : Propagation speed of the pressure waves.

Directly after opening of the valve, a sudden pressure drop occurs, which is referred to as a “suction surge” or “negative pressure surge”. This suction surge results in a “partial vacuum wave” which is propagated at the speed of sound from the valve inlet against the flow direction. At all points covered by the partial vacuum wave, the fluid initially moves at velocity  $w_0$ , while it is at rest at all other positions of the pipe run in the propagation direction in front of the wave front. The pressure wave is reflected at the tank outlet, moves back to the valve inlet and is reflected again there, etc. With these wave movements, the outflow velocity increases gradually until, ultimately, the maximum velocity  $w_1$  is reached at stationary outflow, which can be calculated on the basis of the following formula:

$$w_1 = \sqrt{\frac{2 \cdot \Delta p}{\rho}}$$

Where:

- $w_1$ : Velocity with stationary outflow
- $\Delta p$ : Pressure before opening
- $\rho$ : Density of the fluid.

A suction surge that is produced by a sudden opening of a valve in time  $t_{op} = 0$  reduces the medium pressure at maximum down to 0 bar. The suction surge thus cannot increase above the actual opening pressure or idle pressure. Consequently, the suction surge does not generally contribute in the same way to causing noise and increasing the pressure stressing of the system as does a pressure surge which may reach many times the operating pressure (idle pressure).

A finite opening time of the valve ( $t_{op} > 0$ ) means that the pressure waves are not produced to full strength and that the suction surge cannot, in practical terms, reach the maximum value, i.e. the operating pressure (see Figure 12).

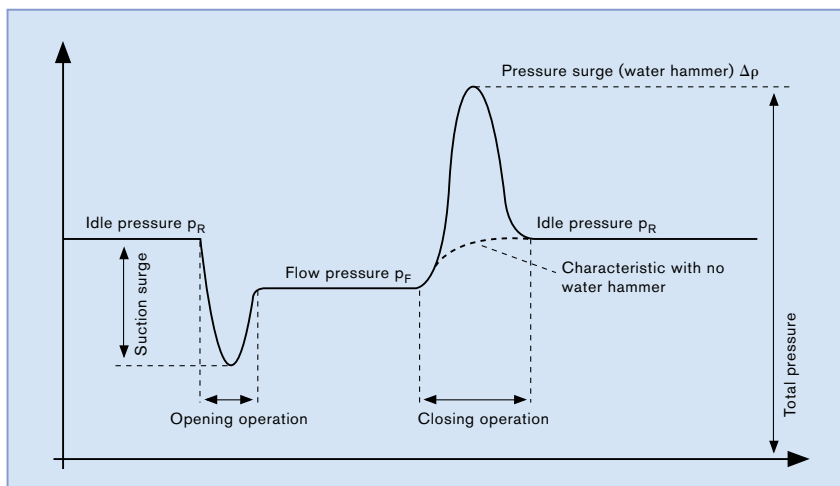


Figure 12: Valve upstream pressure as a function of time when opening or closing the valve

#### 3.4.4. Origination of pressure surges (water hammer phenomena) with fluids

If the valve is suddenly closed (closing time  $t_{cl} = 0$ ) with stationary outflow at velocity  $w_1$  and if the pipe run is thus completely shut off, the fluid column is abruptly decelerated from  $w_1$  to  $w = 0$ . This produces a pressure wave which passes through the medium against the flow direction at the speed of sound "a". The pressure wave is reflected at the tank outlet (see Figure 11), moves back to the valve inlet and is reflected there again, etc. Superimposition of the pressure waves against the flow direction and the reflected pressure waves results in pressure piling, the maximum value of which can be calculated in accordance with the following equation:

$$\Delta p_{max} = a \cdot \rho \cdot w_1$$

Equation 10

Where:

- $\Delta p_{max}$ : Pressure directly after closing the valve
- a: Speed of propagation or sound
- $\rho$ : Density of the fluid
- $w_1$ : Velocity with stationary outflow

This pressure piling in accordance with equation 10 is referred to as pressure surge or water hammer. It can be many times the operating pressure and can thus lead to bothersome noises and, above all, increased pressure stressing of the system.

The maximum value  $\Delta p_{\max}$  of the pressure surge is reduced if closing time  $t_{cl}$  of the valve is longer than the wave propagation time  $T_L$  from the valve to the first pressure wave reflection point (tank outlet in Figure 11) and back, i.e. if the following applies:

$$t_{cl} > T_L$$

**Condition 1**

If we designate the distance between valve and first reflection point (see Figure 11) as  $L$ , we can calculate the wave propagation time  $T_L$  as follows:

$$T_L = \frac{2L}{a}$$

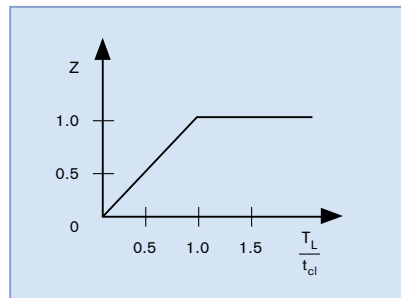
If condition 1 is met, the pressure waves are unable to develop to full strength. This also results in a dependence of the pressure surge  $\Delta p$  in accordance with equation 11 on the ratio  $T_L$  to  $t_{cl}$ . This ratio is referred as the impact number  $Z$

$$Z = \frac{T_L}{t_{cl}}$$

**Equation 11**

The impact number is defined only in the range of  $0 < Z < 1$ .

$$Z = 1 \text{ for } t_{cl} < T_L.$$



**Impact number**

This results in the following everyday formula for calculating pressure surges in the case of fluids:

$$\Delta p = Z \cdot a \cdot \rho \cdot w_1$$

Where:

- $\Delta p$ : Pressure directly after closing the valve
- $a$ : Speed of propagation or sound
- $\rho$ : Density of the fluid
- $w_1$ : Velocity with stationary outflow
- $Z$ : Impact number (see Figure 13)

Other physical laws which will not be explained at this point apply to gaseous flow media since, due to the low medium density in the case of gas pipe systems, the pressure surges are not as violent as with fluids.

### 3.4.5. Example calculation

The resultant velocities and pressures when suddenly opening and closing a pipe run will be demonstrated by way of example.

#### Problem

There is a tank containing pressurized water at the start of a pipe and a pressure of 100 bar =  $100 \cdot 10^5$  N/m<sup>2</sup> prevails in the tank (see Figure 11). At the end of the pipe, there is a solenoid valve which suddenly opens or closes the entire pipe cross-section in time  $t = 0$ . A speed of sound of  $a \approx 1000$  m/s is assumed. The density is  $\rho = 10^3$  kg/m<sup>3</sup>.

Directly after opening, the water flows out of the valve at the following velocity, in accordance with equation 12:

$$w_0 = \frac{100 \cdot 10^5}{10^3 \cdot 10^3} = 10 \text{ m/s}$$

Equation 12

The pressure at the valve suddenly drops from 100 bar to zero in this case. The wave of the pressure gradient of -100 bar moves at the speed of sound to the start of the pipe A and reaches it after  $L/a$  s, so that the water here as well now also starts to flow at 10 m/s.

The flow velocity gradually increases from 10 m/s to the outflow velocity with stationary outflow, which can be calculated in accordance with equation 13, only when the pressure waves moving back and forth in the pipe have receded.

$$w_1 = \sqrt{\frac{2 \cdot \Delta p}{\rho}} = \sqrt{\frac{2 \cdot 100 \cdot 10^5}{10^3}} \approx 140 \text{ m/s}$$

Equation 13

If the valve is suddenly closed again in time  $t = 0$  with stationary outflow, the outflow velocity is reduced from 140 m/s to zero. In this case, a pressure rise as follows is produced in accordance with equation 14:

$$\Delta p = a \cdot \rho \cdot w_1 = 10^3 \cdot 10^3 \cdot 140 = 1400 \cdot 10^3 \text{ N/m}^2 = 1400 \text{ bar}$$

Equation 14

This would be 14 times the pressure originally applied to the start of the pipe. This value applies to  $t_{cl} < T_L$ . If closing time  $t_{cl}$  is, for example, twice as long as the pressure wave propagation time  $T_L$ , the pressure rise would only be half as high, e.g. 700 bar.

#### **3.4.6. Solenoid valves with adjustable closing time and opening time (response times)**

In order to keep pressure surges within limits, it must be ensured that the closing times of valves are not too short. Valves with adjustable closing times that can thus be adapted to the relevant problem, including Bürkert valve Type 5282, are advantageous. On this valve, the closing time can be set with a restrictor adjusting screw.

With servo-assisted 2/2-way solenoid valves, the closing and opening movement is damped. The opening and closing times are determined in this case by the size of the restrictor ports in the supply and discharge of the pre-chamber compartment. The smaller the control bore, the slower the valve will close. On the basis of this interrelationship, it is possible to manufacture solenoid valves with adjustable closing times. They generally feature a constant discharge cross-section and a supply port which can be adjusted by means of a screw.

Further damping of the water hammer phenomenon can be achieved by design and geometrical shaping of a damping cone, e.g. the diaphragm support on diaphragm valves.

## 4. Materials for Bürkert solenoid valves

The materials for body, seals and actuator are selected and intermatched to produce optimum products in regards to functional reliability/safety, fluid compatibility, service life and economy.

Basically, the materials listed in the table below, with the material properties shown, are available. The available materials can be taken from the relevant data sheet for the solenoid valve.

Materials	Code	General chemical resistance	Permissible temperatures		
			Neutral media constant	Neutral media short-term	Aggressive media constant
<b>Coil materials</b>					
Epoxy resin	EP	Resistant to virtually all chemicals. Not resistant to low-molecular organic acids in high concentration and highly oxidizing substances.	-20 °C to +150 °C		
Polyamide	PA	See Body materials (plastics)			
<b>Seal and diaphragm materials</b>					
Ethylene-propylene-rubber	EPDM (A)	Good resistance to ozone and weathering, particularly suitable for aggressive chemicals. Unfavorable for oils and greases.	-30 °C to +130 °C		Dependent on the aggressiveness of the medium and the mechanical load
Fluorinated rubber (Viton)	FPM (F)	The chemical properties are the most favorable of all elastomers.	-10 °C to +150 °C	-10 °C to +200 °C	
Nitrite rubber	NBR (B)	Good resistance to oil and petrol. Unfavorable for oxidizing media.	-10 °C to +90 °C	-10 °C to +120 °C	
Chloroprene rubber (neoprene)	CR (N)	The chemical properties are very similar to those of PVC and lie between those of NBR and EPDM.	-10 °C to +100 °C	-10 °C to +110 °C	
Perfluorinat. rubber Simriz, Kalrez	FFKM	Similar to PTFE (dependent on blend)	-10 °C to +260 °C	to +320 °C (Kalrez only)	
Chemraz			+230 °C		
Polytetrafluoroethylene	PTFE (E)	See Body material (plastics)			
Steel	1.4112		-20 °C to +450 °C		-20 °C to +150 °C

Materials	Code	General chemical resistance	Permissible temperatures		
			Neutral media constant	Neutral media short-term	Aggressive media constant
<b>Metals for bodies</b>					
Stainless steel		See resistance tables	-20 °C to +400 °C		-20 °C to +150 °C
	1.4401	Also 1.4404, 1.4408, 1.4409, 1.44010			
	1.4571	Also 1.4581			
	1.4305	Also 1.4301, 1.4303			
	1.4104	Also 1.4105			
Gray cast iron	GG 25	For neutral media	-20 °C to +180 °C		
Spheroidal graphite steel	GGG 40.3	For neutral media	-20 °C to +400 °C		
Cast steel	GS - C C22, C25	For neutral media	-20 °C to +400 °C		
Brass	MS	See resistance tables	-20 °C to +250 °C		
Red bronze	RG	See resistance tables	-20 °C to +250 °C		
<b>Plastics for bodies</b>					
Polyvinyl chloride, rigid	PVC	Resistant to most acids, lyes and saline solutions	0 °C to +60 °C	0 °C to +60 °C	0 °C to +40 °C
	PVC-HT chlor.PVC		0 °C to +90 °C	0 °C to +110 °C	0 °C to +40 °C
Polypropylene Polyethylene	PP PE	Resistant to aqueous solutions of acids, lyes and salts and a large number of organic solvents. Unsuitable for concentrated, oxidizing acids.	0 °C to +100 °C		0 °C to +60 °C
Polyamide	PA	Resistant to oils, greases, waxes, fuels, weak alkalis, aliphatic and aromatic hydrocarbons.	0 °C to +100 °C		0 °C to +60 °C
Polytetrafluoroethylene	PTFE	Resistant to virtually all chemicals. Not resistant to liquid sodium and fluorine compounds.	-20 °C to +200 °C	-20 °C to +260 °C	-20 °C to +150 °C
Polyvinylidene fluoride	PVDF	Not resistant to hot solvents or ketone, ester and strong alkaline solutions.	-20 °C to +100 °C		
Polyphenyl sulfide	PPS	Resistant to diluted mineral acids, lyes, aliphatic and aromatic hydrocarbons, oils and greases, water, hydrolysis-resistant.	to +200 °C		to +260 °C
Polyether ether keton	PEEK	Resistant to most chemicals. Not resistant to concentrated sulfuric acid, nitric acid and certain halogenated hydrocarbons.	to +250 °C	to +300 °C	

# 5. Approvals

In order to ensure the free exchange of products on the European market and guarantee that valves do not pose a risk during operation, operational safety for the operator and protection for the environment is required in valve technology as well.

Over the course of the years, individual directives and national standards have resulted in clear standards that have been implemented in national or international law by the legislature. These recognized regulations ensure that

- equipment items from different countries are compatible
- that manufacturers adhere to a set of regulations regarding design and production.

These regulations relate to the following aspects:

- Protection against risks and dangers
- Interfaces between technical systems
- Testing and inspections of products
- Clear description of the content and the characteristics of products.

Legal supervisory authorities require that system operators use only equipment which meets the necessary safety requirements pursuant to these regulations. Within its range of valves, Bürkert has a large number of valves which have been granted the corresponding approvals both nationally and internationally.

We shall briefly outline the approvals and their content in the following. Please refer to the separate “Approvals” brochure for more detailed information.

## 5.1. European explosion protection

### **ATEX Directives (formerly Explosion-Protection (EX) Directives)**

The Atex Directive covers equipment, components and protection systems for use in hazardous areas. It also applies to safety facilities outside of hazardous areas if they are required for safe operation of equipment in the hazardous area with respect to the risk of explosion.

Content:

- Applies to mining and all other hazardous areas
- Standard for fundamental safety requirements
- Applies to complete protection systems
- Applies to dust explosion protection
- Classification of the devices into given categories which, in turn, may be used in the corresponding zones
- Manufacturers' quality systems must comply with the precise targets and must be certified by an appointed testing facility
- Identification with CE mark and testing facility number
- Inclusion of non-electrical equipment in this scope of validity.





## 5.2.

### International explosion-protection approvals:

In addition to the European and North American explosion-protection approvals, Bürkert also has approvals in many other countries. Some examples:

- Several Eastern European countries, such as Poland, the Czech Republic, Slovakia, Hungary, Croatia and Russia
- Japan
- Australia.



## 5.3.

### National approvals

National approvals are approvals for which no European Directives are yet available. A few examples concerning the use of solenoid valves can be found below:

#### 5.3.1. VDE approval as water valve for domestic use

The most important requirements are:

- Electrical safety requirements
- Stipulated function behavior
- Compliance with the maximum stipulated water hammer
- Tightness
- Mechanical strength of the fluidic components.



#### 5.3.2. KTW Recommendations (Plastics in Drinking Water)/W270 DVGW:

The KTW Recommendation is also required for the use of solenoid valves with VDE approval in the drinking water sector. The hygiene requirement applicable to non-metallic materials (e.g. elastomer seal materials) which come into contact with the medium is taken as a basis for this recommendation in accordance with the specification of the competent Federal Agency.



#### 5.3.3. Approval as safety shut-off valve

The European Standard EN 264 "Safety Shut-Off Devices for Combustion Plants using Liquid Fuels" is specified as the test regulation for this. A test laboratory (e.g. the German Technical Inspection Authority – TÜV) draws up a report on the requirements, such as:

- Stipulated function behavior
- Continuous loading capability
- Electrical safety requirements
- Tightness
- Mechanical strength of the fluidic components.

A test number is then issued by DIN CERTCO. The product is thus registered.

## 5.4.

### European approvals

The European approvals and CE mark must be considered in conjunction with one another. Since the products with CE marking comply with the specified safety regulations, these marked products must be accepted in all EU and EFTA states. A distinction is made between the regulated and unregulated area.

#### Certified quality system

Approval of the quality system used is performed, depending on the scope, in accordance with Standards ISO 9000 – 9004. ISO 9001 covers the quality system from development to products and up to final inspection of the products.

In the regulated area, the requirement stipulates that an independent body must conduct an EC type examination. The following directives may apply to Bürkert, depending on the particular application:

- Pressure Equipment Directive
- Gas Appliances Directive
- ATEX Directive.

In the unregulated area, it is the manufacturer's direct responsibility to attach the CE mark. In this case, a Declaration of Conformity may be required of the manufacturer, specifying the standards applied. Depending on the particular application, the following directives may apply to Bürkert:

- Low Voltage Directives
- Electromagnetic Compatibility Directive
- Vehicle Directives
- Medical Device Directives.

#### 5.4.1. Existing approvals at Bürkert

In the regulated area, Bürkert offers devices

- with EEx approval
- in accordance with the Pressure Equipment Directives
- in accordance with the Gas Appliances Directives.

Unregulated area

The CE mark on Bürkert devices refers to

- Electromagnetic compatibility in the areas
- Low Voltage Directive with the following limits:
  - 75 - 1500 V for DC voltages
  - 50 - 1000 V for AC voltages
- Pressure Equipment Directive.



## **5.5.**

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### **North American approvals**

These apply to the USA and Canada. The American Occupational Safety and Health Administration (OSHA) drew up the OSHA Regulation. In Standard 29 CFR, the requirement for electrical installations or equipment stipulates that only installations or equipment which have been tested for the specified safety requirements by an NRTL (National Registered Test Laboratory) may be installed. The NRTLs specified include the following:

- Underwriters' Laboratories (UL), with 3 different types of approval:
  - UL-listed
  - UL-recognized
  - UL-classified
- Factory Mutual (FM)
- Canadian Standards Association (CSA).

Bürkert has been granted this approval and offers to serve as an agent for other companies. The complete CSA approval, from the measurements to be carried out up to preparation of the documents can be conducted by Bürkert.

## **5.6.**

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### **International approvals**

European Directives are being increasingly recognized and prescribed in Eastern Europe.

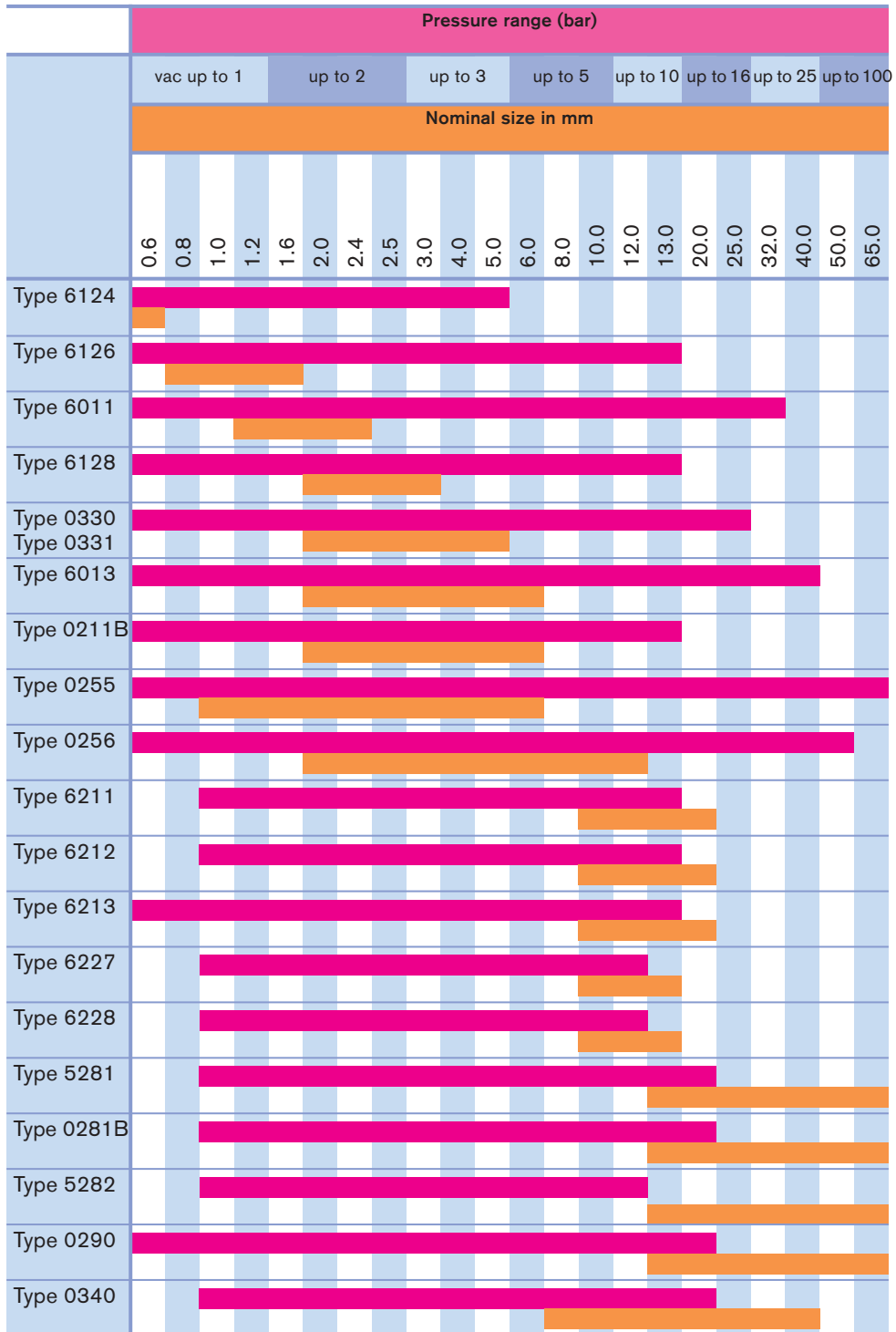


# 6. From the application to the right product:

## 6.1. Water and other neutral media

Bürkert 2/2-way and 3/2-way solenoid valves for water and other neutral media

Circuit function				Function	Body material	Seal material			Port connections	Optional Ex version	Note						
2/2-way NC (A)	2/2-way NO (B)	3/2-way NC (C)	3/2-way NO (D)	Universal distributor/collector(E/F/T)	direct-acting	servo-assisted	force pilot operated	Brass					Stainless steel	Plastic	NBR	EPDM	FPM
▪				▪	▪										Flange	media-separated	Type 6124
▪	▪				▪										Flange	media-separated	Type 6126
▪		▪	▪		▪										M5, G/NPT/RC 1/8 Flange		Type 6011
▪		▪		▪	▪										Flange, G/NPT/RC 1	media-separated	Type 6128
▪	▪	▪	▪	▪	▪										G/NPT/RC 1/4 Flange	▪ media-separated	Type 0330 Type 0331
	▪				▪										G/NPT/RC 1/8, 1/4 Flange	▪	Type 6013
					▪										G/NPT/RC 1/8, 1/4		Type 0211B
▪					▪										G/NPT/RC 1/4, 3/8, 1/2	▪	Type 0255
▪					▪										G/NPT/RC 1/4, 3/8, 1/2	▪	Type 0256
▪					▪										G/NPT/RC 1/4 - 1		Type 6211
▪	▪				▪										G/NPT/RC 1/4 - 1	media-separated	Type 6212
▪					▪										G/NPT/RC 1/4 - 2		Type 6213
▪					▪										Hose G3/8, G3/4	butt-mountable	Type 6227
▪					▪										G/NPT/RC 3/8, 1/2		Type 6228
▪					▪										G/NPT/RC 3/8 - 2 1/2, Flange	▪	Type 5281
	▪				▪										G/NPT/RC 3/8 - 2 1/2, Flange		Type 0281B
▪	▪				▪										G/NPT/RC 1/2 - 2 1/2, Flange	▪ media-separated	Type 5282
▪					▪										1/2 -2", Flange (GG)		Type 0290
		▪	▪		▪										G/NPT 3/8 - 1 1/2	▪	Type 0340



## 6.2. The right product for neutral gaseous media

Bürkert 2/2-way and 3/2-way solenoid valves for neutral gaseous media

Circuit function				Function	Body material	Seal material												
2/2-way NC (A)	2/2-way NO (B)	3/2-way NC (C)	3/2-way NO (D)	Universal distributor/collector (E/F/T)	direct-acting	servo-assisted	force pilot operated	Brass	Stainless steel	Plastic	NBR	EPDM	FPM	PTFE/FFKM	Port connections	Optional Ex version	Note	
		▪	▪		▪					▪			▪		Flange	▪ Also with manual override		Type 6104
		▪	▪	▪	▪					▪			▪		Flange	▪ Also with manual override		Type 6106
▪					▪			▪	▪				▪		M5, G/NPT/RC 1/8 Flange			Type 6011
		▪	▪		▪			▪	▪				▪		M5, G/NPT/RC 1/8 Flange	▪ Also with manual override		Type 6012
	▪				▪			▪	▪	▪	▪	▪	▪		G/NPT/RC 1/8, G1/4 Flange	▪ Also DVGW		Type 6013
					▪			▪	▪		▪	▪	▪		G/NPT/RC 1/8, G1/4			Type 0211B
		▪	▪	▪	▪			▪	▪	▪			▪		G/NPT/RC 1/8, G1/4 Flange	▪ Also with manual override		Type 6014
▪	▪	▪	▪	▪	▪			▪	▪		▪	▪	▪		Flange	▪ Media-separated, manual override		Type 6128
▪	▪	▪	▪	▪	▪			▪	▪	▪	▪	▪	▪		G/NPT/RC 1/4 Flange	▪ Media-separated, manual override		Type 0330 Type 0331
▪					▪			▪	▪	▪	▪	▪	▪		G/NPT/RC 1/4, 1/8, 1/2			Type 0255
▪	▪				▪			▪	▪				▪		G3/8	▪ Also with manual override		Type 6041
▪					▪			▪	▪	▪	▪	▪	▪		G/NPT 1/4, 3/8, 1/2			Type 0256
▪					▪			▪	▪		▪	▪	▪		Rp 1/4, Rp 1/2	DVGW		Type 0285
▪					▪			▪	▪						G3/8, G1/2	DVGW		Type 0288
▪					▪			▪	▪						G3/4, G1	DVGW		Type 0293
▪					▪			▪	▪	▪	▪	▪	▪		G/NPT 1/4, 3/8, 1/2			Type 6211
▪	▪				▪			▪	▪		▪	▪	▪		G/NPT/RC 3/8 - 1			Type 6221
▪	▪				▪			▪	▪				▪		G/NPT/RC 1/2 - 1"			Type 5404
▪					▪			▪	▪	▪	▪	▪	▪		3/8 - 2 1/2, Flange	▪ Also with manual override		Type 5281
▪					▪			▪	▪	▪	▪	▪	▪		1/2 - 2", Flange (GG)			Type 0290
		▪	▪		▪			▪	▪						G/NPT 3/8 - 1 1/2	▪ With manual override		Type 0340
		▪	▪		▪			▪	▪						G/NPT 3/8 - 1 1/2	▪ With manual override		Type 0343
		▪	▪		▪			▪	▪						G/NPT 3/8 - 1 1/2	▪ With manual override		Type 0344



## 6.3. The right product for aggressive media

Bürkert 2/2-way and 3/2-way solenoid valves for aggressive media

Circuit function				Function	Body material				Seal material				Port connections						
2/2-way NC (A)	2/2-way NO (B)	3/2-way NC (C)	3/2-way NO (D)	Universal distributor collector (E/F/T)	direct-acting	servo-assisted	force pilot operated	MS/VA	PPS	PP	PVC	PVDF			PTFE/Tefzel	NBR	EPDM	FPM	PTFE/FFKM
▪				▪	▪				▪								▪	Flange	Typ 6124
▪	▪			▪	▪				▪								▪	Flange	Typ 6126
▪	▪			▪	▪												▪	G/NPT 1/8, Hose, flange, UNF1/4 - 28	Typ 0127
▪				▪	▪								▪				▪	G/NPT/RC 1/8 Flange	Typ 0117
▪		▪		▪	▪					▪		▪					▪	G/NPT/RC 1/4, Flange	Typ 6128
▪	▪	▪	▪	▪	▪						▪	▪					▪	G/NPT/RC 1/8, G1/4	Typ 0124 Typ 0125
▪	▪	▪	▪	▪	▪			▪									▪	G/NPT/RC 1/4, Flange	Typ 0330 Typ 0331
▪	▪	▪	▪	▪	▪			▪		▪	▪	▪	▪				▪	G3/8	Typ 0121
▪		▪		▪	▪			▪									▪	G/NPT/RC 1/4	Typ 6041
▪	▪	▪	▪	▪	▪						▪	▪					▪	G/NPT 3/8 - 3/4, Solvent/fusion spigot	Typ 0131
▪					▪						▪						▪	G/NPT 3/8, 1/2, Solvent spigot	Typ 6642
▪	▪				▪						▪	▪					▪	G/NPT 1/2 - 2"	Typ 0142





## 6.4. The right product for high temperatures and steam up to 180 °C

Bürkert solenoid valves for high temperatures and steam up to 180 °C

Circuit function	Function	Body material	Seal material	Pressure range (bar)							Port connections			
				0	up to 1	up to 2	up to 3	up to 4	up to 6	up to 16				
2/2-way NC (A)	direct-acting	Brass	PTFE/graphite	Nominal size in mm										
2/2-way NO (B)				1.0	2.0	3.0	4.0	6.0	8.0	12.0			16.0	20.0
3/2-way NC (C)	servo-assisted	Stainless steel	PTFE/graphite											
3/2-way NO (D)				1.0	2.0	3.0	4.0	6.0	8.0	12.0			16.0	20.0
Universal distributor/collector (E/F/T)	force pilot operated	Brass	PTFE/graphite											
				1.0	2.0	3.0	4.0	6.0	8.0	12.0			16.0	20.0
											GNPT/RC 1/4, 1/8	Type 6013		
											GNPT/RC 1/4, 3/8, 1/2	Type 0255		
											GNPT/RC 3/8 - 1	Type 6038		
											G/NPT 1/2 - 1 1/2 DIN flange (GG)	Type 0406		
											G/NPT 1/2 - 2 DIN flange (GG)	Type 0407		

# 6.5. The right product for high pressures

Bürkert solenoid valves for high pressures

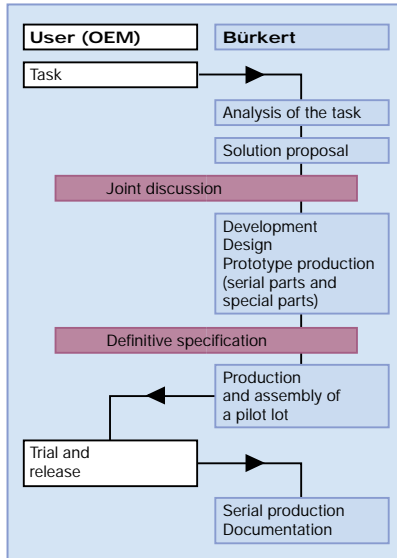
Circuit function		Function	Body material	Seal material	Pressure range (bar)						Nominal size in mm	Port connections	Optional Ex version															
2/2-way NC (A)	2/2-way NO (B)	3/2-way NC (C)	3/2-way NO (D)	Universal distributor/colector (E/F/T)	direct-acting	servo-assisted	force pilot operated	Brass	Stainless steel	PEEK				NBR	PCTFE	PTFE	0 to 1	up to 10	up to 25	up to 50	up to 100	up to 250						
▪					▪				▪	▪			▪	1.0	1.2	2.0	2.5	3.0	4.0	5.0	8.0	10.0	12.0	13.0	20.0	25.0	1/4, 3/8, 1/2	▪ Type 0255
▪	▪				▪				▪	▪			▪	1.0	1.2	2.0	2.5	3.0	4.0	5.0	8.0	10.0	12.0	13.0	20.0	25.0	GNPT 1/8-1/4	▪ Type 2200
▪					▪				▪	▪			▪	1.0	1.2	2.0	2.5	3.0	4.0	5.0	8.0	10.0	12.0	13.0	20.0	25.0	G/NPT RC 1/2-1"	▪ Type 5404
▪	▪				▪				▪	▪			▪	1.0	1.2	2.0	2.5	3.0	4.0	5.0	8.0	10.0	12.0	13.0	20.0	25.0	G/NPT 1/4-1/2	▪ Type 2400

# 7. Always unique

## Every problem is different

The diversity of components, systems and sub-bases available from Bürkert is based on decades of experience in products required by the market. This forms the basis for covering many applications and meeting many tasks. In individual cases, it may not be sufficient to configure the optimum solution for a specific task.

Individual, application-specific solutions are our concept for technically implementing special requirements with a coordinated performance mix. Such solutions frequently contain systems for standard functions such as mixing or dosing, combined with specially developed and manufactured parts. In most cases, these are individually designed and manufactured connectors.



## Every Bürkert solution is systematic

When developing new, customized solutions, it goes without saying that Bürkert draws on its comprehensive development know-how, modern production technology, application knowledge and experience gained from already implemented solutions. But another factor is also involved: the incentive and commitment to utilize all the resources required for your task in close cooperation with you, the customer and partner.

## System partnership

You know what you want. We know what we can do. Close cooperation and continual exchange of information is the path we pursue. Regardless of whether you are an OEM partner manufacturing his or her own equipment or a “normal” user, in Bürkert, you have chosen the right company for achieving a fast and efficient solution. Generally, it takes just a few weeks to solve the problem.

## The project – step by step

The spirit of this cooperation: The combination of specific user knowledge with the know-how of an experienced equipment manufacturer.

## 7.1.

### Safety valve for burner control

#### Field of application

Safety valves are fitted in the supply or return of the oil line for use in oil burner installations.

#### Design

Two versions of safety valve are mounted on the block.

Use as supply valve: the valve is normally open and is tight up to 30 bar.

Use as return valve: the valve is normally closed and is tight up to 30 bar in the direction of the safety shut-off.

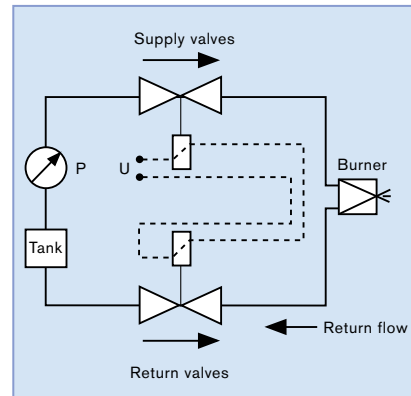
At the same time, the valve operates as a check valve and opens starting with a pressure of 0.15 bar in the return direction.

If a burner or installation is switched off, the return valve operates as a check valve (spring-controlled). Oil which is not used flows unhindered back into the tank. The supply valve shuts off in the safety shut-off (both valves are energized). No oil is routed to the burner and the oil in the line at the burner end is discharged via the return valve.



#### Characteristics

- Body material: brass, stainless steel
- Seal material: brass, stainless steel
- Seal material: FPM, PTFE, graphite
- Media: neutral gases and fluids; oils and hydraulic fluids
- Media temperature: 10 to +140 °C
- Ambient temperature: max. +55 °C
- Operating voltage: 110 V, 50 Hz
- Voltage tolerance:  $\pm 10\%$
- Duty cycle: continuous operation
- Electrical connection: tag connectors in accordance with DIN 43 650 A for Type 2508 appliance plug socket
- Installation position: any position, preferably actuator pointing upwards
- Type of protection: IP 65 with appliance plug socket
- Upstream filter: the use of the valves is allowed only with upstream strainer (mesh aperture less than 0.5 mm)



Components/Function	Quantity	Typical parameters
Supply valve	1	2/2-way valve ; WW B (normally open) DN 13 mm, flow rate = 2.0 m <sup>3</sup> /h Pressure range = 1 to 30 bar; back-pressure 1 bar
Return valve	1	2/2-way valve; WW A (normally closed) DN 13 mm, flow rate = 2.0 m <sup>3</sup> /h Pressure range = 1 to 30 bar; back-pressure 1 bar

## 7.2.

### Cooling water distribution

#### Fields of application

In process control, e.g. automatic coating machines, the individual processes must be thermally controlled with great precision. For this reason, the temperatures and flow rate of the cooling water downstream of the pressure chamber are measured. The cooling circuits are maintained at a constant level by connecting or disconnecting individual inlets.

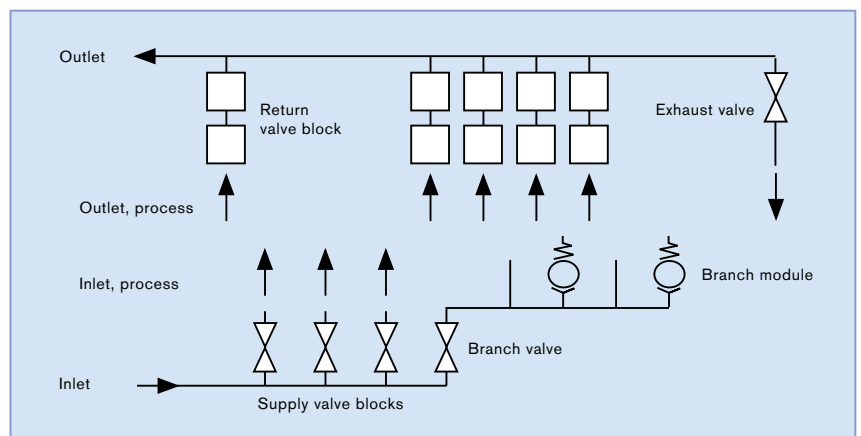
#### Design

A main manifold in the inlet distributes the water over three valves. These valves have a direct connection to the various cooling ducts. The fourth valve controls an independent cooling line. The modular design makes it possible to implement an extremely wide variety of expansion stages by simple flange-mounting. This also applies to the return. Each module in this section contains one flow meter and one temperature sensor.



#### Characteristics

- VA common lines; valve blocks made of POM
- Weight saving due to use of plastic
- Modular design enables flexible implementation of an extremely wide variety of expansion stages
- Retrofitting of expansion stages possible in fitted condition
- Front mounting enables optimum ease of maintenance during operation.



Components/Function	Quantity	Typical parameters
Supply valve block Type 6011	3	Different nominal diameters, seat contour integrated in the blocks
Branch valve, Type 6011	1	Different nominal diameters, seat contour integrated in the blocks
Branch module	1 - x	Flange-mounted distributor block with integrated check valves
Return valve block	1 - x	With integrated flow and temperature sensors
Exhaust valve	1	

### 7.3.

## Control device for lubrication equipment

### Field of application

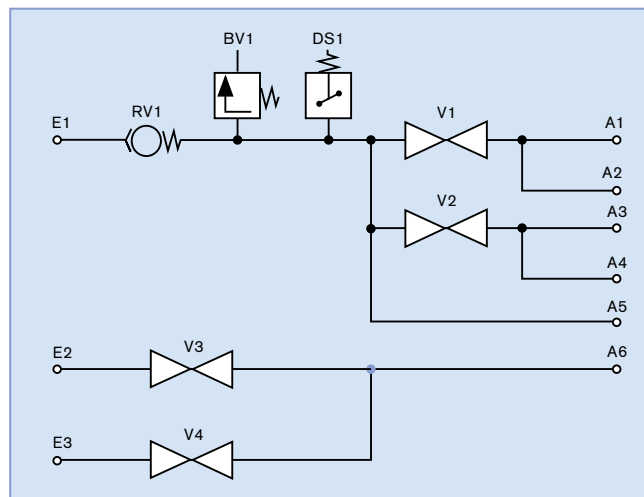
The system controls dosed application of lubricants to surfaces. It is used, among other things, for wheel flange lubrication on rail vehicles. Noise emission is minimized by application of the lubricant.

### Design

The valve block is made of anodized aluminum. The pressure relief valve protects the block against excessively high pressure from the compressor.

### Characteristics

- Aluminum body, anodized
- Seal material NBR
- For neutral gases
- Medium temperature 0 to +50 °C
- 24 V operating voltage
- Any installation position.



Components/Function	Quantity	Typical parameters
2/2-way solenoid valve, Type 6212	2	0.2 to 10 bar, required pressure differential 0.5 bar
2/2-way solenoid valve, Type 0375	2	0 to 10 bar
Pressure relief valve	1	Opening pressure 9 bar
Pressure switch	1	
Check valve		

## 7.4.

### Vacuum block for tightness control of serial parts

#### Field of application

Tightness control of packaged goods in the production process. In this case, tight packaging may not be damaged or destroyed. Leaking packaging must be detected within a short period so that action can be taken to intervene in the defective production process. The system is primarily used in series production or packaging.

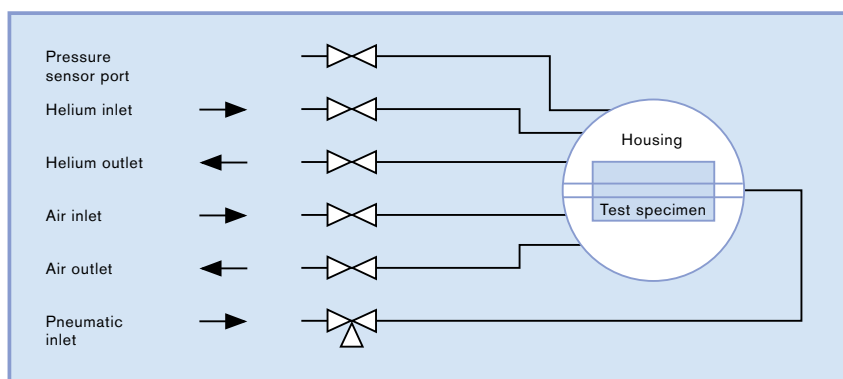
#### Design

The test specimen is positioned in a housing and the housing is sealed. The following functions are then controlled by the valve block. The air volume is evacuated from the housing. Helium is then admitted into the housing. During a brief waiting period, helium penetrates a leaking packaging. This pressure drop in the housing is measured. The helium is then evacuated from the housing and the pressure is equalized with the atmosphere. The test specimen can be removed.



#### Characteristics

- Body material: aluminum
- Seal material: EPDM
- Media: neutral gases
- Media temperature: -10 to +50 °C
- Duty cycle: continuous operation
- Ports: swiveling plug-in ports for the pneumatic end, Triclamp for the vacuum end
- Cleaning: valves and valve block cleaned for analysis version. Organic residue in the PPB range
- Vacuum valve tested  $1 \times 10^{-8} \frac{\text{mbar} \cdot \text{l}}{\text{s}}$
- Vacuum block tested  $1 \times 10^{-8} \frac{\text{mbar} \cdot \text{l}}{\text{s}}$
- Expansion stages: integrated in valve block. In some cases, equipped with further valves depending on level of automation.



Components/Function	Quantity	Typical parameters
Valve Type 0127	1	3/2-way valve; WW B (normally open)
Valve Type 0256	4	3/2-way valve; WW A (normally closed); DN 8 mm
Valve Type 0301	1	3/2-way valve; miniature valve, flange-mounted
Valve Type 6013	2	2/2-way valve; WW A (normally closed)



## 7.5.

### Water block for compressors

#### Field of application

The valve block is used in an oil-free screw compressor with water injection cooling. The compressor is driven via V-belt and operates in a closed circuit. For this purpose, the internal water supply must be constantly conditioned and cooled.

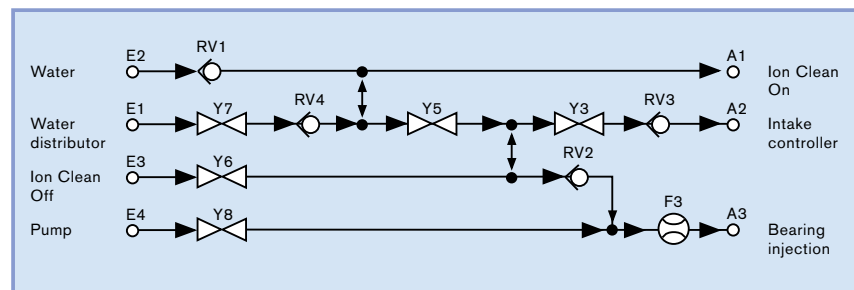
#### Design

The compact valve block consists of a coated aluminum block with 5 integrated Type 0280 valves, 4 check valves and a flow switch with flapper sensor. Material and design also allow use of de-ionized water. The block has 4 inlets and 3 outlets.



#### Characteristics

- Valve block material: coated aluminum
- Valve body material: brass
- Check valve material: brass
- Seal material: NBR
- Media: non-potable water, de-ionized water
- Media pressure: 0.2 to 16 bar
- Media temperature: -10 to +90 °C
- Ambient temperature: max. +55 °C
- Operating voltage: 230 V, 50 Hz
- Type of protection: IP 65



Components/Function	Quantity	Typical parameters
Valve Type 0280	5	DN 13 mm; $k_v$ value 4.0 m <sup>3</sup> /h
Check valve	4	
Flow switch	1	

## 7.6.

### Valve block for the food industry Valve block in the test units



#### Field of application

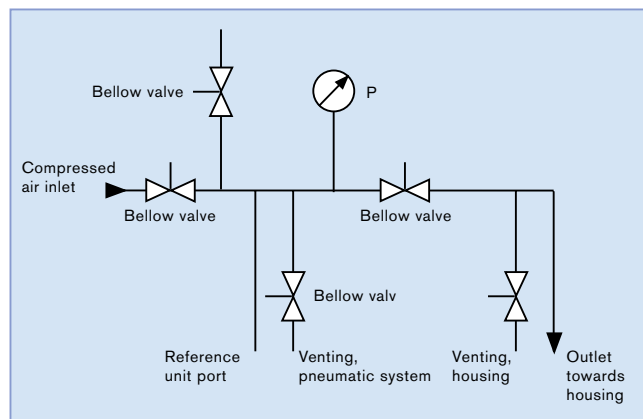
Particularly suitable in the food industry for filling containers with viscous media such as yogurt or jam. Or as a test unit in test stands for tightness testing on the basis of a reference specimen.

#### Design

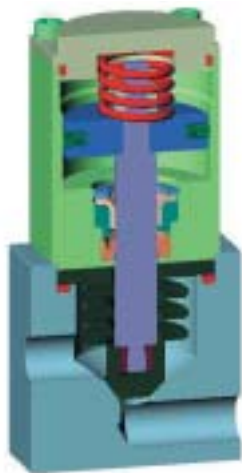
As test unit in this example: the process valves are bellows valves which are controlled pneumatically via docked pilot valves.

#### Characteristics

- Medium pressure range: vacuum up to 8 bar
- Pilot pressure range: 4.5 to 5.5 bar
- Medium port: G1/8 threaded port
- Pneumatic port: M5 threaded port
- Medium temperature range: -30 to +100 °C
- Max. ambient temperature: 0 to +55 °C
- Arrangement of inlet and outlet bores: application-specific, also laterally offset for enhanced flushing or mixing of the valve interior.



Components/Function	Quantity	Typical parameters
2/2-way bellow valve	2	Pneumatically actuated, DN 6 mm; normally closed
2/2-way bellow valve	3	Pneumatically actuated, DN 6 mm; normally open
Pilot valve	3	3/2-way flipper solenoid valve with bistable (impulse) switching function
Pilot valve	1	Stainless steel 1.4305 (optionally 1.4571), integrated valve seats



### 7.6.1. Application: bellow valve

- Pneumatically actuated 2/2-way valve
- Media separation with PTFE bellows
- Self-draining design of valve interior
- Aseptic body seal, preventing gap formation
- Light-weight pneumatic actuator housing made of aluminum.

### Characteristics

- Medium pressure range: vacuum up to 8 bar
- Pneumatic actuator pressure range: 4 bar to 8 bar
- Medium: neutral to aggressive fluids and gases
- Pneumatics: compressed air, both conditioned and also dry and oil-free
- Pneumatic port: M5 threaded port
- Medium temperature range: -30 to +100 °C
- Maximum ambient temperature: -20 to +100 °C.

Valve WWB (normally open)

Valve WWA (normally closed)

### 3/2-way pilot

- 3/2-way flipper solenoid valve with bistable (impulse) switching function
- Universally usable (circuit function T)
- Adaptation to bellows valve by means of special flange plate
- Pressure range: vacuum up to 5.5 bar
- Nominal diameter: 0.6 mm
- Power consumption: 1.5 W
- Permissible medium: neutral to aggressive gases
- Pneumatic port: M5 threaded port
- Medium temperature range: 0 to +50 °C
- Maximum ambient temperature: maximum +55 °C.

### 5/3-way pilot

- 5/3-way diaphragm booster with 3/2-way flipper solenoid valve for fluidic control
- Control valve features a bistable (impulse) switching function
- Universally usable (circuit function H)
- Adaptation to bellows valve with special flange plate
- Pressure range: 2.5 to 5.5 bar
- Nominal diameter: 2.5 mm
- Power consumption: 1.5 W
- Permissible medium: neutral gases
- Pneumatic port: M5 threaded port
- Medium temperature range: 0 to +50 °C
- Maximum ambient temperature: maximum +55 °C.



## 7.7.

### Solenoid valves in fuel cell technology

#### Field of application: exhaust valves

The system serves to drain off the moisture in fuel cell systems, regardless of whether the fuel cell system is a fuel cell system in cars, in mobile stations or in stationary installations.

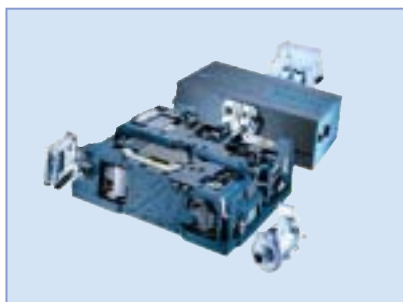
#### Field of application: recirculation

The system serves to recirculate media within the fuel cell systems, regardless of whether the fuel cell system is a fuel cell system in cars, in mobile stations or in stationary installations. With integrated additional functions such as

- Back-pressure safety
- Function without pressure differential

#### Design

Depending on the application, it is integrated as a single valve or as a modular application in the relevant systems. The single valve is generally mounted directly in the piping. With the modular application, two or more exhaust valves are combined to form a valve block. This valve block is then integrated through easy installation via optimized piping.

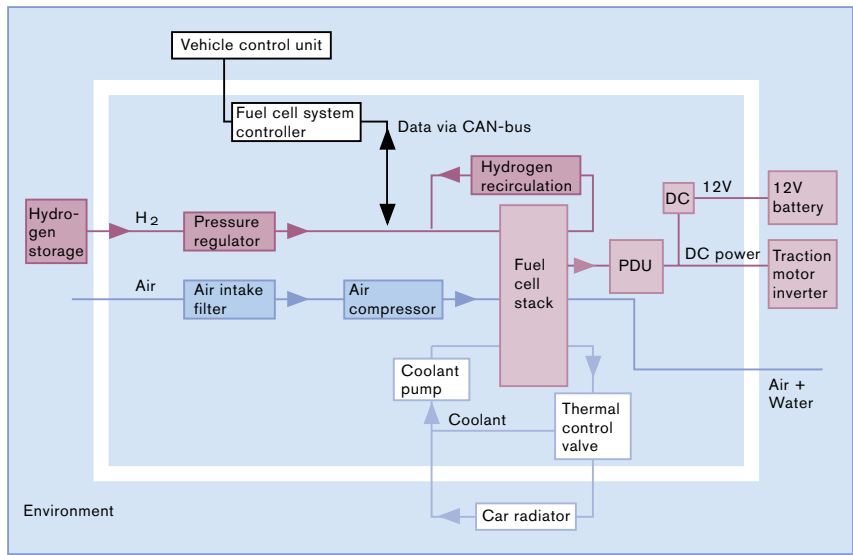


**Characteristics**

- Thanks to isolating diaphragms, suitable for de-ionized water, hydrogen, air and aggressive media
- Low weight due to use of plastic body
- Voltage range in accordance with customer requirements
- Electrical connections to automobile standard possible
- Block design means less interfaces (ports)
- Very low leakage rate.



**Basic types of the valves used**



Components/Function	Quantity	Typical parameters
Single valve		Overall widths 10, 16 or 20 mm for very high cycling rate
System solution		1 to x valves on customized block

**A**

Appliance plug socket	Page	15
Approvals	Page	40
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**C**

CE mark	Page	42
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Circuit symbols	Page	17
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Closing impact	P.	24, 25, 34, 37, 41
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Control valve	Page	27
Critical pressure ratio	Page	30
CSA approval	Page	43
$c_v$ value	Page	28

**D**

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**I**

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**U**

UL Underwriters' Laboratories	Page	43
UC Universal current	Page	18

**V**

VDE approval	Page	41
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**W**

Water hammer	Page	24,25,34,37,41
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