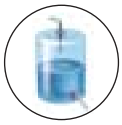
System solutions: filling level control



The smart choice of Fluid Control Systems

bürkert
Fluid Control Systems

Contents

The components of a filling level control loop

Closed-loop control is a process which occurs in more than just technical applications. Closed-loop controls run virtually everywhere and continuously. Setting the required water temperature for showering or complying with a preset speed when driving a car involves closed-loop control processes.
In principle, closed-loop control appears to be a very simple process. However, technical implementation and design are complex processes.
In order to achieve faultless operation of a closed-loop control, the individual components of the control loop must be intermatched and matched to the system to be controlled.

- The measuring instrument or sensor for detecting the variable to be controlled. A suitable sensor has to be selected in accordance with the measuring method, measuring range, media compatibility, ambient conditions and the pressures and temperatures obtained in the system.
- The controller.
  The structure or circuit function (2-point, 3-point, P, PD, PI, PID) of the controller must be matched to the system to be controlled.
  The control parameters must be matched to the controlled system.
- The final control element or actuator, via which the controller influences the system to be controlled.
  It is primarily process valves in various designs that are used as final control elements or actuators for closed-loop control of fluid streams in systems. These units must be adapted in regards to the nominal diameters (kv value) and the pressure and temperature range to the conditions in the system.
- The system to be controlled; this part is referred to as the controlled system. It is a given quantity and, in most cases, it cannot be modified.

1. Sensor selection, which measuring principle?

The overview below shows the most conventional filling level measuring methods. The operating parameters specified provide an approximate overview of the possible applications.

Measuring method	**Continuous measurement in fluids**	**Limit level detection in fluids**
Radar Microwave	Non-contact measuring method applicable in virtually all fluids and pasty media. Can even be used under difficult conditions such as the formation of hazes, mists, vapors and gas. Measuring range: up to 30 m Temperature: up to 300 °C Pressure: up to 64 bar Cannot be used in applications with media with a low dielectric constant (♏ < 1.4).	
Ultrasonic	Non-contact measuring method, can be used universally, even with aggressive fluids. Measuring range: up to 50 m Temperature: up to 90 °C Pressure: up to 2 bar Can only be restrictedly used with in the formation of hazes, mists or gas or foaming media and cannot be used with high tank pressures or vacuum.	Non-contact measuring method or measuring method involving physical contact with the medium, depending on the type, can be used universally, even with aggressive fluids. Temperature: up to 90 °C Pressure: up to 2 bar Can be used on a restricted basis with the formation of hazes, mists or gas or foaming media and cannot be used with high tank pressures.
Hydrostatic pressure	Measuring method involving physical contact with the medium. Can be used with fluids and pasty media. Insensitive to foaming. Measuring range: up to over 40 m (special versions up to 200 m) Temperature: up to 100 °C The measurement result is dependent on the density of the medium. In the case of pressurized tanks, two measuring instruments or a differential pressure measuring instrument must be used.	

Measuring method	Continuous measurement in fluids	Limit level detection in fluids
Capacitive	Universal measuring method involving physical contact with the medium, can be even be used in aggressive fluids. Largely insensitive to adhering media. Measuring range: up to 25 m Temperature: up to 400 °C Pressure: up to over 100 bar The dielectric constant of the medium should be greater than 1.4. Fluctuations in the dielectric constant of the medium (e.g. resulting from temperature changes or a change in composition) affect the measurement results. Special designs or installations are required for measurement in plastic tanks.	Universal measuring method involving physical contact with the medium, can even be used in aggressive fluids. Largely insensitive to adhering media. Druck: bis über 100 bar Temperature: up to 400 °C Pressure: up to over 100 bar In contrast to continuous measurement, fluctuations in the dielectric constant of the medium are non-critical in this case.
Vibration		Measuring method involving physical contact with the medium, for use in all types of fluids. Can also be used in pasty media. Measurement is independent of turbulence, contamination of the medium and the electrical properties of the medium. Temperature: up to 150 °C Pressure: up to over 30 bar The medium must meet the following requirements with respect to density and viscosity: Density: > 0.7 kg/dm^3 Viscosity: < 10,000 mPas
Conductive		Measuring method involving physical contact with the medium. Simple, low-cost measuring method for virtually all conductive fluids. Temperature: up to 150 °C Pressure: up to over 60 bar The measuring method is sensitive to adhering media. Cannot be used in non-conductive media (e.g. hydrocarbons).

2. Controller selection, which controller type?

A closed-loop control system must ensure that the actual value is equal to the set-point value or is adjusted to the set-point value under all circumstances. In addition, the closed-loop control must operate stably.

In order to meet these requirements when designing a control loop, the appropriate controller must be selected for a given controlled system and the controller must be matched to the controlled system.

The following evaluation of the suitability of the various controllers for use in a closed-loop filling level control system can be stated on the basis of practical experience.

On/off switching controllers	
2-point	**3-point**
Suitable	Suitable

Continuous-action controllers			
P	**PD**	**PI**	**PID**
Permanent control deviation		No permanent control deviation	
Suitable	Suitable	Suitable	Over-dimensioned

After an appropriate controller has been selected, the controller's parameters must be matched to the controlled system in a second step. Our "Competences" brochure provides a more detailed description of how to access the parameters.

3. Control elements/selection, rating

It is mainly process valves, in a very wide variety of designs, which are used as final control elements or actuators for open-loop control and closed-loop control of fluid streams in installations.

Pilot valves which have only two or a few circuit states are used for open-loop control tasks. Control valves that are able to continuously set fluid streams are used for closed-loop process control tasks. Pilot valves and control valves have very different tasks in some cases, so that the rating and selection of both valve types necessitates greatly different procedures.

3.1. Rating and selection of pilot valves

Pilot valves can either open or close a line (on/off valve) or can switch over a material stream from one line to another.
The first important criterion for the valve being selected is to ensure that the required fluid quantity be able to flow through the valve at a given pressure differential, i.e. the valve cross-section must be adequately large. The following rule of thumb often applies: line cross-section is equal to valve (connection) cross-section. A subsequent requirement is that the valve be able to switch against the maximum pressure differential, i.e. that the valve actuator be adequately powerful. The max. switchable pressure differential is specified in the data sheet. Once the type of auxiliary energy (electrical or pneumatic) has been defined and the material suitability checked, a specific valve type can be defined and the specific valve selected.

3.2. Rating and selection of control valves

Control valves are able to constantly change their operating cross-section and thus continuously influence fluid streams. Control valves must be rated and selected in line with their specific task in order to be able to ensure correct closed-loop control function.

Initially, the connection nominal diameter must be defined in accordance with the medium and the related efficient flow velocity. The following guideline values apply in this case: 2 m/s for liquids, 20 m/s for gases and 45 m/s for steam. At minimum, the anticipated flow velocity should be checked.

The nominal pressure stage arises from knowing the valve material, the operating temperature and the max. operating pressure, e.g. from DIN 2401, or from a valve data sheet.

The actual closed-loop control function, i.e. setting a fluid flow rate of the given temperature and given pressure while simultaneously producing a defined pressure loss, is determined by the flow characteristic, the kv value. The kv value is a reference variable and is defined as follows: kv value = quantity in m^3/h of cold water (+5 ... +35 °C) which flows through the valve at 1 bar differential pressure across the valve and at stroke s.
The kv_S value is the quantity at stroke s = 100 % (valve fully open).
Analogous to this, the flow-rate coefficient cv is described in the American literature and defined as follows: the cv value (in US gal/min) is the flow rate of water at 60 °F which passes through at a pressure loss of 1 psi with the relevant stroke s.

The kv value must be calculated for the current operating data. A distinction must be made between maximum load:
maximum quantity Q_{max},
minimum $\Delta p_{(min)}$ → kv_{max}
and minimum load:
minimum quantity $Q_{(min)}$,
maximum $\Delta p_{(max)}$ → kv_{min}.

The following applies to cold water:

$$kv = Q \cdot \sqrt{\frac{1}{\Delta p}}$$

Q: Volumetric flow rate in m^3/h
Δp: Pressure differential at the valve in bar

The following applies to liquids in general (sub-critical):

$$kv = Q \cdot 0{,}032 \cdot \sqrt{\frac{\rho_1}{\Delta p}}$$

ρ_1: Density of the medium in kg/m^3

The following applies to saturated steam (sub-critical, i.e. $p_2 > \frac{p_1}{2}$):

$$kv = \frac{G_S}{22{,}4\sqrt{\Delta p \cdot p_2}}$$

G_S: Saturated steam quantity in kg/h
p_1: Pressure upstream of the valve in bar absolute
p_2: Pressure downstream of the valve in bar absolute

The following applies to saturated steam (super-critical, i.e. $p_2 < \frac{p_1}{2}$):

$$kv = \frac{G_S}{11{,}2 \cdot p_1}$$

The following applies to gases (sub-critical, i.e. $p_2 > \frac{p_1}{2}$):

$$kv = \frac{Q_N}{514} \cdot \sqrt{\frac{\rho_N \cdot T_1}{\Delta p \cdot p_2}}$$

Q_N: Volumetric flow rate in Nm^3/h
ρ_N: Standard density in kg/m^3 (standard state: 0 °C and 1013 mbar)

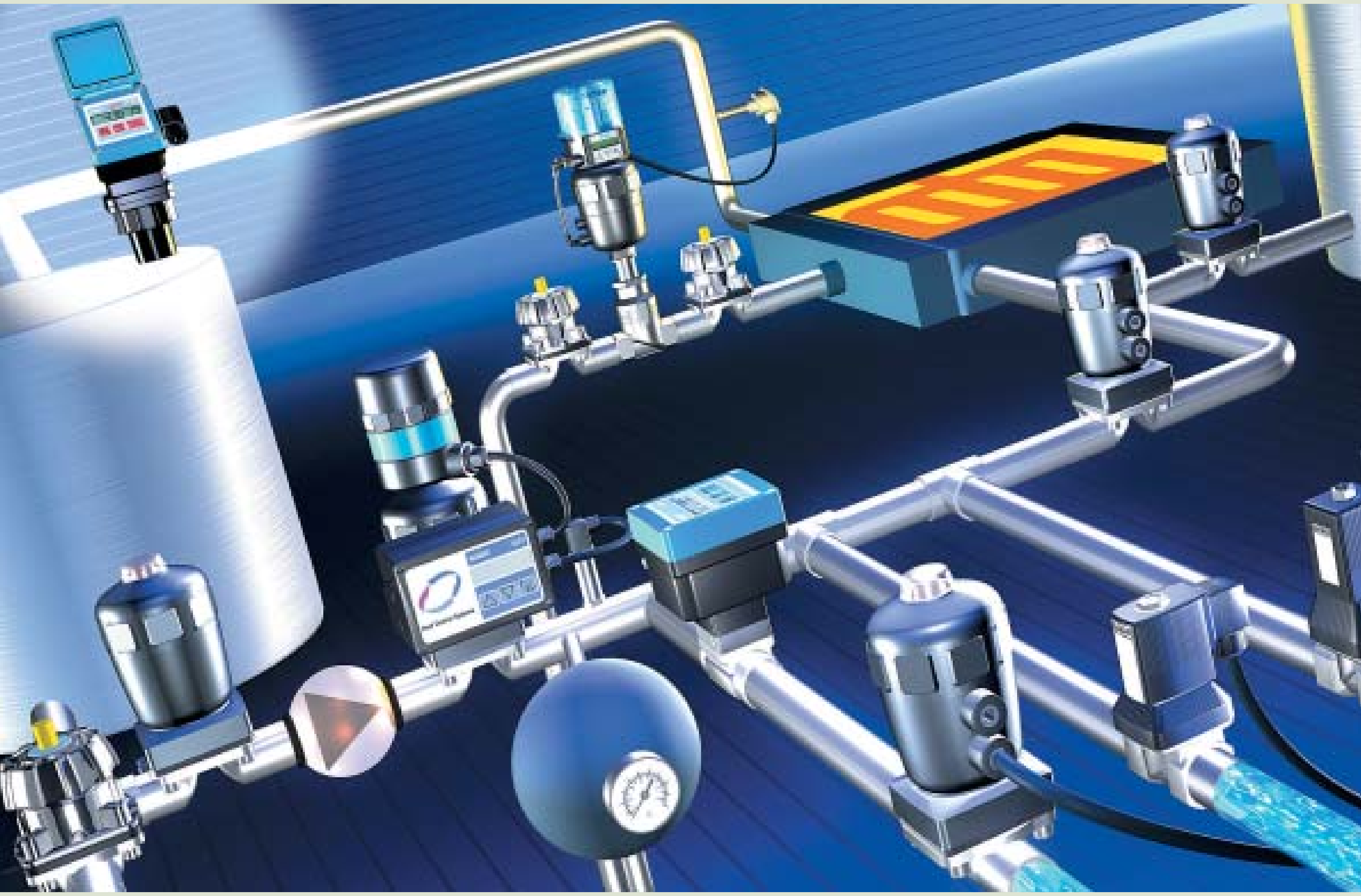
The following applies to gases (super-critical, i.e. $p_2 < \frac{p_1}{2}$):

$$kv = \frac{Q_N}{257 \cdot p_1} \cdot \sqrt{\rho_N \cdot T_1}$$

T_1: $T_1 = 273 + t_1$

After calculating the kv values, the kv_S value is determined with the aid of the tables in the data sheets. The kv_S value should only be slightly higher than the kv_{max} value. Excessive kv_S values diminish the usable rangeability and thus the control response when subject to a weak load. The kv_{min} value must be able to be reached with the selected control valve, i.e. it must lie within the rangeability. If kv_{min} lies below this limit, it should be considered whether to split the quantity over two differently sized valves, whereby the kv_S value of the smaller valve should be approx. 10 % of the kv_S value of the larger valve.

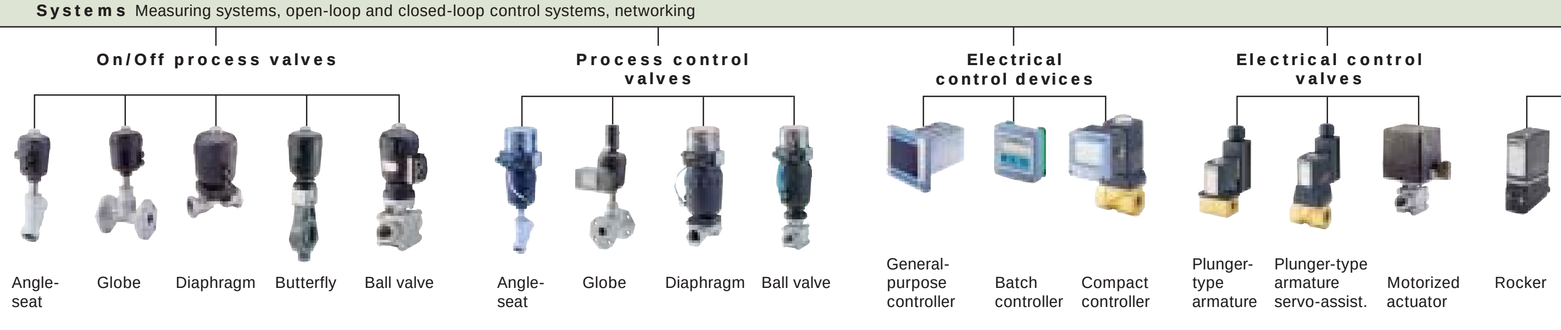
Implementing what is possible. Systematic



In principle, automation technology is very simple. The right hardware has to be combined with the right software to solve the task at hand.

The focus is always on sensors, controllers, open-loop control systems and final control elements/actuators. Nevertheless, a primary focus is also put on knowing how to deploy them to produce a functioning and efficient system for the user. This is where the subject becomes complex and when the competence of a technology leader can be of special benefit to you.

Systems Measuring systems, open-loop and closed-loop control systems, networking



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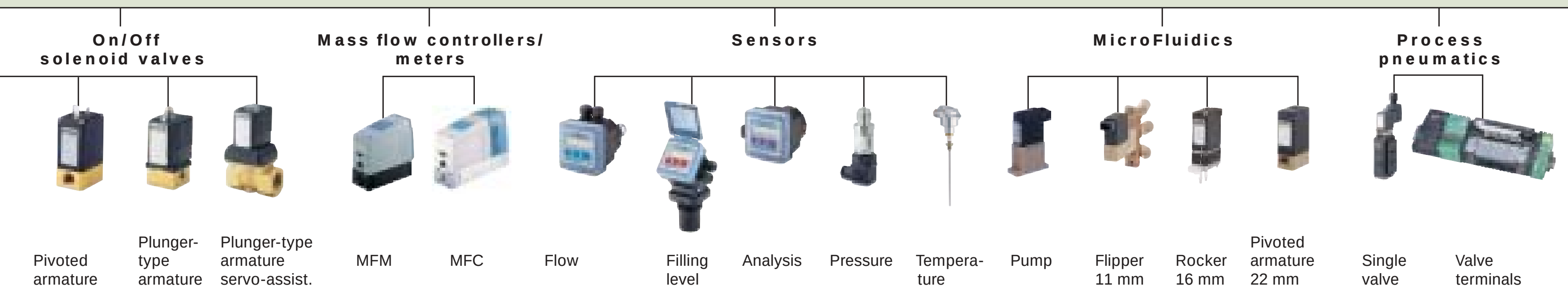
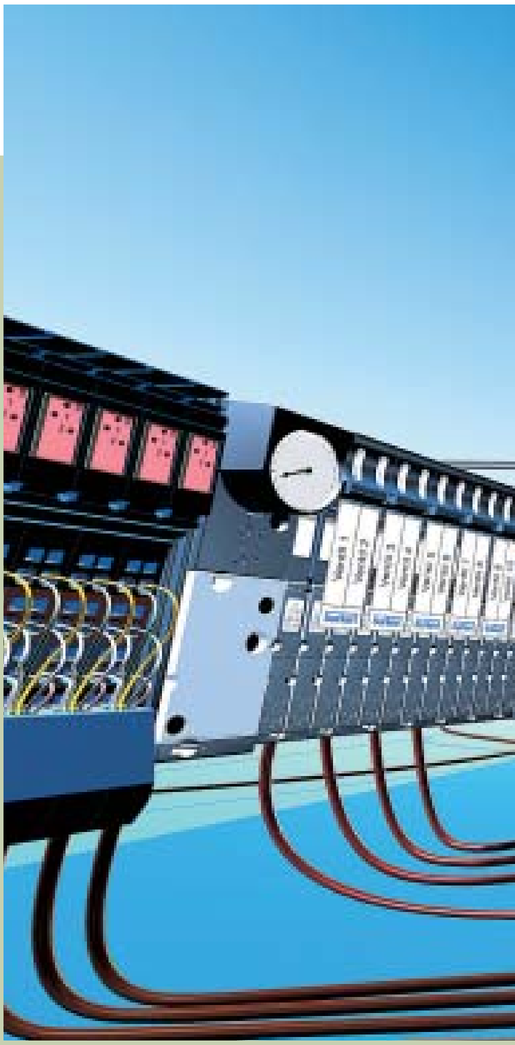
This brochure explains a part of the automation world by explaining open-loop control of processes, closed-loop control of pressures, temperatures, filling levels, flow rates and setting conductivities, pH values and other chemical variables. In short, it is a comprehensive guide to the world of filling level control which illustrates exemplary projects systematically implemented. This is supported by even more than future-oriented, combined hardware and software. We have our eye on your success!

The smart choice of Fluid Control Systems

Just as modern fluidics are more than just the technical implementation of measurement, open-loop control and closed-loop control functions, Bürkert offers more than just efficient components for this purpose. Whenever you require systematic all-in solutions that ensure your success with individually matched services, we are at your disposal. Systematic performance, from the individual component to project planning of an installation and up to how to use ecologically practical reusable packaging.
What can we do for you?



Distribution of a fluid over several tanks



Task
The fluid level in several supply tanks is to be constantly maintained within a certain range. The tanks are fed from a feed tank that is continuously kept at a constant level.

Solution
The supply tanks each feature two level switches, one for minimum filling level and one for maximum filling level. The undershoot of the minimum filling level is signaled to the master control system via the AirLINE electrical/pneumatic automation system. The diaphragm valve for filling the tank then opens. The valve is closed again when the maximum filling level is reached (upper level switch).

The filling level in the feed tank is maintained on a constant level by means of a local control loop. A continuously measuring ultrasonic level transmitter detects the filling level in the feed tank. The closed-loop filling level control function is performed by a diaphragm control valve with attached positioner. The positioner incorporates a process controller to whose actual value input the signal output of the level transmitter is connected. The set-point value of the control loop is preset via a 4 … 20 mA signal which is made available by the electrical/pneumatic automation system.

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Bürkert process valves

	Nominal diameter	Oper. press.	Function		Mode of actuation					Body material				EEx
	mm	bar	on/off	continuous	pneumatic	electropneum.	solen. actuator	motor. actuator	manual	VA	Brass	Casting	Plastic	Approval
Diaphragm	8–100	10	•	•	•	•			•	•			•	•
Globe	0.3–100	16	•	•	•	•	•		•	•	•	•		•
Angle-seat	13–65	16	•	•	•	•	•		•	•	•			•
Butterfly	50–100	10	•	•	•	•		•		•		•	•	•
Ball valve	8–80	64	•	•	•	•		•	•	•	•		•	•

Type 2031

2/2-way diaphragm control valve

Diaphragm valve 2031 embodies time-proven valve technology in a compact design for demanding tasks involving hygiene and sterilization systems, as well as for tasks in the sector of contaminated or abrasive media.

Depending on the particular application, various bodies are available, including forged bodies, precision casting bodies or cold-formed pipe valve bodies made of stainless steel. They are available in nominal diameters 8 to 100 mm and in various surface qualities.

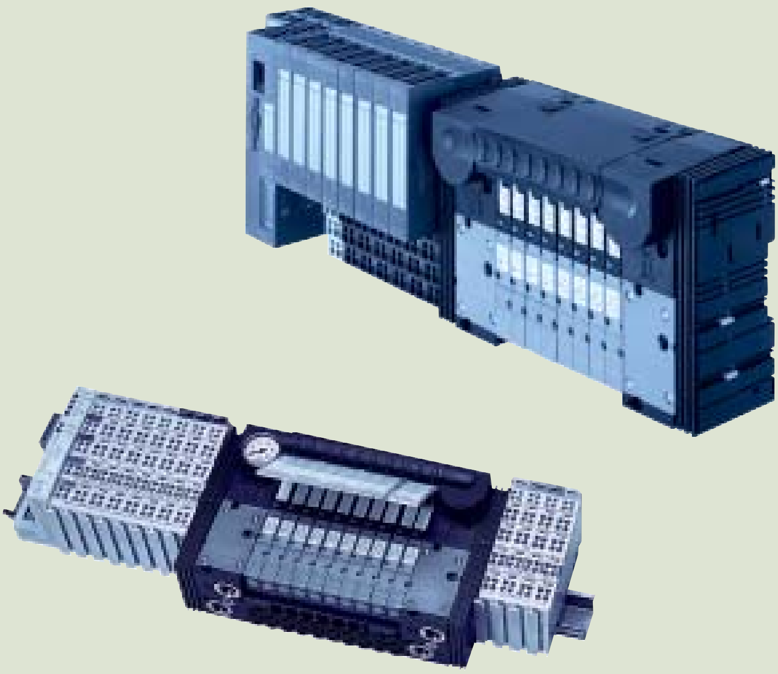
All conventional connection types as well as customized solutions can be provided. The product chamber can be fitted free of dead volumes and self-draining. Diaphragms are available made of EPDM or as sandwich diaphragms made of PTFE/EPDM and are actuated by spring-loaded open or closed polyamide or PPS actuators. High temperatures and aggressive cleaning agents are unproblematic.

Bürkert process pneumatics

	Function		Circuit function				Body material						
	direct-acting	servo-assisted	3/2-way	4/2-way	5/2-way	5/3-way	Aluminium	Plastic	Brass	Flow rate	Presssure range	Ex approval	Field bus enabl.
Pilot valves for direct mounting	•		•					•	•	up to 120 l/min	0 –10 bar	•	
Single valves	•	•	•	•	•	•	•	•		up to 1.600 l/min	Vacuum up to 10 bar	•	•
NAMUR valves	•	•	•	•	•	•	•	•		up to 1.600 l/min	0 –10 bar	•	•
Valve blocks	•	•	•	•	•	•	•	•		up to 1.300 l/min	Vacuum up to 10 bar	•	
Valve terminals	•	•	•	•	•	•	•	•		up to 1.300 l/min	Vacuum up to 10 bar	•	•

Type 8644
AirLINE electrical/pneumatic automation system

The cross-manufacturer range of control functions and electrical and pneumatic I/O modules in one product enables flexible and application-orientated system construction. The modules are interconnected by means of extremely simple snap-on mechanisms and plugged onto a standard rail. That means that assembly involves virtually no tools and no cross-wiring, drastically cutting assembly costs and minimizing the number of possible fault sources.



Mixing different fluids in a given ratio

Task

Several fluids are to be mixed in a predetermined ratio in an mixing tank. Containers are filled with the product after thorough mixing.

Solution

The first component is added to the empty mixing tank via a solenoid valve until the required quantity is reached. The volume is determined by the level sensor on the basis of the filling height and tank geometry. The controller closes the solenoid valve when the required quantity is reached and opens the valve for the second component, etc. After adding the last component, the components are thoroughly mixed by an agitator to provide a homogenous product, which is then filled into containers or further processed. During the filling process, the product is added to a container until a load cell determines that the required filling quantity has been reached.

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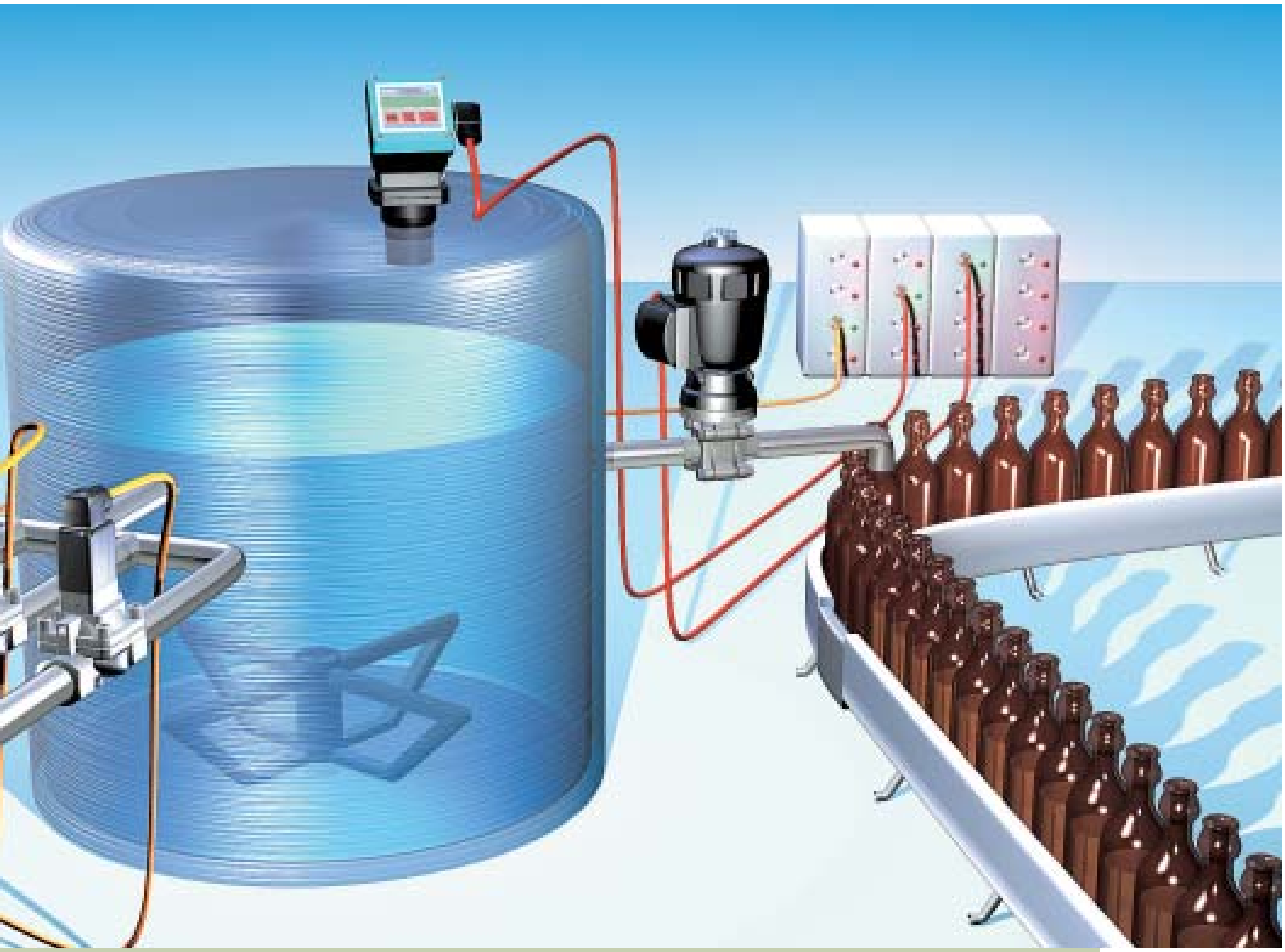

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Bürkert solenoid valves

	Circuit function			Function		Body material						
	2/2-way	3/2-way	2/2-way proportional	direct-acting	servo-assisted	Brass/ red bronze	Stainless steel	Plastic	Nominal diameters in mm	Port connections	Ex approval	Approvals e.g. UL/UR/CSA
Water and other neutral media	•	•	•	•	•	•	•	•	0.6–65	Sleeve M5 – G 2 1/2 Flange	•	•
Neutral gaseous media	•	•	•	•	•	•	•		0.4–65	Sleeve M5 – G 2 1/2 Flange	•	•
Aggressive media	•	•		•	•	•	•	•	0.6–50	Threaded couplings Fusion/solvent spigots Flange	•	•
High press. up to 250 bar	•			•	•	•	•		1–12	G 1/8–G 1/2	•	
Steam	•			•	•	•			2–50	G 1/4–G 2 Flange		•
MicroFluidics for biotechnology, medical technology a. analysis technology	•	•		•			•	•	0.4–4	G 1/8–G 1/4, hose Flange, UNF	•	•

Type 8175

Ultrasonic level transmitter

The digital level transmitter continuously measures the filling level or the filling volume of open or closed tanks with no physical contact. Due to the non-contact measuring method, the substances contained in the tank are not contaminated as the result of the measurement.

Simple menu prompting with an easily readable plain text display allows fast commissioning and operation.

Type 5282
2/2-way solenoid valve for neutral media

The servo-assisted 2/2-way solenoid valve with isolating diaphragm, Type 5282, is particularly suitable for dosing fluids. The opening and closing speed of the valve can be adjusted with restrictor screws. This largely avoids unintentional after-running of the medium.

Manual after-dosing is possible due to the manual override provided as standard. Optionally, the valves can also feature optical or electrical position feedback. A well-rounded range of equipment with various nominal diameters, seal and body materials and explosion-proof versions comply with even individual requirements.

Three-way pilot control with medium separation affords major advantages over conventional valves with two-way pilot control and is thus particularly insensitive to contaminated media.

Bürkert level sensors

Measuring method	Contin. measurement 4 … 20 mA	Level switch (sound output)	Measuring range (m)	Measurem. involv. physical contact with medium	Non-contact measurement	Max. pressure range in bar	Temperature range (°C)	Materials: Stainless steel	Materials: PTFE	Materials: PVDF	Materials: PP
Ultrasonic	•		0.3…10		•	2	–40…+80			•	
Capacitive		•		•		10	–30…+125		•		
Floar		•		•		4	–25…+105	•		•	•

Metered addition into a flowing medium

Task
A chemical is to be added on a controlled basis to water flowing in an open trench. The metered addition is to be set proportional to the quantity of water flowing through.

Solution
The non-contact ultrasonic level sensor measures the filling height of the trench as a measure of the flow velocity or the flow rate of the water. A surge pipe eliminates the influence of wave movements on the measured filling level. Metered addition of the chemical is controlled by a pneumatically operated diaphragm control valve, whose aperture can be varied by means of a TopControl positioner.

The positioner or control valve is activated via the standard signal output of the level sensor.

The function enabling free presetting of a characteristic integrated in the positioner allows the rangeability of the control valve and, thus, the flow rate of the chemical to be matched to the measured filling level or the water flow rate in the trench.

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Type 2731/8630

Pneumatically operated diaphragm control valve with digital TopControl Continuous positioner

Attachment of the TopControl Continuous digital electropneumatic positioner produces a powerful control system for critical media. At the press of a button, the Autotune function automatically adapts the TopControl to the valve.

The integrated process controller with PID response can be used as a higher-level controller for setting up local closed-loop control systems. Analog feedback, binary inputs and outputs and two additional initiators, which can be integrated as limit switches, round out the equipment. The control system can be connected via the Top-Control to field bus communication with the PROFIBUS DP and DeviceNet protocols.

Positioners/control head

	Digital electronics	2-wire device	3-wire device	Display	Process controll. (PID)	Stand. sign. (4...20 mA)	Feedback indictor	Analog feedback sign.	Binary input/output	Field bus	HART protocol	Bürkert process valves	Explosion protection
Positioners for													
lift actuator													
single-acting	•	•	•	•	•	•	•	•	•	•	•	•	•
double-acting	•	•	•	•	•	•	•	•	•	•	•	•	•
Swivel actuator													
single-acting	•	•	•	•	•	•	•	•	•	•	•	•	•
double-acting	•	•	•	•	•	•	•	•	•	•	•	•	•
Control head Electopneumatic actuator unit for													
lift actuator													
single-acting							•			•		•	•
double-acting							•			•		•	•
seat lift							•			•		•	
Swivel actuator													
single-acting							•			•		•	•
double-acting							•			•		•	•

Bürkert process valves

	Nominal diameter	Oper. press.	Function		Mode of actuation					Body material				EEx
	mm	bar	on/off	continuous	pneumatic	electropneum.	solen. actuator	motor. actuator	manual	VA	Brass	Casting	Plastic	Approval
Diaphragm	8–100	10	•	•	•	•			•	•			•	•
Globe	0.3–100	16	•	•	•	•	•		•	•	•	•		•
Angle-seat	13–65	16	•	•	•	•	•		•	•	•			•
Butterfly	50–100	10	•	•	•	•		•		•		•	•	•
Ball valve	8–80	64	•	•	•	•		•	•	•	•		•	•

Type 2730

The Type 2730 diaphragm valve unites time-proven diaphragm technology with bodies made of robust plastics (PVC, PP, PVDF) in nominal diameters 15 to 100 and is particularly suitable for applications with aggressive and abrasive media.

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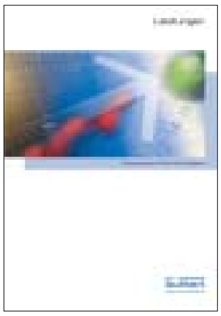
Information paves the path to the appropriate system solution. We provide five different levels for accessing information, products and services, so that you can easily find out everything you need to know to make the right choice.

Service brochure

A systematic overview of the range of products and services offered by Bürkert. A network of comprehensive solutions integrating coordinated services.



Competence brochures

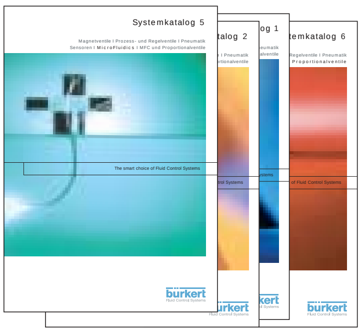
Essential information for the person planning control loops and field bus systems and who wants to ensure basic knowledge of the structure and selection of system components.

Application brochures

Example applications for deriving the appropriate system solution, supplemented by information on product advantages, user advantages and the range of products specifically available.

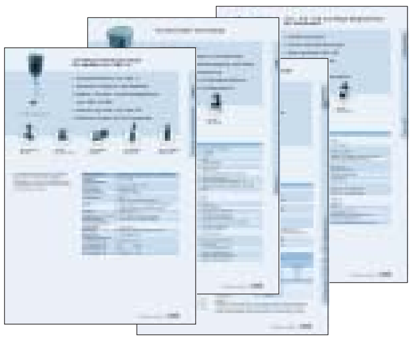
System catalogs

Background knowledge on product technology, including an up-to-date overview of the current offers. Rounded out with information to help you make your decision on the best application option.



Technical data sheets

Detailed technical information for checking specific suitability.
In addition, all the data needed for direct ordering.



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