System Catalog 6

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

The smart choice of Fluid Control Systems

bürkert
Fluid Control Systems

Bürkert GmbH & Co. KG
Fluid Control Systems
Christian-Bürkert-Straße 13-17
D-74653 Ingelfingen

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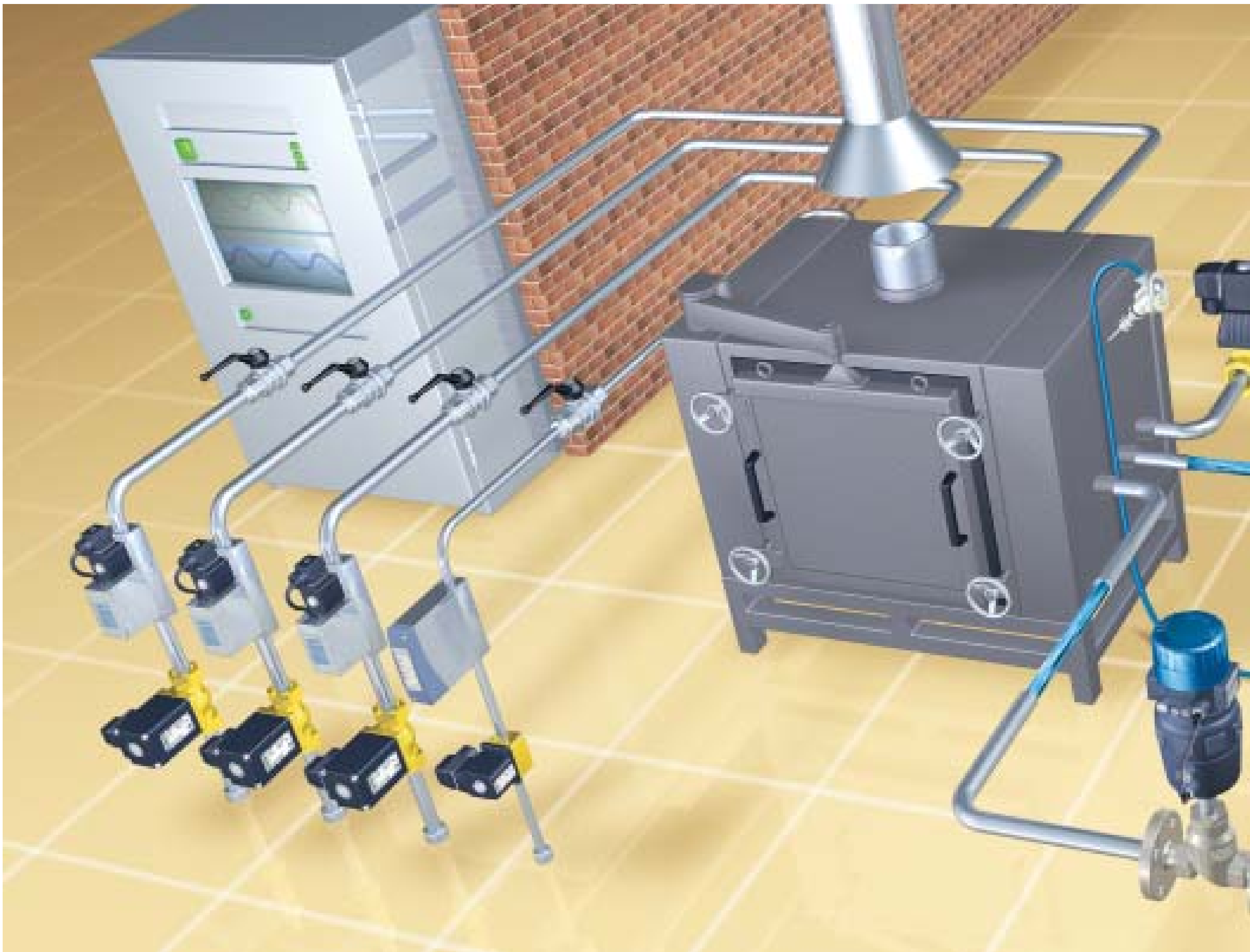
High tech for mass flow measurement



Digital right from the start

Whether for use in the automotive or aircraft sector, chemical or biotechnology industries – mass flow controllers from Bürkert are among the most in demand for thermal mass flow measurement due to their incomparable accuracy and reproducibility. This success is based on the fact that from the very outset, MFCs were made with future technology in mind, or to be more precise, with digital technology. The advantage of controlling all the required processes via software and the ability to save the relevant data in the memory is still a major feature in favor of the practical system technology supplied from the Ingelfingen based company.

Measured by the future

With their outstanding control properties, such as optimal dynamic and digital control via serial interfaces or field bus, Bürkert MFCs are ideal for the applications of the future. But even as we speak, the trend is moving towards miniaturized semiconductor sensors that are positioned in the actual gas flow. The latest sensor tech-

nology enables the achievement of even faster and more sensitive measurement results. Even measurements in the main flow can become a matter of course with Bürkert technology. In short, our developers set the standards for pioneering mass flow technology.

Error diagnostics included

The new generation of mass flow controllers notify the operator if they require servicing or are malfunctioning. While this is not a sensation, of course, it simply demonstrates the overall vision at Bürkert. Technical “intelligence” in every sense of the word is combined to form a system that ensures that production process can continue at all times. Maximum economy is one of the main features of the effective functioning of the measurement and control systems, which handle a whole range of flow measurement volumes, from large industrial furnaces to dosing 20 milliliters per hour. Technology that adds up. A claim that we make for every single component and every single system.

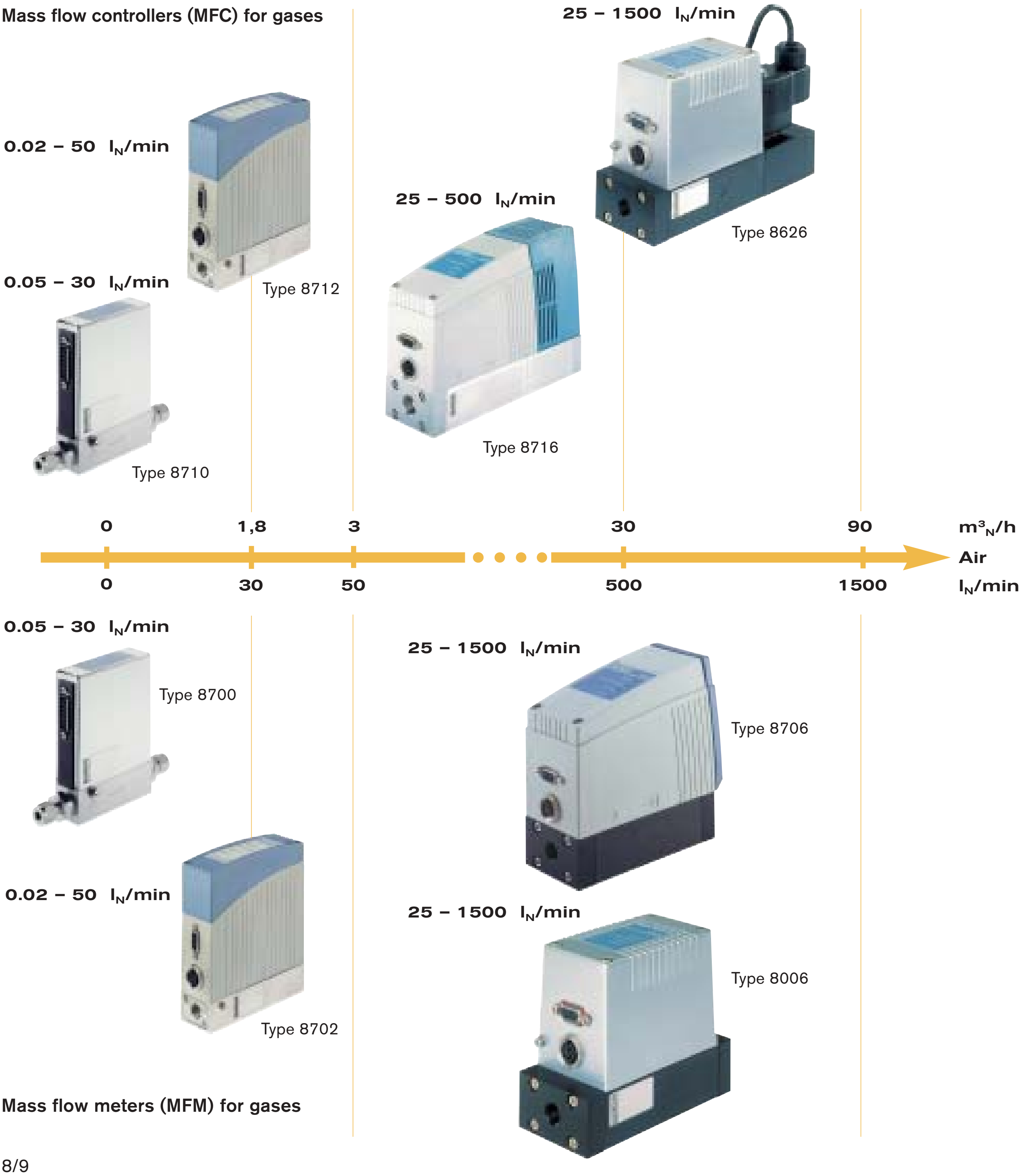
When the going gets tough

Mass flow controllers are components that are responsible for ensuring the precise control of gases even under the harshest conditions (see our illustrated example). MFCs from Bürkert are control instruments that reduce the tolerances between individual batches and therefore dramatically increase the quality of the product. One example of this is hardening materials for which specific furnace atmospheres are required. Among other things, mass flow controllers control the nitrogen, ammonia, carbon dioxide and air levels in the furnace chamber. This means that gas consumption can be controlled more accurately than ever before. And moreover, new processes, recipes and gas volumes can be created in a particularly reproducible form. The bottom line is maximum quality in the process and thus also in the end product.

Bürkert Mass Flow Controllers | Meter

Range of possible measuring range limits using the example of Type 8712

The instrument can be calibrated in the minimum case to a measuring range of 0.4 – 20 ml_N/min or in the maximum case to 1 – 50 l_N/min, each relating to using air as the medium.



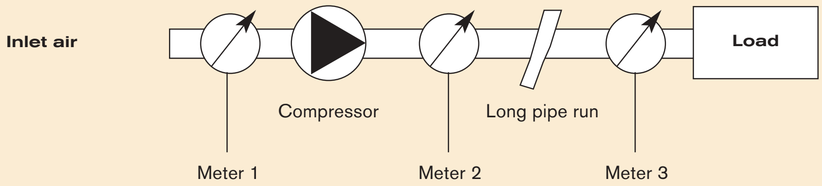
1. Principles of thermal mass flow measurement

1.1. Measuring gaseous substances

In contrast to liquids, gases can be compressed. The gas density changes depending on the pressure and temperature. Pursuant to the ideal status equation for gases

$$\frac{p_1 \cdot V_1}{T_1} = \frac{p_2 \cdot V_2}{T_2}$$

the volume in the example in Figure 1 changes from 1 m^3 upstream of the compressor to 0.172 m^3 downstream of the compressor. Since there is a flow in the example, the volume is specified dependent on the time (volume flow).



	Meter 1	Meter 2	Meter 3
Volume flow	1 m^3/h	0.172 m^3/h	0.167 m^3/h
Temperature	20 °C (293 K)	80 °C (353 K)	20 °C
Pressure	1 bar(a)	7 bar(a)	6 bar(a)
Density	1.205 kg/m^3	7.001 kg/m^3	7.23 kg/m^3
Mass flow	1.205 kg/h	1.205 kg/h	1.205 kg/h

Figure 1: Diagram of volume flow change, depending on the measurement position

$$V_2 = \frac{p_1 \cdot V_1}{T_1} \cdot \frac{T_2}{p_2} = \frac{1\ \text{bar} \cdot 1\ \text{m}^3}{293\text{K}} \cdot \frac{353\text{K}}{7\ \text{bar}} = 0.172\ \text{m}^3$$

The transported quantity of substance is independent of the pressure and temperature.
The figure shows the air mass flow. This remains constant at 1.205 kg/h over the entire distance. The density changes from 1.205 kg/m^3 upstream of the compressor to

$$\varrho_2 = \frac{m}{V_2} = \frac{1.205\ \text{kg}}{0.172\ \text{m}^3} = 7.001\ \frac{\text{kg}}{\text{m}^3}$$

downstream of the compressor. The gas volumes can only be compared if they relate to the same conditions. In general the mass flow is specified as a standard volume flow, in other words, in the form of a volume flow as defined in DIN 1343.

Table 1: Principles of thermal mass flow measurement

Measured variable	Definition	Typ. units	Remarks
Volume flow Q (operating flow rate)	Gas volume flow per unit of time	l/min	The most common flow rate
Mass flow $\dot{m}$	Gas volume flow per unit of time	kg/h, g/s	Measured variable relevant for most applications,
Normal volume flow $Q_N = \dot{m}/\varrho_N$ (DIN 1343)	Gas volume flow per unit of time, converted into its volume in standard conditions (T=0 °C/273K and p=1013 mbar/760 Torr)	l_N/min, m_N^3/h	a compromise between conventional and relevant measured variable, gas type-specific mass flow relating to the defined reference conditions.
Standard volume flow $Q_S = \dot{m}/\varrho_S$	Gas volume flow per unit of time, converted into its volume in standard conditions (T=20 °C/293K and p=1013 mbar/760 Torr)	l_S/min, slpm, m_S^3/h, sccm	

The conventional measuring methods for measuring gas volumes are

- **Floats (rota meters):**
  In practice, floats do not perform their measurement either in the volume flow or in the mass flow. They can be used for gases or fluids with a low pressure loss. The measuring span is approx. 10:1. If floats are operated in calibrated conditions, they supply the mass flow.

- **Orifices:**
  With orifices, the gas quantity is obtained by deriving it from the pressure differential. To obtain the mass flow, it must be ensured that the pressure and temperature remain constant at the measurement point. The measuring span is the same as for floats.

- **Vortex:**
  Vortex sensors measure the volume flow that then has to be converted into the mass flow. They have a very linear characteristic curve and are suitable for contaminated media. Special attention must be paid to the design of the input and output sections for this measuring method.

- **Coriolis:**
  Sensors of this type measure the mass flow itself. They do not need any input and output sections and can also measure fluids. The measuring method and the sophisticated electronics are reflected in the price.

- **Anemometers (thermal measurement):**
  Anemometers measure the mass flow itself, independent of the pressure and temperature, and offer a good measuring span of greater or equal to 50:1. Depending on the design of the sensor, they can also be used to measure fluids.

Bürkert Mass Flow Controllers and Meters (MFCs and MFMs) use the anemometric principle: measurement signals can be easily evaluated and the measuring method is very sensitive to slight flow-rate changes.

1.2. Explanation of the thermal (anemometric) measuring method

The measured value pick-ups for the thermal measuring method are electrical resistors and part of a measurement bridge circuit (Figure 2). They may be in the actual flow channel (inline instrument) or wound around the flow channel (bypass instrument).

The controller in Figure 2 sets the current I so that the temperature differential between the heating resistor R_S and the measuring resistor R_T is kept constant at all times. Since R_T is very high ohm compared to R_S, the current I_S is almost identical to current I. The resistor R_S is always heated to such a degree that there is always a certain overtemperature to the fluid temperature, measured with R_T.
If gas flows past R_S, heat is dissipated more or less effectively depending on the gas. The heating current that is required to maintain the overtemperature is a function of the gas flow passing through the channel and represents the primary measured variable. The method is known as the CTA, Constant Temperature Anemometer, and is a variant of the thermal measuring method. Mass flow controllers/meters are designed as main flow or bypass flow instruments.

Figure 3 shows the measuring element of an inline instrument. The flow conditioning produces a uniform flow through the channel cross-section on the inline instrument. Input sections to smooth the flow are therefore not necessary.

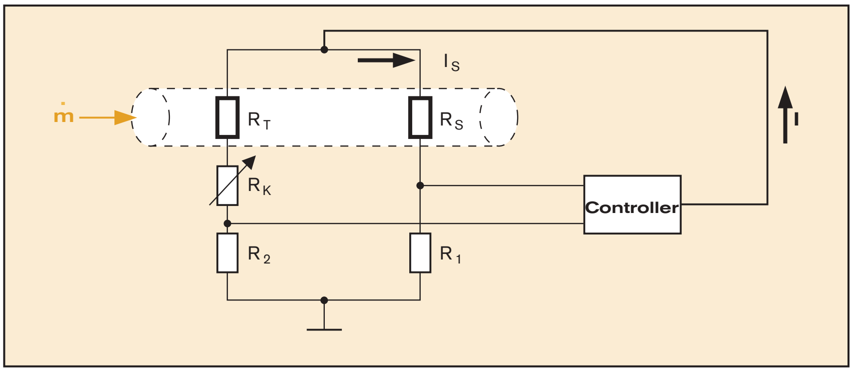


Figure 2: Simplified electrical diagram of the measurement bridge circuit (resistors placed directly in the flow channel)

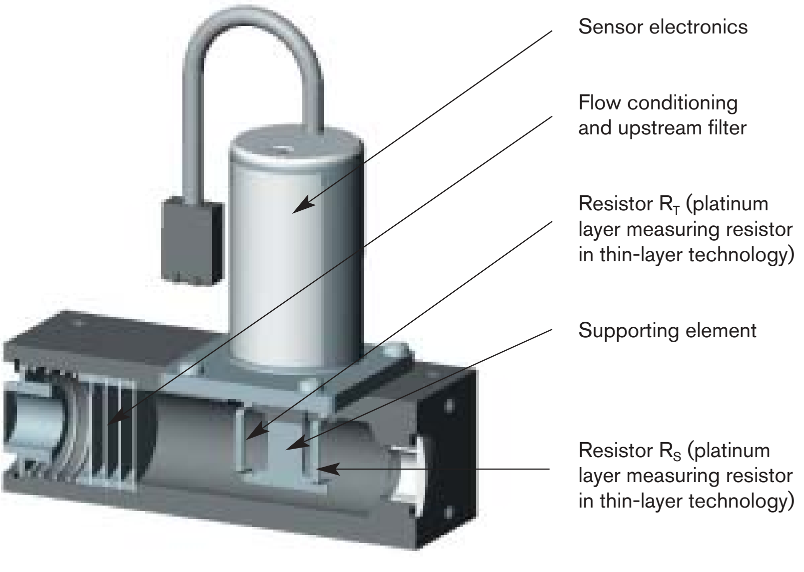


Figure 3: Cross section of a main flow sensor block

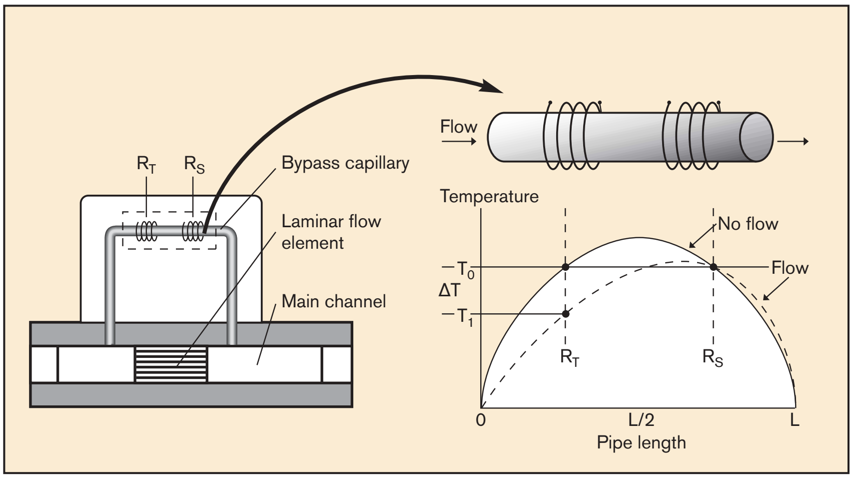


Figure 4: Sketch of a bypass sensor block

Bypass flow or bypass sensors (see Figure 4) essentially have a bypass capillary around which the measuring resistors R_T and R_S are wrapped, as well as a laminar flow element.
The laminar flow element generates a pressure drop proportionate to the flow, which drives the flow through the bypass capillary. The element must be designed so that both the flow in the bypass and in the main channel is laminar and that the proportions remain constant.

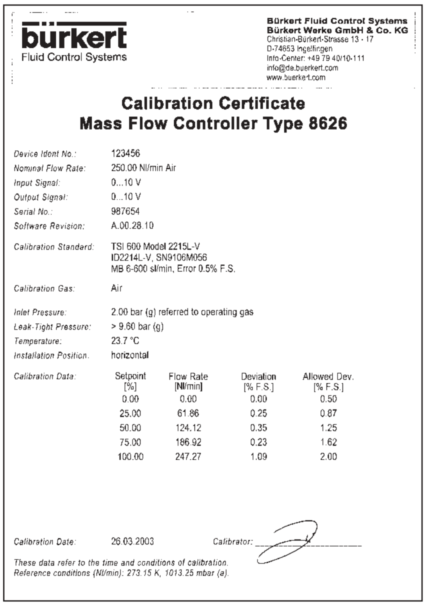
Depending on the gas flow, the temperature conditions registered by the measuring resistors change. Different technical designs for the bypass principle are possible. The thermal measurement is based on the thermal properties of the gas, the geometric design of the measuring body and the flow velocity of the gas. In thermal terms, gases differ by their specific heat capacity c_p and heat conductivity λ_F. This means that, depending on the measured gas, the measuring range of a unit can be greater or smaller.

1.3. Calibration of thermal mass flow meters

In the calibration process, the measurement signal range of the sensor is clearly assigned to the flow control or measuring range. For this purpose, flow rates are set and the relevant sensor signals recorded on the basis of highly accurate flow normals (for example, heating wire anemometers, which are regularly tested on a test bench with super-critical nozzles that has been approved by the calibration authority). When the flow characteristic curve has been registered, the electrical inputs and outputs can be calibrated. All the data are saved in digital form in an EEPROM. Mass flow controllers or meters generally contain a calibration curve for a certain gas. They can only be used to control or measure a different gas if a second calibration curve has been stored. Exceptions to this rule are gases with very similar properties (e.g. oxygen and nitrogen). In this case, a single conversion factor is sufficient for the entire flow range. In principle, every gas mixture can be measured, provided its composition does not change.

Mass flow controllers or meters are often calibrated for the following gases:

- Air, nitrogen, oxygen and nitrous oxide (laughing gas)
- Argon, helium, neon, krypton (inert gases)
- Hydrogen, methane (natural gas), ethylene, propane, butane
- Ammonia, carbon dioxide, carbon monoxide, sulfur dioxide
- Mixtures of nitrogen and hydrogen or methane, endogas, exogas, city gas, mixtures of methane and carbon dioxide.



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Fluid Control Systems

Bürkert Fluid Control Systems
Bürkert Werke GmbH & Co. KG
Christian-Bürkert-Strasse 13 - 17
D-74653 Ingelfingen
Info-Center: +49 79 40/10-111
info@de.buerkert.com
www.buerkert.com

Calibration Certificate
Mass Flow Controller Type 8626

Device Ident No.: 123456
Nominal Flow Rate: 250.00 Nl/min Air
Input Signal: 0...10 V
Output Signal: 0...10 V
Serial No.: 987654
Software Revision: A.00.28.10

Calibration Standard: TSI 600 Model 2215L-V
ID2214L-V, SN9106M056
MB 6-600 sl/min, Error 0.5% F.S.

Calibration Gas: Air

Inlet Pressure: 2.00 bar (g) referred to operating gas
Leak-Tight Pressure: > 9.60 bar (g)
Temperature: 23.7 °C
Installation Position. horizontal

Calibration Data:

Setpoint [%]	Flow Rate [Nl/min]	Deviation [% F.S.]	Allowed Dev. [% F.S.]
0.00	0.00	0.00	0.50
25.00	61.86	0.25	0.87
50.00	124.12	0.35	1.25
75.00	186.92	0.23	1.62
100.00	247.27	1.09	2.00

Calibration Date: 26.03.2003 *Calibrator:* ____________

These data refer to the time and conditions of calibration.
Reference conditions (Nl/min): 273.15 K, 1013.25 mbar (a).

Figure 5: Calibration protocol

2. Basic design of mass flow controllers (MFC) and mass flow meters (MFM)

2.1. Description of the control loop

Type 8626, 8716, 8712 and 8710 mass flow controllers are compact instruments designed to control the mass flow of gases. They maintain a specified flow-rate set-point regardless of disturbance variables such as pressure fluctuations or flow resistance that differs over time, for example as a result of filter contamination. MFCs contain a flow sensor (Q sensor), electronics (with signal processing, control and valve actuation functions) and a proportional solenoid valve acting as the final control element or actuator (see Figure 6).

The set-point value (w) is defined by electrical means using a standard signal or field bus. The actual value (x) recorded by the sensor is compared to the set-point value in the controller. A pulse width modulated voltage signal is supplied to the proportional valve by the controller to act as the control variable (y_2). The duty cycle of the voltage signal is varied in accordance with the registeed control deviation (x_d). The frequency of the PWM signal is tailored to the proportional valve used. In addition, the actual value is output by an analog electrical interface or a field bus (x_{out}) and is available to the user for control purposes or for further evaluation (for example to establish consumption by integration). The mass flow meter has the same components as the MFC with the exception of the proportional valve acting as a positioning valve, thus these instruments can only be used to measure mass flow, not to control it. The compact and integrated construction of mass flow controllers and mass flow meters ensures easy installation and operation of the entire closed-loop flow-rate control or measurement system. Additional work such as wiring and tuning individual components or taking into account pipe lengths is not necessary. The instruments supply very high-quality measurement results. One of the reasons for this is that a great deal of attention has been put into flow technology. Inline instruments have a flow conditioning system at the input side, which enables a reproducible flow profile at the site of the sensor and therefore precise calibration. Long input and output sections to smooth the flow, such as those required for sensors bolted into pipelines are not necessary. All MFCs and MFMs also contain input filters that can be replaced easily without damaging any other components.

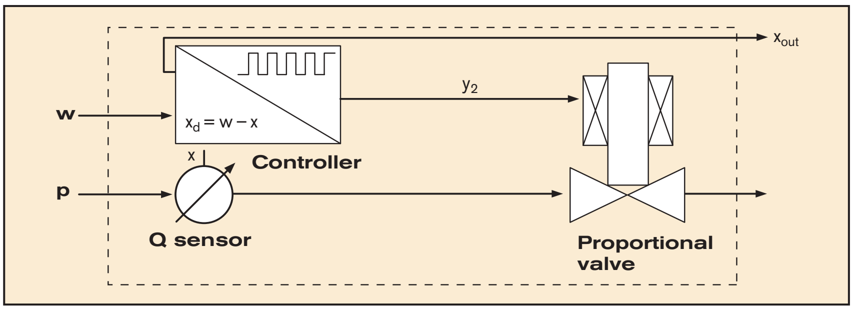


Figure 6: Components of a mass flow controller

2.2. Characteristic parameters

- **Full scale value range/ Nominal flow rate**
  The full scale (F.S.) value range is the range of possible measuring range limits. The minimum value is the smallest possible full scale value for the nominal flow rate while the maximum value is the highest possible full scale value for the nominal flow rate. Any full scale values between these are also possible of course. The specifications refer to defined reference conditions (for example, standard liters per minute or standard cubic centimeters per minute).

- **Operating medium/calibration medium**
  The operating medium is generally used for the calibration process, although a reference gas (for example nitrogen) may be used in exceptional cases.

- **Span**
  Specified as a ratio, for example 1:50. Ratio of the smallest flow rate that can be adjusted to the nominal flow rate.

- **Settling time**
  Time required by the MFC to achieve 95 % of the difference between the old and new flow rate.

- **Response time**
  Time required by a MFM to adjust its display to 95 % of the new value after a sudden change in flow rate from Q_1 to Q_2.

$$Q_{MFM}(t_{95}) = Q_1 + 0.95\,(Q_2 - Q_1)$$

- **Accuracy**
  The most realistic is a combined figure in ± x % of rate ± y % of full scale value.

- **Repeatability**
  Figure in ± x % of full scale value. Repeatability, or reproducibility as it is also called, is a measure of the distribution of the actual values that result from the repeated adjustment of a reproduced set-point value, starting from a specific starting value.

- **Linearity**
  Figure in ± x % of full scale value. Maximum deviation of the signaled actual value from the set-point value, if this is passed slowly over the entire range.

- **Sensitivity**
  Figure in ± x % of full scale value. The smallest change in set-point value that results in a reproducible change in the flow rate.

3. Components of a mass flow controller/meter

3.1. Mass flow sensor

3.1.1. Inline sensor, direct measurement in the main flow

The sensor acts as a hot film anemometer in CTA (Constant Temperature Anemometer) mode. In this case, two resistors located in the actual media flow with precisely specified temperature coefficients and three resistors outside the flow are connected to form a bridge. The first resistor in the media flow (R_T) measures the fluid temperature, the second resistor of lower impedance (R_S) is always heated to such a point that it is held at a fixed, specified temperature above the fluid temperature. The heating current required for this is a measure of the heat dissipation through the flowing gas and represents the primary measured variable. Adequate flow conditioning within the MFC and calibration using high-quality flow normals ensure that the primary signal allows the gas volume flow per unit of time to be derived with great accuracy.
The direct medium contact of the resistors R_T and R_S, which are located in the main flow, ensures very good dynamics of the instruments with response times of just a few hundred milliseconds in the event of a sudden change in the set-point or actual valves.

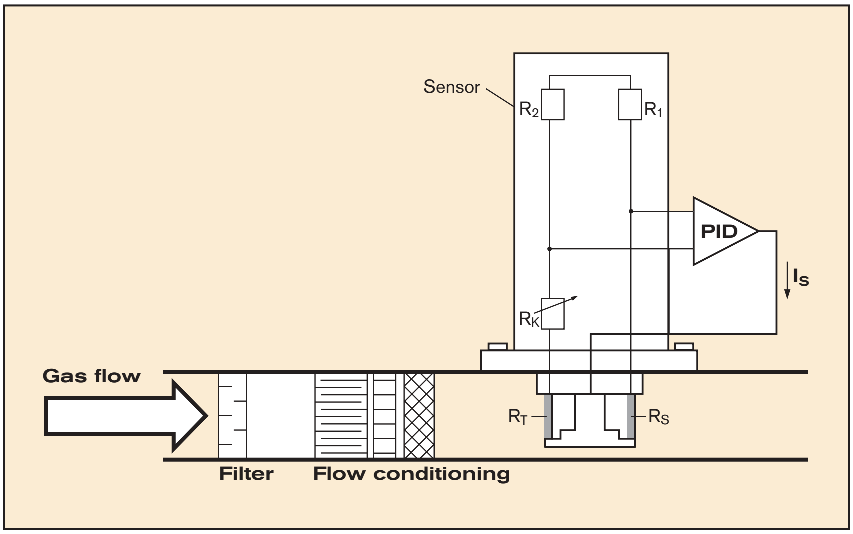


Figure 7: Function diagram of the inline sensor

By positioning the resistors on a glass support fitted at a tangent to the flow, the sensor is relatively insensitive to contaminated media. The measuring range of the inline sensor is limited on the downside by the inherent convection in the flow channel, which occurs even if the control valve is closed. It is therefore not suitable for instruments with an operating range of flow rates of less than approx. 1 l_N/min.
The signal of the inherent convection in the flow channel depends on the installation position of the instrument. To achieve high accuracy with low flow rates, the installation position should be identical to that specified in the order. The operating pressure should not be too far away from the calibration pressure for the same reason.

3.1.2. Bypass sensor, indirect measurement in the bypass flow

In this case, the measurement is taken using the bypass principle. A laminar flow element in the main channel generates a slight pressure drop, which drives a small proportion of the full flow through the actual sensor tube. Two heating resistors are wound on thin stainless steel tubes and are interconnected to form a measurement bridge. When the medium passes through the tube, heat is transported in the direction of the flow and this misaligns the previously balanced bridge.
The dynamics of the measurement is determined by the wall of the sensor tube that acts as a thermal barrier and is therefore considerably poorer than that offered by sensors with resistors directly in the medium flow, simply by virtue of the principle employed.
Using software algorithmus settling times are achieved which are adequate for the majority of applications (generally a few seconds).
These sensors can also be used to control some aggressive gases, since all the main parts that come into contact with the medium are made of stainless steel.

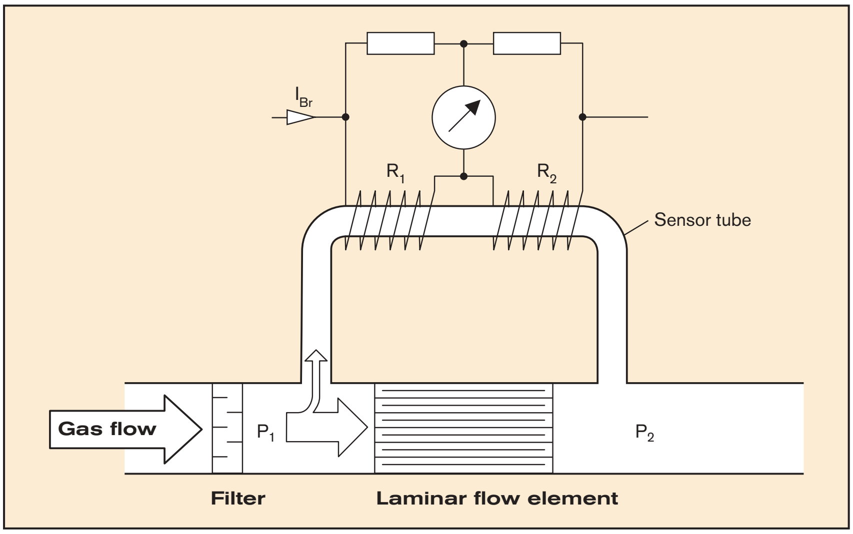


Figure 8: Function diagram of the bypass measuring principle

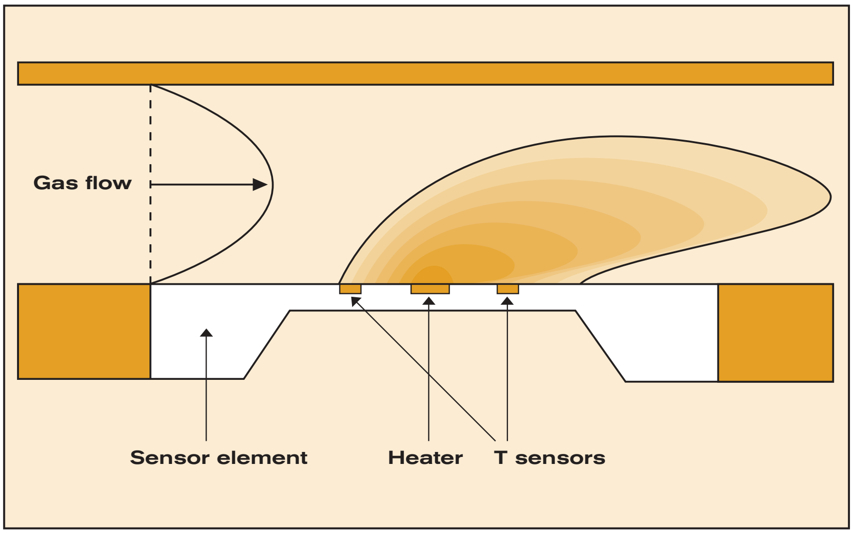


Figure 9: Function diagram of the bypass sensor in CMOSens® technology (cross section from the bypass channel)

3.1.3. Bypass CMOS sensor, direct measurement in the bypass flow

The measurement is taken directly in the bypass channel. A laminar flow element in the main channel generates a slight pressure drop, which drives a small proportion of the full flow through the bypass channel. The sensor located therein records the mass flow rate directly by measuring the temperature differential. The measurement in this case is taken in a specially shaped flow channel whose walls contain a Si chip in one place with an exposed diaphragm. Using CMOSens® technology, a heating resistor is connected to this diaphragm along with two temperature sensors upstream and downstream of it.
If the heating resistor is supplied with a constant voltage, the voltage differential of the temperature sensors is a measure of the mass flow of the gas flowing through the flow channel past the chip.

The low thermal mass of the temperature sensors and their direct contact with the flow (apart from a protective layer) means the sensor signal reacts extremely fast to quick flow-rate changes and the MFC is capable of settling set-point value or actual value changes within a few hundred milliseconds. In addition, they are extremely sensitive, even with very low flow rates, and also offer additional correction and diagnostic facilities via the signal of a separate temperature sensor located on the chip.

3.2. Digital electronics

Microprocessor electronics is used to process the current set-points and actual flow rates and actuate the final control element (proportional valve). The analog sensor signal is filtered by the control electronics and converted into a value that corresponds to the actual flow rate using a calibration curve stored in the instrument. The control deviation x_d between the set-point value w and the actual value x is processed by the controller using a PI algorithm and is used to calculate the manipulated variable y_2, with which the control valve is actuated. The control parameters are set during the calibration process. To allow for the properties of the controlled system, the controller uses system-dependent amplification factors that are detected automatically using a self-optimization routine (autotune). An overshoot (see Figure 10) must be accepted for high dynamic requirements. The control dynamics can, however, be adjusted retrospectively using the Mass Flow Communicator communication software. This also applies to the filter level and the smoothing of the actual value signal, which is returned. Figure 10 shows the step response of mass flow controller Type 8712 (with CMOS sensor), Figure 11 shows the same from the mass flow controller Type 8626 (with inline sensor). The figures show the responses of the actual value and controller output signals when the set-point value is increased from 10 % to 95 %.
Depending on the design of the instrument, the set-point and actual value signals can be specified and returned in analog form via the standard signal interface or in digital form via an RS-232 or field bus interface.

Communication with the Mass Flow Communicator software (see Section 4 for further information) is via the RS-232 or RS-485 (depending on the instrument).
In addition to reduced drift and offset by the components, microprocessor-based digital electronics offer the major advantage that all the required processes can be controlled by software (flash-programmed, in other words, the electronics can be updated). Data relevant to this (calibration curves, correction functions, control functions, etc.) can be stored in the memory.

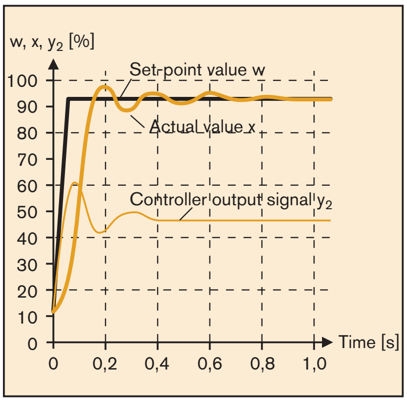


Figure 10: Step response of Type 8712 Mass Flow Controller after a set-point step from 10 % to 95 %

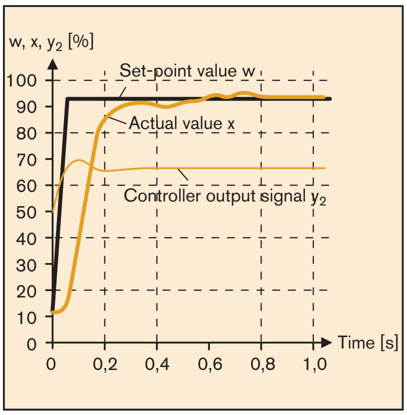


Figure 11: Step response of Type 8626 Mass Flow Controller after a set-point step from 10 % to 95 %

3.3. Proportional solenoid valve acting as final control element in a mass flow controller

Direct-acting plunger-type proportional valves (see Section 9, Proportional valves) from the Bürkert valve range are used as final control elements in all MFC series. Constructive measures, in particular on valves in the MFCs for low flow rates (Types 8710 and 8712), ensure that the moving plunger is guided with low friction. Together with the PWM actuation, this ensures a constant, almost linear characteristic curve along with high response sensitivity. Both of these features are important for optimal function in the MFC's closed control loop. The nominal diameters of the valves result from the required nominal flow rate Q_{nom}, the pressure conditions in the application and the density of the operating gas. Using these data, a proportional valve can be selected whose flow-rate coefficient k_{Vs} allows the maximum flow of at least the required nominal flow rate in the specified pressure conditions and in compliance with the flow-rate equations:

$$\psi = \frac{(\Delta p)_{V0}}{(\Delta p)_0} = \frac{{k_{Vs}}^2}{[{k_{Va}}^2 + {k_{Vs}}^2]}$$

The "valve authority" is important for the MFC control properties in the system. It should not be below a value of 0.3 ... 0.5.

Meaning of formula symbols:

k_{Va}	Flow-rate coefficient of system without installed MFC in m³/h
k_{Vs}	Flow-rate coefficient of the MFC with final control element fully open in m³/h
$(\Delta p)_0$	Pressure drop through the entire system
$(\Delta p)_{V0}$	Proportion of this that drops through the MFC with the valve fully open.

The system section should not be designed in terms of its flow-rate coefficient k_{Va}, so that at the required nominal flow rate, the vast majority of the available pressure is used there and thus the selected nominal valve diameter is too large. In this case, the valve authority is too small, in other words, only a small proportion of the valve working range is used. This considerably impairs the resolution and control quality of the MFC. If the system section is designed to be too "small", increasing the nominal valve diameter will not help, and the remedy is either to increase the supply pressure or increase the k_{Va} value, e.g. by means of a larger pipe diameter.

4. Expanded functionality of Bürkert MFCs/MFMs

4.1. Special hardware features

- All standard signals in analog form are available for the input of the set-point value or output of the actual value.
  Communication in digital form is enabled via the RS-232/RS-485 or field bus (e.g. Profibus DP or DeviceNet).

- Digital microprocessor electronics allow two gas calibrations in a single instrument (under the condition that the application parameters of the two gases can be covered with the same rating).

- Display of the operating status of the instrument using LED
  POWER-LED: The unit is ready
  COMMUNICATION-LED: The instrument is communicating via field bus or serial interface
  LIMIT (y)-LED: The instrument has reached the settling or measuring limit
  ERROR-LED: Error display

- 3 binary inputs (on Type 8710/8700, 2 binary inputs)
  A fixed function can be assigned to the binary inputs, which is then executed when the input is set.
  The following functions may be assigned (Table 2):

Table 2:

without function	No function is assigned to the binary input.
activate autotune	The MFC goes into autotune mode in which the parameters dependent on the controlled system are optimized.
activate gas 2	This binary input allows the system to switch to gas 2 if the instrument has been calibrated for 2 gases.
safety value active	If the binary input is set, the MFC settles on the flow rate set in the safety value, regardless of the set-point value.
reset totalizer	The totalizer value is set to zero.
safety value inactive	Inverse action like a “safety value active” (safety value is settled if the binary input is not set).
start predefined profile	The pre-adjusted set-point profile is run.
control mode active	The controller is no longer in control mode. The valve pulse duty factor 0 ... 100 % is controlled by set-point figures 0 ... 100 %.
close valve completely	The valve is closed regardless of the set-point value.
open valve completely	The valve is fully opened regardless of the set-point value.

- 2 relay outputs (on Type 8710/8700, 1 relay output) take the form of voltage-free SPDT contacts. Fixed events can be assigned to the relay outputs. If the event occurs, the output is set. The following assignments are possible, for example (Table 3):

- No additional shut-off valve is required on the MFC since the final control element (proportional valve) performs the tight-closing function.

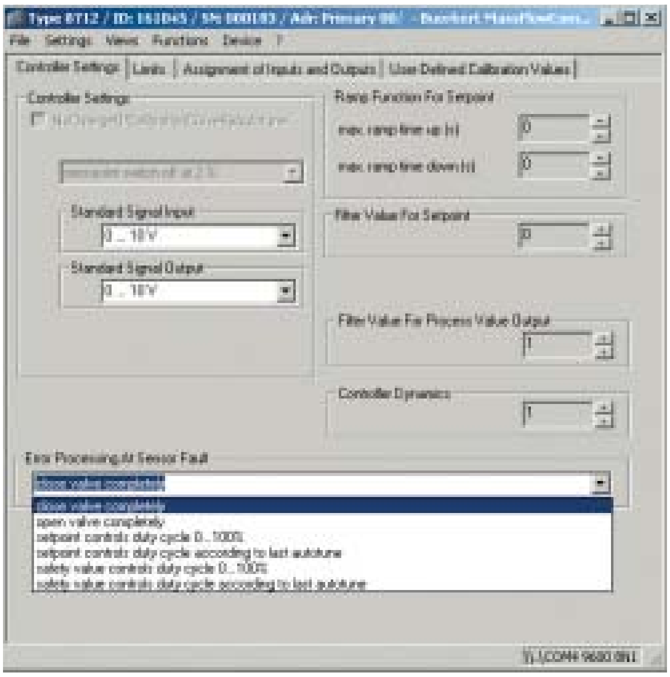
Table 3:

Power ON	Voltage supply is connected to the unit
Autotune active	Autotune mode active
Limit	Value has moved above or below the set limit value (e.g. for actual value, set-point value, control signal or totalizer)
Error	Error has occurred (e.g. sensor break)

4.2. Mass Flow Communicator communication software

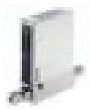
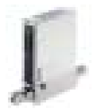
- Customers can configure and parameterize the instrument using the Mass Flow Communicator PC software via the RS-232, e.g. configuration of binary inputs and outputs, LEDs, limit values, etc.
- Limit value switches (limits) for set-point/actual value, control signal and integrated totalizer can be configured.
- The dynamics of the instrument can be adjusted to the application.
- Instrument behavior can be defined in the event of an error, for example: go to safety value, fully open or close valve.
- Autotune function: automatic adjustment of the controller to the system conditions.
- Adjustable ramp function for the set-point value can be configured.
- Set-point profile can be defined and stored. Set-point values with the relevant time intervals can be entered in the required order in which the instrument automatically moves to them at a later time (for example, after activating a binary input).

The latest version of the configuration software can be downloaded from the Bürkert website (www.buerkert.com).



5. MFC/MFM range

Table 4: Overview of Bürkert Mass Flow Controllers/Meters

MFM type	MFC type	Nominal flow rates $[l_N/min]$ (air or N_2)	Measuring principle	Max. operating pressure [bar]	Body material	Proportional valves (not in MFM)	Binary inputs	Binary outputs	Communication
8700 	8710 	0.05–30	Bypass (standard)	10	VA 1.4305	2821 2822	2	1	Standard signal, RS-232
8702 	8712 	0.02–50	Bypass (CMOS)	10	VA 1.4305	2821 2822	3	2	Standard signal, RS-232 or fieldbus
8006 	8626 	25–1500	Inline	10	VA 1.4305, Al anod.	6022 2834 6024 2836	3	2	Standard signal, RS-232 or field bus
8706 	8716 	8706: 25–1500 8716: 25–500	Inline	10	VA 1.4305, Al anod.	6022 2834 6024	3	2	Standard signal, RS-232 or field bus

6. Brief instructions: How to select the right MFC/MFM for an application

Do you want to control/dose the gas or just measure it?

Mass flow controllers contain a proportional control valve that sets the required gas throughput. Mass flow meters only return the current gas throughput in the form of an actual value signal.

What medium do you want to control or measure?

A mass flow controller/mass flow meter is calibrated for the operating gas. If the operating gas is a mixture, the precise composition in percentages is important for the rating and calibration of the instrument. The relative humidity of the gas can be almost 100 %, but a liquid phase must be avoided under all circumstances. Particle contents should be removed by upstream filters.
The medium resistance of wetted MFC/MFM components must be ensured. As a result of the gas properties, it may be necessary to carry out the calibration with the operating medium. For example, this will guarantee the reproducibility and accuracy of the instrument.

What process data are available?

To achieve the optimal design, in addition to the required maximum flow rate Q_{nom}, the pressure values immediately upstream and downstream of the MFC (p_1, p_2) at this flow rate Q_{nom} must be known. These often differ from the input and output pressure of the system as a whole because both upstream and downstream of the MFC, there may be additional flow resistors (pipes, shut-off valves, nozzles, etc.). If the input pressure (p_1) and output pressure (p_2) are not known or cannot be obtained by measurement, an estimate must be made, taking into account the approximate pressure drops through the flow resistors upstream and downstream of the MFC at Q_{nom}. For rating purposes, it is also necessary to provide details of the medium temperature T_1 and the standard density ρ_N of the medium (can be obtained for mixtures using the percentage values).

The possible measuring span must be checked to determine whether the minimum flow rate Q_{min} can be adjusted.
The maximum expected input pressure p_{1max} must be specified to ensure the tight-closing function of the final control element in the MFC under all operating conditions.

How can the MFC/MFM be connected to the pipes?

As a standard feature, the instruments are mounted using the screw-in thread to match the flow rate. However, instruments can also be supplied with screw-in connectors. The external diameter with a metric (mm) or imperial (inch) figure is important for the size of the screw-in connectors.

The possible measuring span must be checked to determine whether the minimum flow rate Q_{min} can be adjusted.
The maximum expected input pressure p_{1max} must be specified to ensure the tight-closing function of the final control element in the MFC under all operating conditions.

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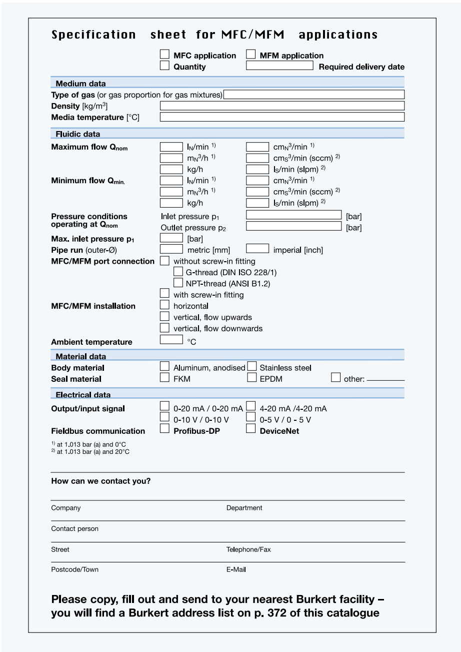


Specification sheet for MFC/MFM applications

☐ **MFC application** ☐ **MFM application**
☐ **Quantity** ☐ **Required delivery date**

Medium data

Type of gas (or gas proportion for gas mixtures)
Density [kg/m³]
Media temperature [°C]

Fluidic data

Maximum flow Q_{nom} ☐ l_N/min [1] ☐ cm_N^3/min [1]
☐ m_N^3/h [1] ☐ cm_S^3/min (sccm) [2]
☐ kg/h ☐ l_S/min (slpm) [2]

Minimum flow $Q_{min.}$ ☐ l_N/min [1] ☐ cm_N^3/min [1]
☐ m_N^3/h [1] ☐ cm_S^3/min (sccm) [2]
☐ kg/h ☐ l_S/min (slpm) [2]

Pressure conditions operating at Q_{nom} Inlet pressure p_1 [bar]
Outlet pressure p_2 [bar]

Max. inlet pressure p_1 [bar]

Pipe run (outer-Ø) metric [mm] imperial [inch]

MFC/MFM port connection ☐ without screw-in fitting
☐ G-thread (DIN ISO 228/1)
☐ NPT-thread (ANSI B1.2)
☐ with screw-in fitting

MFC/MFM installation ☐ horizontal
☐ vertical, flow upwards
☐ vertical, flow downwards

Ambient temperature °C

Material data

Body material ☐ Aluminum, anodised ☐ Stainless steel
Seal material ☐ FKM ☐ EPDM ☐ other: ______

Electrical data

Output/input signal ☐ 0-20 mA / 0-20 mA ☐ 4-20 mA /4-20 mA
☐ 0-10 V / 0-10 V ☐ 0-5 V / 0 - 5 V

Fieldbus communication ☐ **Profibus-DP** ☐ **DeviceNet**

[1] at 1.013 bar (a) and 0°C
[2] at 1.013 bar (a) and 20°C

How can we contact you?

Company Department

Contact person

Street Telephone/Fax

Postcode/Town E-Mail

Please copy, fill out and send to your nearest Burkert facility – you will find a Burkert address list on p. 372 of this catalogue

Figure 12: Specification sheet
This enables you to benefit from the experience of Bürkert engineers in the planning phase of your system.

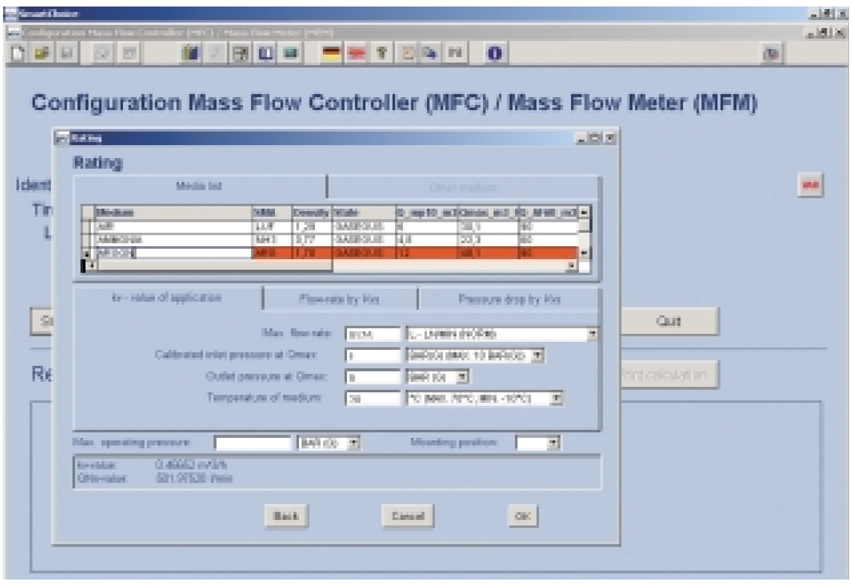


Figure 13: Configurator
The data on the specification sheet are evaluated using the Bürkert MFC/MFM configurator.
This tool aids Bürkert engineers in selecting the correct instrument on-site.

7. Bürkert MFC/MFM type descriptions

Figure 14:
MFC 8712, MFM 8702

7.1. MFC Type 8712, MFM Type 8702

The Type 8712 Mass Flow Controller and Type 8702 Mass Flow Meter are characterized by their new semiconductor flow sensors featuring CMOS technology. This revolutionary bypass measuring technology enables attaining measurement and display times of a few hundred milliseconds.

Typical applications include

- Process engineering
- Packaging and food industries
- Environmental engineering
- Surface treatment
- Material coating
- Burner control systems
- Fuel cell technology

Characteristics:

- High level of accuracy
- Fast response and settling time
- Excellent span
- Optional calibration for two gases
- Integrated totalizer
- Field bus optional
- Mass Flow Communicator (PC configuration software)
- 3 binary inputs and 2 binary outputs (relay outputs)
- Galvanic isolation of inputs and outputs

Main technical data:

- Full scale range 0.02 – 50 l_N/min (N_2 at 273.15 K and 1013.25 mbar)
- Settling time < 300 ms
- Accuracy ± 0.8 % of rate ± 0.3 % F.S.
- Repeatability ± 0.1 % F.S.
- Linearity ± 0.1 % F.S.
- Span 1:50, 1:500 on request
- Max. operating pressure 10 bar depending on the application
- Type of protection IP 65
- Port connection G1/4, NPT1/4, screw-in connector
- Analog signal transmission or digital communication (RS-232, RS-485, field bus)
- Voltage supply 24 V DC
- Power consumption max. 10 W
- Dimensions 115 x 137.5 x 37 mm
- Stainless steel body

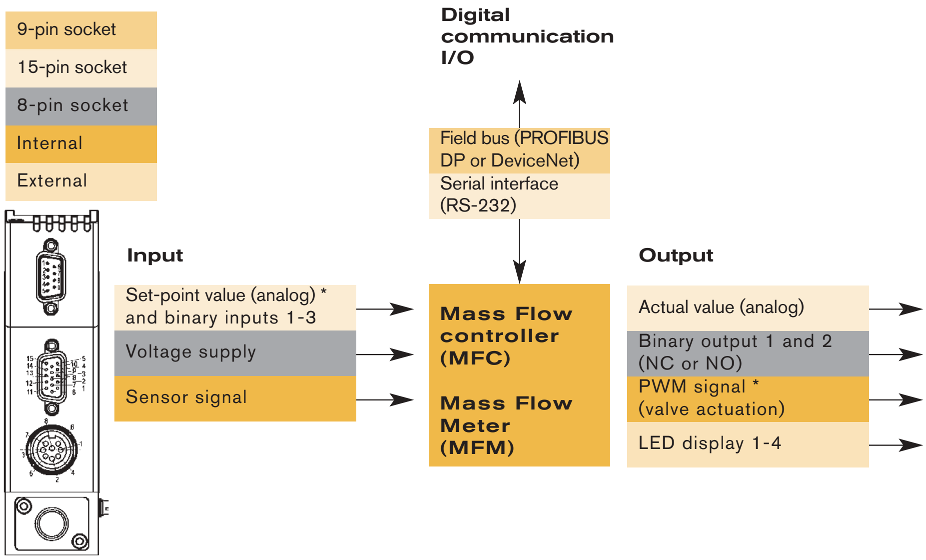


Figure 15: Electrical interfaces Type 8712/8702

(* Not with MFM)

Figure 16:
MFC 8710, MFM 8700

7.2.
MFC Type 8710, MFM Type 8700

MFC Type 8710 and MFM Type 8700 use the classical bypass measuring method. This indirect measuring method offers the advantage that the measuring resistors are not in direct contact with the medium and therefore can also be used to measure and control aggressive gases.

Typical applications include
- Process engineering
- Packaging and food industries
- Environmental engineering
- Surface treatment
- Material coating

Characteristics:
- High level of accuracy
- Excellent span
- Calibration of critical gases with air and conversion factor
- Optional calibration for two gases
- Integrated totalizer
- Mass Flow Communicator (PC configuration software)
- 2 binary inputs and 1 binary output (relay output)

Main technical data:
- Full scale range 0.05 – 30 l_N/min (N_2 at 273,15K and 1013.25 mbar)
- Settling time approx. 3 seconds
- Accuracy ± 1.0 % of rate ± 0.3 % F.S.
- Repeatability ± 0.2 % F.S.
- Linearity ± 0.25 % F.S.
- Span 1:50
- Max. operating pressure 10 bar depending on the application
- Type of protection IP 50
- Port connection G1/4, NPT1/4, screw-in connector
- Analog signal transmission or digital communication (RS-232, RS-485, field bus)
- Voltage supply 24 V DC
- Power consumption max. 7.5 W
- Dimensions 80 x 109 x 25 mm
- Stainless steel body

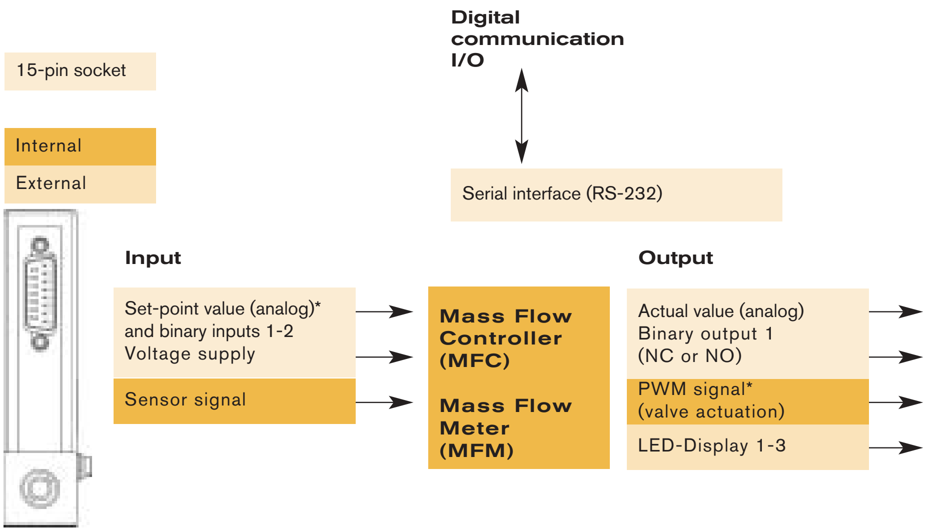


Figure 17: Electrical interfaces type 8710/8700

(* Not with MFM)

Figure 18: MFC 8716

Figure 19: MFM 8706

7.3. MFC Type 8716, MFM Type 8706

For large flow rates, the MFC 8716 and MFM 8706, with their inline measuring method, are used. As a result of this measuring method, these units feature excellent dynamics and very low sensitivity to dirt.

Typical applications include

- Process engineering
- Packaging and food industries
- Environmental engineering
- Surface treatment
- Material coating
- Burner control systems
- Fuel cell technology

Characteristics:

- High level of accuracy
- Fast response and settling time
- Excellent span
- Optional calibration for two gases
- Integrated totalizer
- Field bus optional
- Mass Flow Communicator (PC configuration software)
- 3 binary inputs and 2 binary outputs (relay outputs)
- Galvanic isolation of inputs and outputs

Data:

- Full scale range 25–500 l_N/min (8716) 25–1500 l_N/min (8706), (N_2 at 273.15 K and 1013,25 mbar)
- Settling time < 500 ms
- Accuracy ± 1.5 % of rate ± 0.3 % F.S.
- Repeatability ±0,1 % F.S.
- Linearity ± 0.25 % F.S.
- Span 1:50
- Max. operating pressure 10 bar depending on the application
- Type of protection IP 65
- Port connection G1/4-3/4, NPT1/4-3/4, screw-in connector
- Analog signal transmission or digital communication (RS-232, RS-485, field bus)
- Voltage supply 24 V DC
- Power consumption max. 32.5 W
- Stainless steel or aluminum body

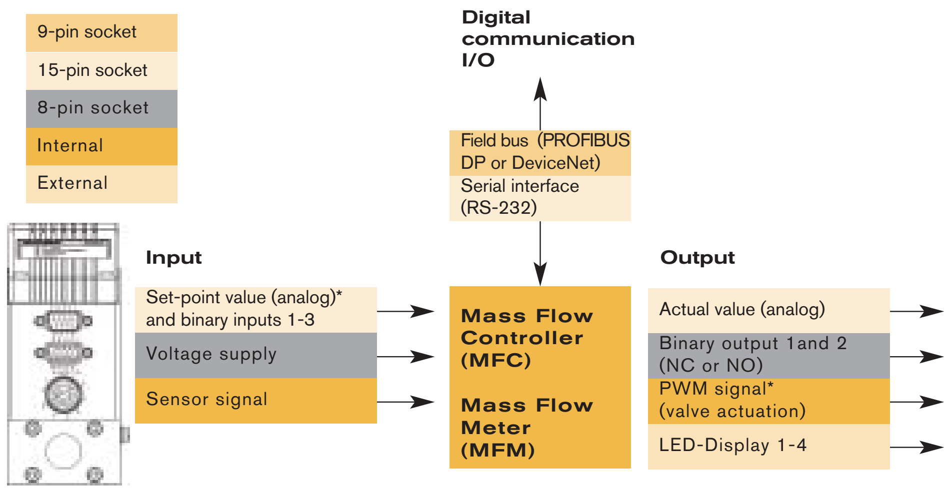


Figure 20: Electrical interfaces Type 8716/8706

(* Not with MFM)

7.4. MFC Type 8626, MFM Type 8006

Types 8626 (MFC) and 8006 (MFM) are particularly suitable for very large flow rates and harsh conditions. They also use the inline measuring method, enabling these units to offer excellent dynamics as well as low sensitivity to dirt and low pressure loss.

Figure 21: MFC 8626

Figure 22: MFM 8006

Typical applications include

- Process engineering
- Packaging and food industries
- Environmental engineering
- Heat treatment of metals
- Burner control systems
- Fuel cell technology

Characteristics:

- High level of accuracy
- Fast response and settling time
- Excellent span
- Optional calibration for two gases
- Integrated totalizer
- Field bus optional
- Mass Flow Communicator (PC configuration software)
- 3 binary inputs and 2 binary outputs (relay outputs)
- Galvanic isolation of inputs and outputs

Data:

- Full scale range 25–1500 l_N/min (N_2 at 273.15K and 1013.25 mbar)
- Settling time <500 ms
- Accuracy ± 1.5 % of rate ± 0.3 % F.S.
- Repeatability ± 0.1% F.S.
- Linearity ± 0.25 % F.S.
- Span 1:50
- Max. operating pressure 10 bar depending on the application
- Type of protection IP 65
- Port connection G1/4-3/4, NPT1/4-3/4, screw-in connector
- Analog signal transmission or digital communication (RS-232, RS-485, field bus)
- Voltage supply 24 V DC
- Power consumption max. 50 W
- Stainless steel or aluminum body

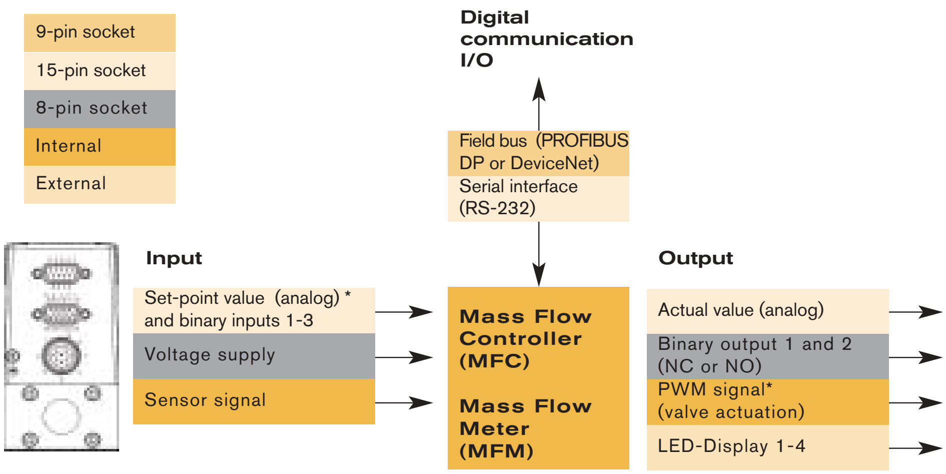


Figure 23: Electrical interfaces Type 8626/8006

(* Not with MFM)

8. Example applications

8.1. Industrial furnace control

Using the program controller and the MFC, it is possible to create a range of recipes (gas atmospheres) in the furnace. Gas control system for industrial furnaces, for example for nitriding or plasma coatings, have a similar design.

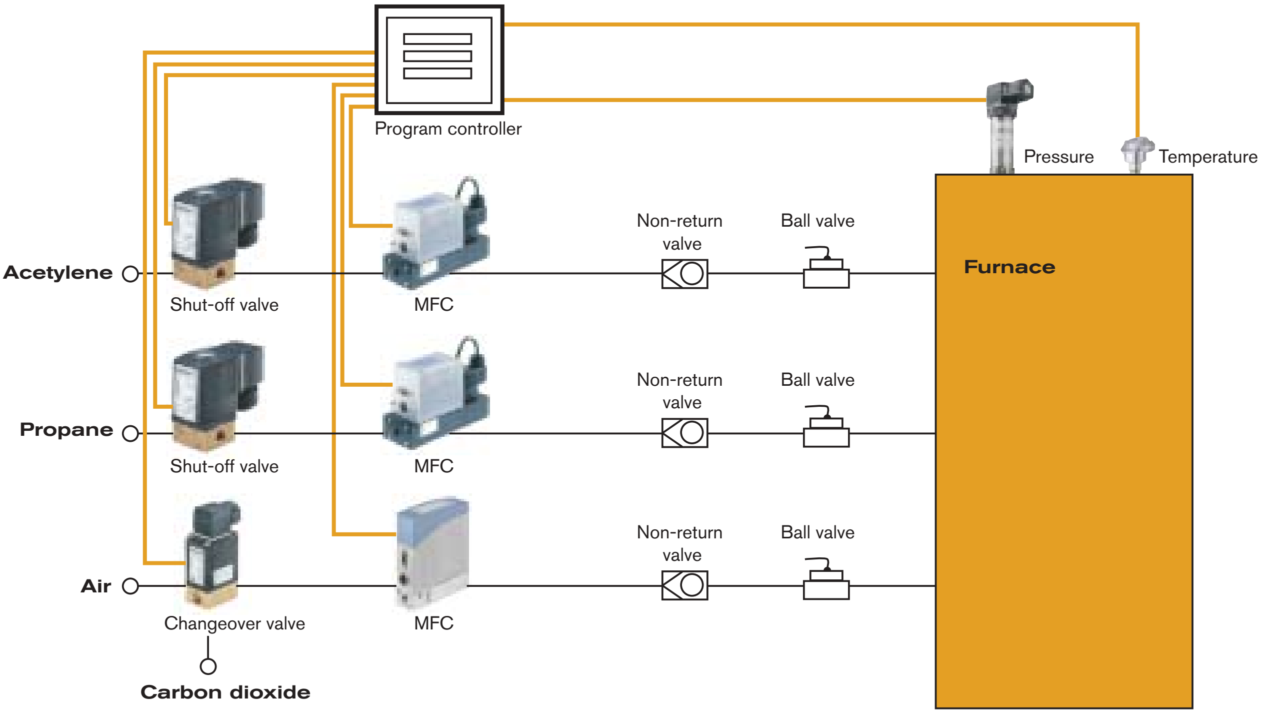


Figure 24: Gas control system for a heat treating furnace

8.2. Burner control

In this application, a combustion gas (for example methane, acetylene or hydrogen) is mixed with an oxidizing gas. Depending on the proportions of each gas, various flames (economy, pilot or main flame) can be adjusted. A stable and reproducible flame can be created by the MFCs.

8.3. Bioreactor control

The microprocessor control system contains two MFCs designed so that a certain O_2-N_2 mixture is fed into the bioreactor. The dimensions of the MFCs mean that they can be integrated into a 19" rack and controlled digitally directly through the RS-232. The control system also controls the pressure and temperature in the reactor.

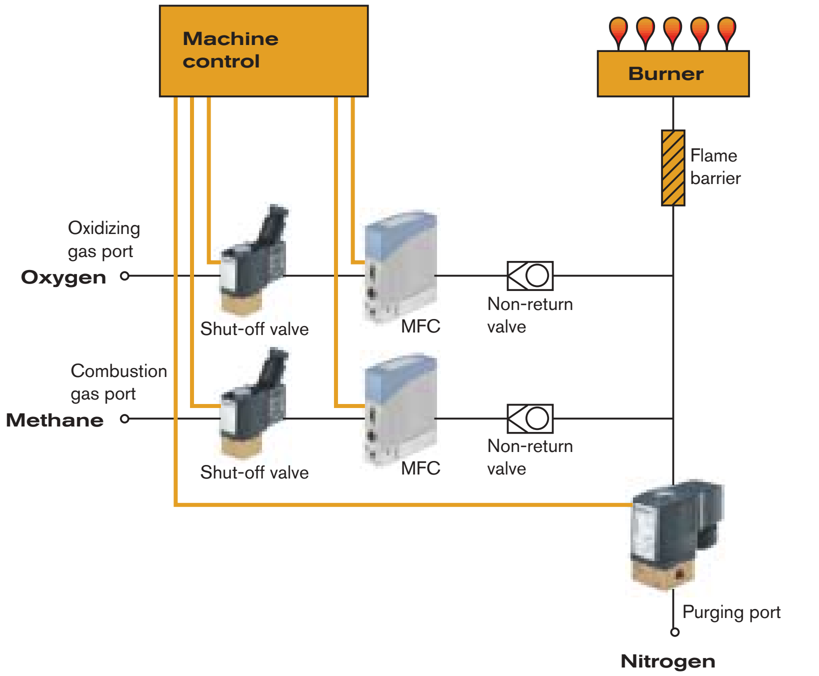


Figure 25: Example of burner control

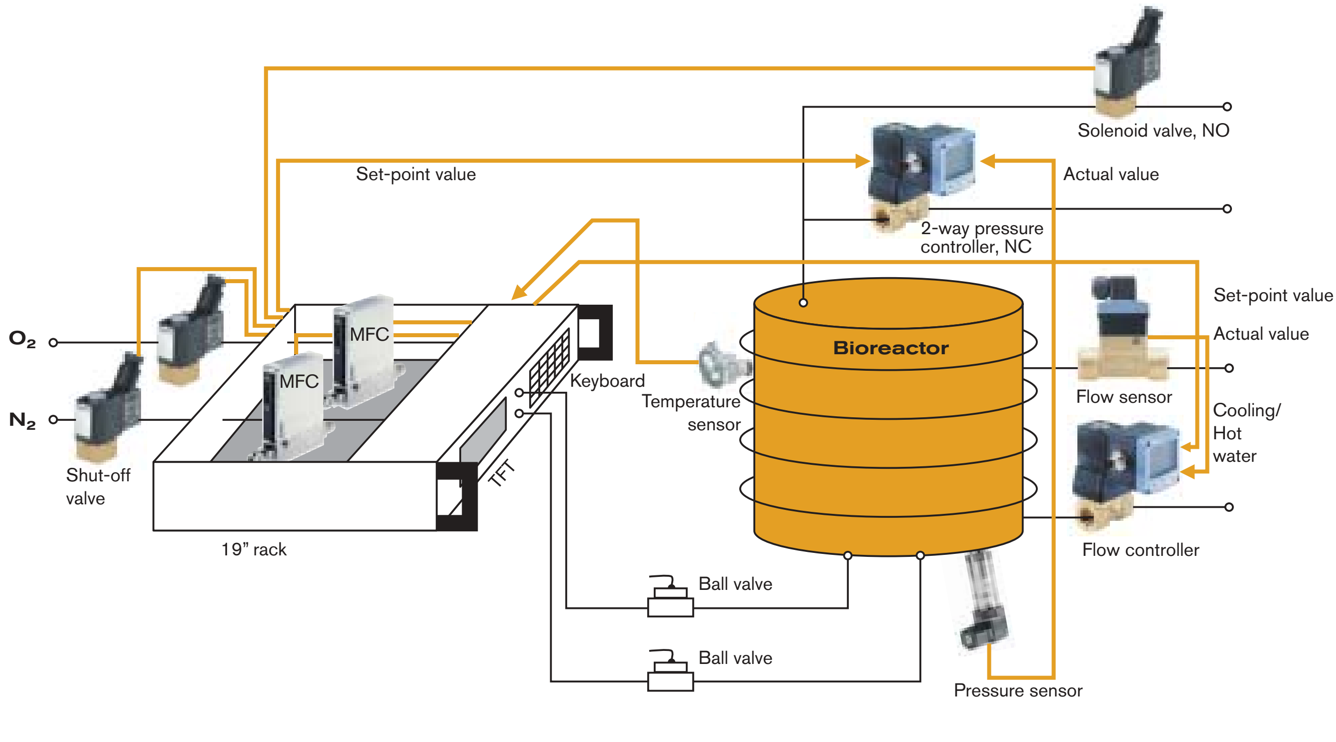


Figure 26: Example of bioreactor control

9. Proportional valves

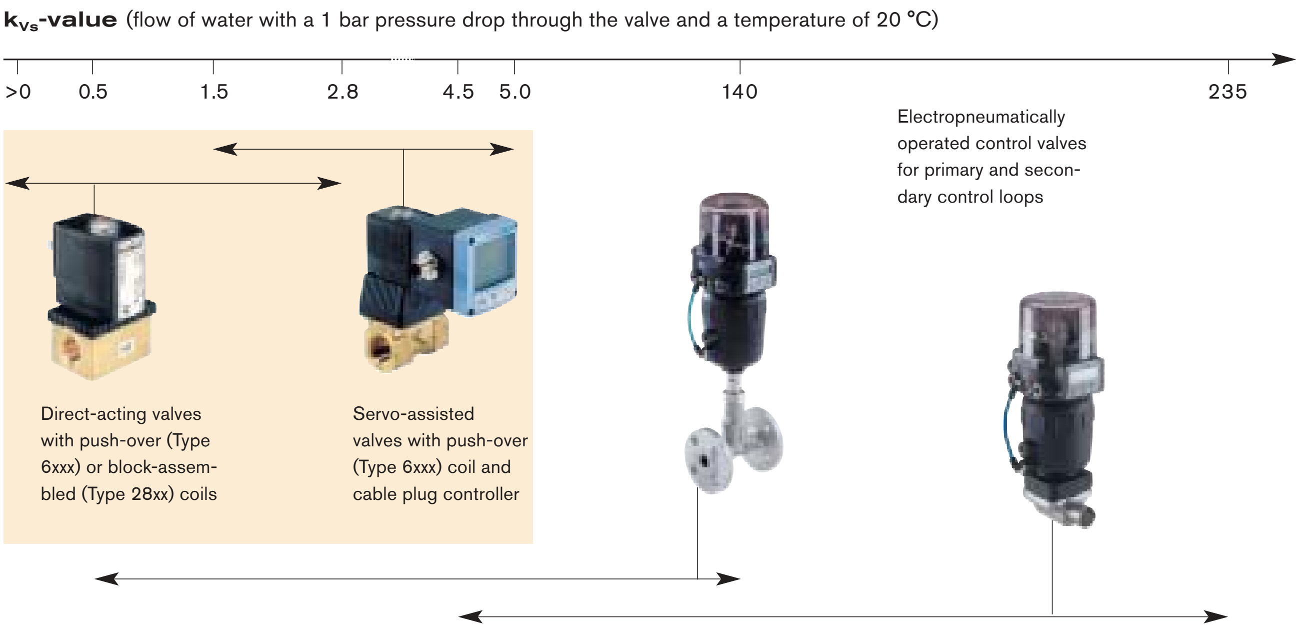


Figure 27: Extract from Bürkert range of control valves

9.1. Features of solenoid-operated proportional valves

Positioning valves can be combined with pneumatic, motorized, piezo-electric or solenoid actuators.
The main differences between the various actuation principles are price, type of media separation and dynamic and force properties. Solenoid-operated positioning valves are known in practice as proportional valves and cover the nominal diameter range below 25 mm. The magnetic force required for larger nominal diameters would require a coil size that is neither practical nor economical.

Open and closed control loops can be developed using proportional valves. Open control loops control the valve without feedback signal, while closed control loops control the difference between the set-point and actual values (see Section 9.5, Use of proportional valves in open or closed control loops). Switching solenoid valves, which are normally closed, form the basis for Bürkert proportional valves. Making constructive modifications to switching solenoid valves can achieve a balance of the spring and magnetic force for any coil current. The level of the coil current and magnetic force determines the stroke of the plunger or the valve opening, whereby the valve opening and the current are ideally linked by a linear dependence.

Direct-acting proportional valves (up to a nominal diameter of 12 mm) receive their feed below their seat, while servo-assisted models (with a nominal diameter over 12 mm) receive their feed above their seat. Since the medium pressure (on direct-acting valves) and magnetic force act against the return spring that presses the plunger against the seat, it is a good idea to set the minimum and maximum flow rate of the working range (coil current) in operating conditions. Bürkert proportional valves are normally closed (NC).

With shut-off valves, the magnetic force, generated by the minimum permissible switching current, is greater than the spring force of the return spring in every stroke position. The minimum switch-on current opens the valve (the curves in Figure 29 apply to normally closed valves). The greater the stroke, the smaller the air gap between the armature and the opposite armature pole, and the lower the required coil current. This is because the smaller the air gap, the greater the force of attraction created by the magnets. Proportional solenoids have a considerably different stroke force characteristic map. There is a plateau of at least the length of the working stroke for all current values. That means that there is a well-defined point of intersection for the magnetic force with the spring force that acts dependent on the stroke. I.e. the current value can be used to determine the stroke and therefore the opening of the valve.

Stroke force characteristic curves with a plateau can be obtained by preventing the large drop in magnetic force with a growing working air gap that occurs with a flat geometry of the armature and opposite armature pole, for example by using a conical transition area in the outer section of the opposite armature pole and a corresponding angle at the top of the armature (see Figure 28).

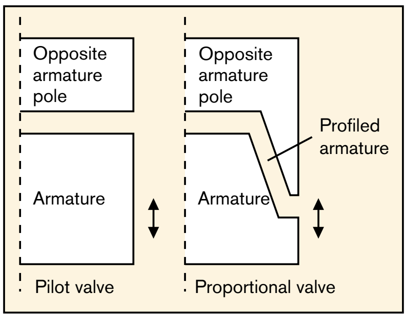


Figure 28: Comparison of the geometries in the working air gap of shut-off and proportional valves

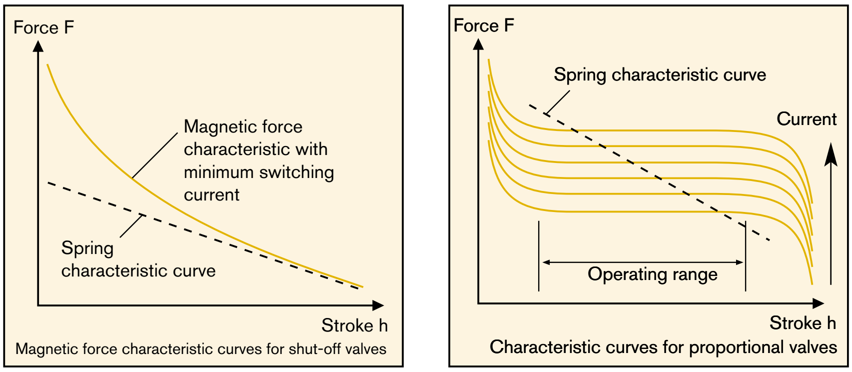


Figure 29: Comparison of the characteristic curves of shut-off and proportional valves

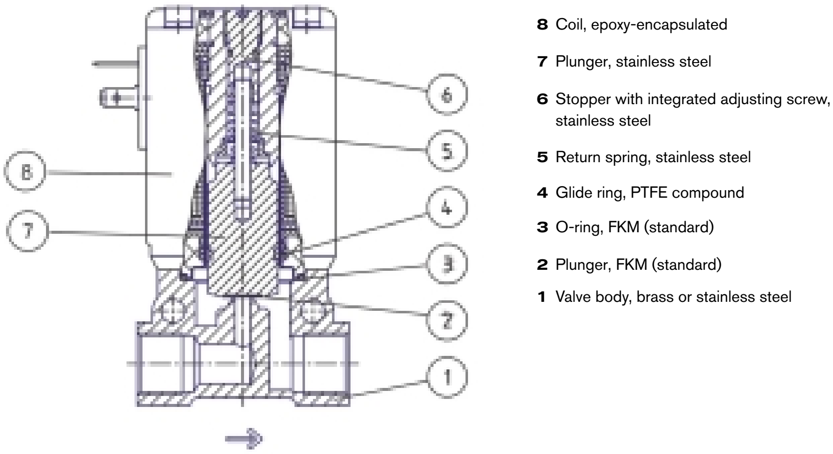


Figure 30: Cross section drawing of Type 2834 proportional valve

Cross section of a direct-acting valve with a block-assembled coil

The coil on the direct-acting proportional valve in Figure 30 is secured to the valve body by four screws (block-assembled). The armature, also known as the plunger, contains a plunger seal that ensures that the valve is closed tightly by spring force when no current is applied to it. The plunger-type armature is guided by a pin and a glide ring. The PTFE glide ring has a negative effect as a result of the friction it generates. Minimizing this friction is particularly important inrespect to the hysteresis and response sensitivity (see Section 9.3, Characteristic parameters of proportional valves). This can be achieved through perfect guidance of the plunger with low friction glide rings and electronically by using a suitable actuation system (see Section 9.2, Actuating proportional valves). The pressure range can be established using the adjusting screw in the opposite armature pole.

Cross section of a direct-acting valve with push-over coil

In addition to direct-acting valves with block-assembled coils, there are coils that are pushed over an armature guide tube and secured with a locknut (Figure 31). Push-over coils can be turned and replaced easily. In contrast to block-assembled valves, the armature is guided by two glide rings.

In newly developed direct-acting proportional valves, such as Type 2822, shaped springs, rather than glide rings and spiral springs, are used for guidance and resetting. This form of guidance results in virtually no friction. The bottom shaped spring guides the plunger while the top one takes care of the resetting action.

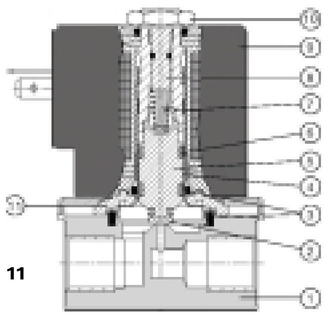


Figure 31: Cross section drawing of a proportional valve with push-over coil

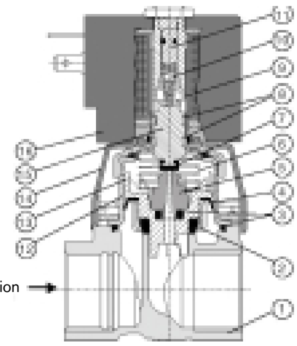


Figure 32: Cross section drawing of a servo-assisted proportional valve

Cross section of a servo-assisted valve

In the case of seat valves, for large flow rates, in other words large nominal diameters, the force requirements on the solenoid actuator increase. The use of direct-acting proportional valves for large flow rates would therefore require very large solenoid actuators. For servo-assisted systems (Figure 32), the main seat of the final control element is not opened and closed by the solenoid actuator, but rather by a pilot piston.
The pilot piston supports the solenoid actuator, thus necessitating less effort and expense.

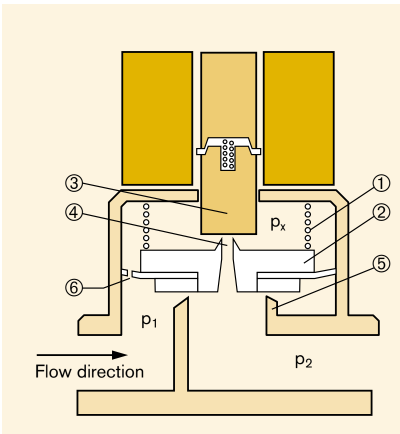


Figure 33: Diagram of a servo-assisted proportional valve

Figure 33 shows the operating principle of such a valve. When it is closed, the medium at the input side has a pressure of p_1, the core or plunger (3) has dropped out and therefore presses on the pilot seat (4). As a result of this and the force of the piston spring, which acts on the piston (2), the main seat (5) is closed. A restrictor port (6) allows the medium to enter the control chamber (1) and press on the diaphragm or gasket from above with a pressure p_x. If the coil is operated at a higher current and the plunger is therefore attracted, the medium can escape from the control chamber.

As soon as the force formed from the product of p_x and the piston surface area A_k is lower than the force formed from the product of p_1 and the circular ring surface area ($A_k - A_s$), the medium at the input has a supporting role in opening the main seat. If the restrictor port, pilot seat and area ratios on the main stage are rated accordingly, the compression forces on the piston reach equilibrium when the seat is opened by a certain position. With proportional pilot control, ideally, the piston follows the continuous axial movement of the plunger precisely at the distance that creates this equilibrium. Theoretically, the force requirement for the pilot solenoids can be drastically reduced by the parallel reduction of the pilot seat and the restrictor port, but its sensitivity to dirt, the negative effects on the dynamics, and friction forces limit this process.
A minimum input pressure is required for servo-assisted systems to overcome the frictional forces that counteract the opening motion of the piston. In addition, it must also overcome the force of the piston spring, which primarily ensures the availability of adequate sealing force even if the pressure is low.

9.2. Actuating proportional valves

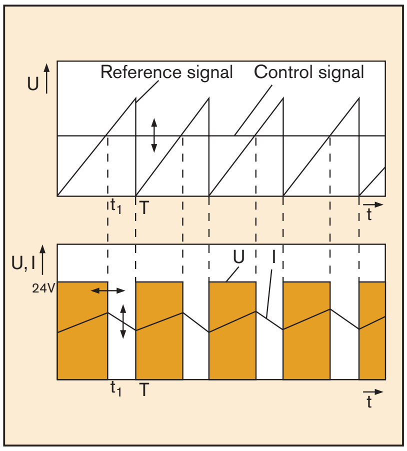


Figure 34: Pulse width modulation principle sketch

In principle, it is possible to actuate the proportional solenoid with variable DC voltage, but as a result of the friction on the guiding points of the plunger, this results in poor response sensitivity and characteristic curves with high hysteresis and a step structure (stick-slip effect). To prevent this, the standard input signal is converted into a continuously varying solenoid excitation. This kind of actuation results in the plunger being made to oscillate constantly around its equilibrium position at low amplitude. This means that it remains in its sliding friction state. The conventional kind of actuation is a pulse width modulated voltage signal (PWM actuation, see Figure 34). With PWM actuation, the effective solenoid current with a constant voltage supply is set by the duty cycle of the rectangular signal. The PWM frequency is tailored to the intrinsic frequency and attenuation of the spring-plunger system as well as the inductance of the magnet circuit.
If the control signal rises (Figure 34, top), the duty cycle t_1/T (t_1: on time, T: cycle duration, f = 1/T: frequency) also rises. The effective coil current rises at the same time since the pulse width of the rectangular signal increases (Figure 34, bottom).
The reference signal is a periodic signal.

Functions of the control electronics

Essentially, the control electronics converts the analog set-point signal at the input into a corresponding pulse width modulated output signal, which is used to control the valve.
In addition, the control electronics contains a current control facility to compensate for coil heating, a facility to adjust the minimum and maximum coil current to the pressure conditions in the specific application, a zero switch-off function to close the valve and a ramp function.

- **Current control facility to compensate for coil heating**
  Since the resistance changes over time as a result of the coil heating, a current control facility is integrated into the control electronics. A current control facility is particularly important in open control loops. The current control facility is irrelevant in closed process control loops.

- **Adjustment of the minimum and maximum coil current to the pressure conditions in the specific application**
  Under operating conditions, potentiometers can adjust the current values at which the valve starts to open or reaches its fully open setting.

- **Zero switch-off function to close the valve**
  The zero switch-off function ensures that the valve is closed if the input signal is less than 2 % of the maximum value. The coil current is then set to zero. The zero switch-off function must generally be deactivated to set the minimum coil current.

- **Ramp function**
  Set-point adjustments can be sent to the proportional valve with a delay of 0 – 10 seconds. Sudden changes in the set-point value, which may cause oscillations in some systems, can thus be suppressed.

9.3. Characteristic parameters of proportional valves

- **k_{Vs}-value/Q_{Nn}-value**
  Valves are comparable in fluidic terms by their k_V value (unit: m^3/h), which is measured by the flow of water at 20 °C and 1 bar relative pressure at the valve input against 0 bar at the valve output. A second flow characteristic, the Q_{Nn} value, is often stated for gases. The Q_{Nn} value specifies the standard flow rate in l_N/min of air (20 °C) at 6 bar (overpressure) at the valve input and 1 bar pressure loss through the valve. Reference conditions for the gas are 1.013 bar absolute and a temperature of 0 °C (273 K).

- **Hysteresis**
  The maximum difference of the fluid output signal as it passes through the full electrical input signal range in the upward and downward directions; stated as a percentage of the maximum fluid output signal (the flow rate is assumed for the example in the sketch).
  Hysteresis is caused by friction and magnetization.

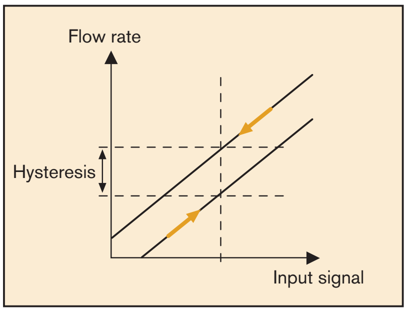


Figure 35

- **Sensitivity**
  Smallest set-point differential that results in a measurable change in the fluid output signal; stated as a percentage of the maximum fluid output signal.

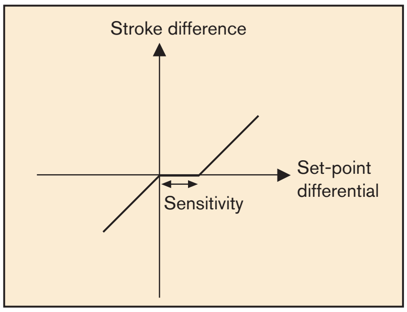


Figure 36

- **Linearity**
  Measure of the maximum deviation from the linear (ideal) characteristic curve; stated as a percentage of the maximum fluid output signal.

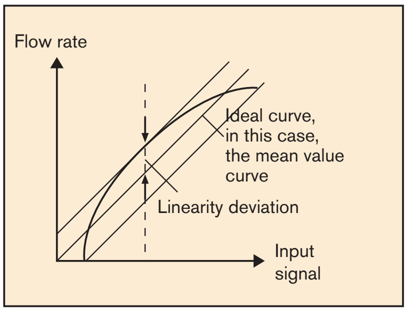


Figure 37

- **Repeatability (reproducibility)**
  Range within which the fluid output variable deviates if the same electrical input signal, coming from the same direction, is set repeatedly; stated as a percentage of the maximum fluid output signal.

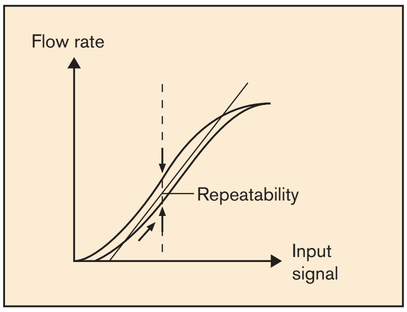


Figure 38

- **Span**
  Ratio of the k_{V_s} value to the minimum k_V value at which the characteristic curve remains within a tolerance band about the ideal characteristic curve in terms of its height and gradient.

Span = k_{Vs}/k_{Vmin}

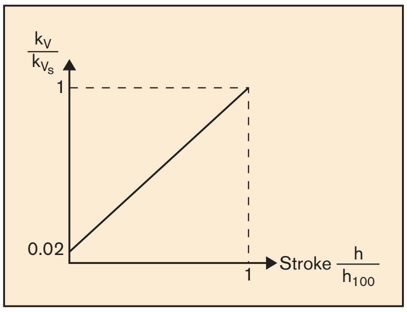


Figure 39

9.4. Rating of proportional valves

To ensure smooth, problem-free control functioning, proportional valves must be rated and selected for a specific task. The most important characteristic parameters for selecting a proportional valve are the k_V value and the pressure range of the application. In addition to the k_V value, the maximum supply or input pressure is the main value required when selecting a valve (type and nominal diameter). The smaller the nominal diameter of the valve or the stronger the coil, the greater the possible maximum pressure it can handle.

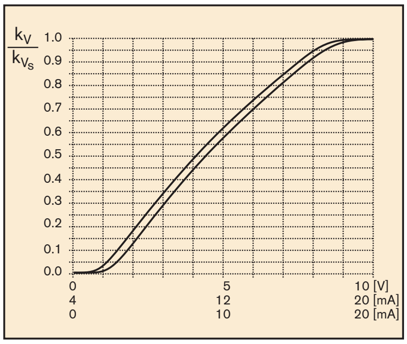


Figure 40: Typical flow-rate characteristic curve of a proportional valve

The k_V value can be calculated using the following formulae.
Using the calculated k_V value and the pressure range of the application, it is possible to find the valve type using the type selection diagram (see Section 10, Proportional valve range).
The k_V value of the application must be less than the k_{V_s} value of the valve achieved when it is fully open.

Calculation formulae for determining the k_V value

Pressure gradient		Liquids, k_v in m³/h	Gases, k_v in m³/h
Sub-critical	$p_2 > \frac{p_1}{2}$	$= Q \cdot \sqrt{\frac{\rho}{\Delta p \cdot 1000}}$	$= \frac{Q_N}{514} \cdot \sqrt{\frac{\rho_N \cdot T_1}{\Delta p \cdot p_2}}$
Super-critical	$p_2 < \frac{p_1}{2}$	$= Q \cdot \sqrt{\frac{\rho}{\Delta p \cdot 1000}}$	$= \frac{Q_N}{257 \cdot p_1} \cdot \sqrt{\rho_N \cdot T_1}$

k_V = Characteristic flow rate in m³/h
Q = Flow rate of application in m³/h (Liquids)
Q_N = Normal flow rate in m_N^3/h
$Q_{Nn} = Q_N$ (p_1=7 bar(a), P_2 = 6 bar(a), T_1=293 K)
p_1 = Input pressure in bar(a)[1]
p_2 = Output pressure in bar(a)
Δp = p_1-p_2 in bar
ρ = Density in kg/m³
ρ_N = Normal density in kg/m³
T_1 = Medium temperature in (273+t) K

[1] bar(a) = absolute pressure, barg corresponds to the pressure relative to the atmospheric pressure (1.013 bar)

Conversion from standard or operating into normal conditions:

$$Q_N = Q_S \cdot \frac{T_N \cdot p_S}{T_s \cdot p_N}$$

Q_S = Flow rate under standard (1.013 bar and 20 °C) or under other operating conditions
p_S = Absolute pressure under standard (=1.013 bar) or under other operating conditions
T_S = Temperature under standard (=293 K) or under other operating conditions (=(273+t)K)
Q_N = Normal flow rate
p_N = Normal pressure (=1.1013 bar)
T_N = Normal temperature (= 273 K)

Conversion from k_V into Q_{Nn} and k_V into c_V:

k_V = 1078 · Q_{Nn}
k_V = 0.86 · c_V
c_V = characteristic flow rate in US gal/min = 0.227 m³/h. Flow rate of water at a temperature of 60 °F and at a pressure drop of 1 psi through the armature (1 psi = 0.069 bar)

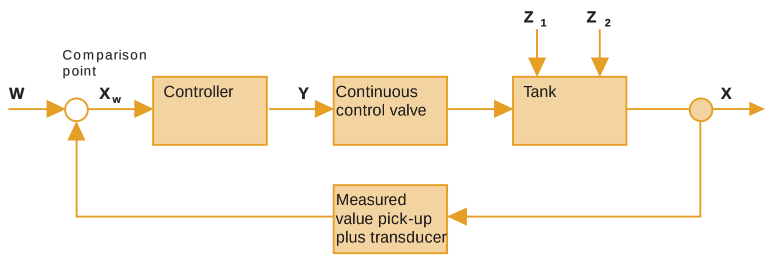
The aim is to avoid a situation where the “final few percentage points of flow rate are squeezed out of a system” by increasing the size of the valve (k_{Vs}) too far. If k_{Vs} exceeds the flow-rate coefficient of the system k_{Va} to a great extent, the valve authority

$$\psi = \frac{(\Delta p)_{V0}}{(\Delta p)_0} = \frac{k_{Vs}^2}{k_{Va}^2 + k_{Vs}^2}$$

becomes too low, leading to a situation where only a small proportion of the operating range of the valve is used. This can result in impairment of the resolution and the general control quality.
In this, $(\Delta p)_{V0}$ is the pressure drop through the fully opened valve and $(\Delta p)_0$ is the pressure drop through the entire system.

The valve authority ψ should not be below 0.3 ... 0.5 in order to ensure an acceptable operating characteristic curve for the system.

9.5. Use of proportional valves in open and closed control loops



w: Set-point value or reference variable (required filling level)
x: Actual value or controlled variable (measured filling level)
x_w: Control deviation (actual value – set-point value), also known as x_d
y: Controller out put signal (control variable)
z_1: Disturbance variable 1 (outflow from the tank)
z_2: Disturbance variable 2 (evaporation of liquid from the tank)

Figure 41: General block diagram of the closed control loop

Comparisons of open and closed control loops and continuous and on/off controllers
Figure 41 shows a closed control loop. Without returning the actual value or controlled variable x by using a measured value pick-up with an integral transducer, an open control loop is produced. The influence of disturbance variables (z_1, z_2), for example coil heating in proportional valves, leads to control differences in open control loops that cannot be compensated. The controller finds the control signal y depending on the control deviation x_w (difference between set-point and actual value). The proportional valve is controlled by the manipulated variable with the aim of reducing or eliminating the deviation in the controlled system.
Example: if the water supply to a tank is controlled (open control loop), the tank will overflow or be completely emptied. Regulating the supply depending on a signal relating to the filling level (level measurement) guarantees that the filling level will be regulated by the set-point value.

When a closed control loop is designed, the appropriate controller is selected for a specific controlled system. In addition to knowledge of the dynamic and static properties of the controlled system, this also requires knowledge about the properties of the various controller versions or controller types.
Controllers can be divided into two main groups, continuous and on/off controllers. Continuous controllers output a continuous control signal, while on/off versions output a cycled signal. The positioning valve must therefore be capable of stopping in every stroke position (positioning range) if a continuous controller is used, while a on/off valve will suffice if an on/off controller is used. Depending on the cycle frequency, a range of set-point values can be handled. The drawback of on/off controllers is the fluctuation of the actual value around the set-point value. Examples of on/off controllers are two and three-point controllers.

Continuous (PI) controllers
Continuous controllers are used for demanding closed-loop control tasks. There is a whole series of continuous controllers, with the main ones in use being P, PI, PD and PID controllers. These controller types differ from each other in terms of their dynamics, in other words the speed with which they move the actual value towards the set-point value depending on the level of control deviation. These controllers are characterized by their step response, or to be more precise, by the speed with which they react after a sudden change in the input variable, the control deviation x_w.

Cable plug controllers, as shown in Figure 42, contain a PI controller and can be mounted directly on proportional valves.

Figure 42: Bürkert cable plug controller combined with a proportional valve

The PI algorithm consists of a proportional component and an integral component. In a stationary state, the control variable of the proportional component is directly proportional to its input variable (x_w). The control variable of the P-component can be calculated as follows:

$$y = k_p \cdot x_w = k_p \cdot (w - x)$$

Depending on k_p the control variable may be less than ($k_p < 1$) or greater than ($k_p > 1$) the control deviation. k_p is known as the proportional gain factor or proportional co-efficient.

Characteristics of a pure P controller:

- Operates without delay and very quickly
- Control loops with a pure P controller have a permanent control deviation.

The integral component calculates its share of the control variable via the time integral of the control deviation. If there is a control deviation, the integral component increases the control variable. This avoids the permanent control deviation that occurs on P controllers and PD controllers.

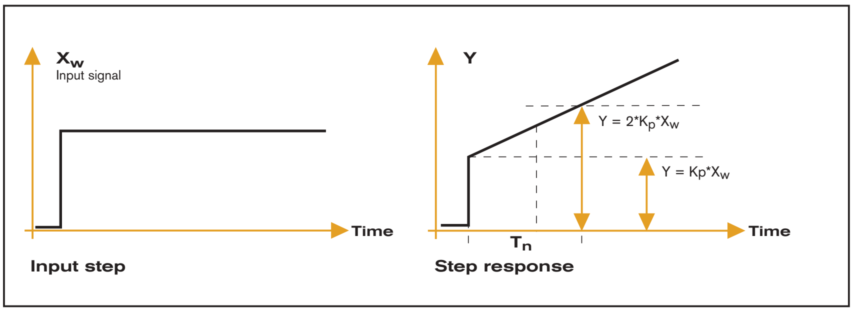


Figure 43: Step response of the PI controller

The control variable of a PI controller is calculated as follows:

$$y = K_p * \left(\frac{1}{T_n} * \int (x_w(t)dt) + x_w(t) \right)$$

As can be seen from the above calculation formula for the control variable, the influence of the I-component is determined by parameter T_n. The lower T_n becomes, the greater the I-component becomes when calculating the control variable. Integral-action time T_n is the time that the controller requires to generate a control variable of the same magnitude as that which occurs immediately as the result of the P-component by means of the I-component (see Figure 43).

Characteristics of the PI controller:

- Responds quickly (P-component) and eliminates control deviations (I-component)
- Better adjustment to controlled system possible, since two parameters can be adjusted.

Practical experience has shown that the following estimate on the suitability of conventional controller types can be made for controlling important technical controlled variables.

Table 5: Suitability of various continuous controllers for controlling important technical controlled variables

	Controller type			
	P	**PD**	**PI**	**PID**
Controlled variable	**Permanent control deviation**		**No permanent control deviation**	
Temperature	Conditionally suitable	Conditionally suitable	Suitable	Suitable for stringent demands
Flow	Unsuitable	Unsuitable	Suitable	Over-dimensioned
Pressure	Suitable	Suitable	Suitable	Over-dimensioned
Filling level	Suitable	Suitable	Suitable	Over-dimensioned

Additional, more detailed control information is contained in our “Competences” brochure.

10. Proportional valve range

Table 6: Overview of Bürkert Proportional Valves

	Nominal diameters DN [mm]	k_{Vs} range [m^3/h]	Max. operating pressure [bar]	Port connections	Gases	Fluids	Max. power consumption	Type
Type 28xx Block-assembled coil	0.8..1.60, 0.3..1.0 0.8..4.0 2..6 3..12	0.018..0.05 0.002..0.03 0.018..0.33 0.12..0.65 0.25..2.5	12..6 10..2 16..2 25..4 25..2	1/8“, flange 1/8“, flange 1/8“ / 1/4“, flange 3/8“ 1/2“ / 3/4“	X X X X X	X X X X X	4W 1W 8W 14W 24W	2821 2822 2832 2834 2836
Type 6xxx Push-over coil	0.8..1.6 0.8..4.0 4..6 8..12 10..20	0.018..0.05 0.018..0.33 0.4..0.7 1.4..2.8 1.4..5.0	12..6 16..2 4..2 0.7..0.2 10	1/8“ 1/8“ / 1/4“ 3/8“ 1/2“ / 3/4“ 3/8“–1“	X X X X	X X X X X	4W 8W 10W 14W 18W 8W 10W 14W	6021 6022 6023 6024 6223

10.1. Brief instructions: How to find the right proportional valve?

1. What medium do you want to control or supply?
The parts of the valve that come into contact with the medium must be suitable for it.

2. What is the maximum input pressure?
The maximum input pressure p_{1max} must be checked to ensure that the valve can completely close against the medium pressure.

3. What are the process data?
To achieve the optimal design of the nominal valve diameter, in addition to the required maximum flow rate Q_{nom}, the pressure values immediately upstream and downstream of the valve (p_1, p_2) at this flow rate Q_{nom} must be known. These often differ from the input and output pressure of the system as a whole because both upstream and downstream of the valve, there may be additional flow resistors (pipes, shut-off valves, nozzles, etc.). If the input pressure (p_1) and output pressure (p_2) are not known or cannot be obtained by measurement, an estimate must be made, taking into account the approximate pressure drops through the flow resistors upstream and downstream of the valve at Q_{nom}. For rating purposes, it is also necessary to provide details of the medium temperature T_1 and the standard density ϱ_N of the medium (can be obtained for mixtures using the percentage values). The possible measuring span must be checked to determine whether the minimum flow rate Q_{min} can be adjusted.

In the type selection diagram, you can find valves that comply with the following rules:

- k_{Vs} of valve > k_V of the application and
- pressure p_{1max}, that the valve can switch > pressure p_{1max}, that can apply upstream of the valve.

10.2. Type selection diagrams

k_{Vs} [m³/h]	DN [mm]	Max. operating pressure [bar] 0	0.2	0.4	0.5	0.7	1	1.5	2	3	3.5	4	5	6	8	10	12	16	25		Type
0.002	0.3																				2822
0.004	0.4																				2822
0.01	0.6																				2822
0.018	0.8																				2822
0.025	1.0																				2822
0.018	0.8																				2821 6021
0.025	1.0																				2821 6021
0.04	1.2																				2821 6021
0.05	1.6																				2821 6021

Table 7: k_{Vs} ≤ 0.05 m³/h

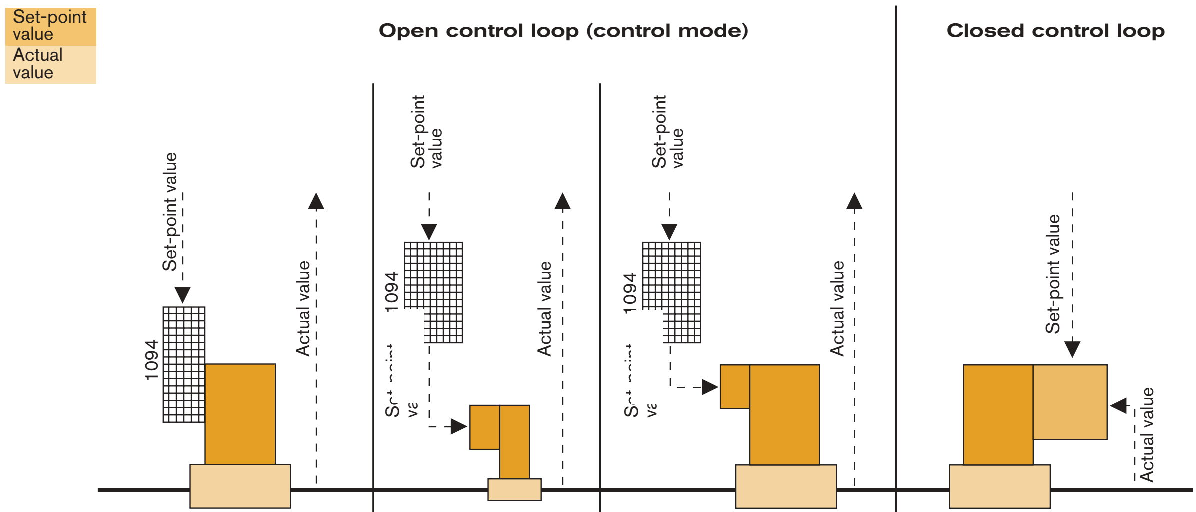
k_{Vs} [m³/h]	DN [mm]	Max. operating pressure [bar] 0	0.2	0.4	0.5	0.7	1	1.5	2	3	3.5	4	5	6	8	10	12	16	25		Type
0.018	0.8																				2832 6022
0.04	1.2																				2832 6022
0.06	1.5																				2832 6022
0.01	2.0																				2832 6022
0.15	2.5																				2832 6022
0.23	3.0																				2832 6022
0,33	4,0																				2832 6022
0.12	2.0																				2834
0.25	3.0																				2834
0.4	4.0																				2834
0.7	6.0																				2834
0.4	4.0																				6023
0.7	6.0																				6023

Table 8: k_{Vs} ≤ 0.7 m³/h

k_{Vs}	DN	Max. operating pressure [bar]																			Type
[m^3/h]	[mm]	0	0.2	0.4	0.5	0.7	1	1.5	2	3	3.5	4	5	6	8	10	12	16	25		
0.25	3.0																				2836
0.4	4.0																				2836
0.9	6.0																				2836
1.4	8.0																				2836
2	10.0																				2836
2.5	12.0																				2836
1.4	8.0																				6024
2	10.0																				6024
2.8	12.0																				6024
1.4	10.0																				6223
2.5	13.0																				6223
5	20.0																				6223

Table 9: k_{Vs} ≤ 5.0 m^3/h

10.3.
Overview of possible actuators



	Open control loop (control mode)			Closed control loop
Valve	2832, 2834, 2836, 6022, 6023, 6024, 6223	2821, 2822, 6021	2832, 2834, 2836, 6022, 6023, 6024, 6223	2832, 2834, 6022, 6023, 6024, 6223
Cable plug	–	2506, 2507 (28xx)	2508	–
Controller	1094	1094	1094	–
	–	–	–	8623-2, 8624-2, 8625-2

Figure 44: Possible combinations of Bürkert actuators with Bürkert Proportional Valves

11. Type descriptions of proportional valves and actuators

Figure 45:
Proportional Valve, Type 2821

11.1.
Type 2821

Direct-acting 2/2-way Proportional Valve; 1/8" or flange (DN 0.8 – 1.6 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.018 to 0.05 m³/h
- Max. operating pressure depending on nominal diameter, 12 bar (175 psi) (DN 0.8)
- Stainless steel or brass valve body
- Viton seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1:25
- Medium temperature –10 to +90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 4 W
- Control signal pulse width modulated (PWM)

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time (20 – 30 ms)

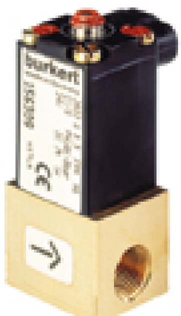


Figure 46:
Proportional Valve, Type 2822

11.2.
Type 2822

Direct-acting 2/2-way Proportional Valve; 1/8" or flange (DN 0.3 – 1.0 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.002 to 0.027 m³/h
- Max. operating pressure depending on nominal diameter
- Stainless steel or brass valve body
- Viton seals, EPDM or PTFE on request
- Hysteresis < 10 %
- Repeatability < 0.25 % F.S.
- Span 1:500
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 12 V or 24 V DC
- Power consumption depending on nominal diameter, min. 1 W, max. 4 W
- Control signal pulse width modulated (PWM)

Characteristics:

- Process and product optimization as a result of continuous control
- Excellent span
- Good sensitivity (< 0.1 % F.S.)
- High repeatability
- Low-friction and low-noise valve, PWM control not necessary
- Low-power and low-flow valve
- Very short response time (< 20 ms)

Figure 47:
Proportional Valve, Type 2832

11.3. Type 2832

Direct-acting 2/2-way Proportional Valve; 1/8", 1/4" or flange (DN 0.8 – 4.0 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.018 to 0.58 m^3/h
- Max. operating pressure depending on nominal diameter, 16 bar (DN 0.8, 230 psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1: 25
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 8 W
- Control signal pulse width modulated (PWM)
- Option EEx ed II C T4/ATEX/ Zone 2, 22

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time (50 ms)

Figure 48:
Proportional Valve, Type 2834

11.4. Type 2834

Direct-acting 2/2-way Proportional Valve; 3/8" (DN 2 – 6 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.12 to 0.65 m^3/h
- Max. operating pressure depending on nominal diameter, 25 bar
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1:25
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 14 W
- Control signal pulse width modulated (PWM)
- Option EEx m II T4/ATEX/ Zone 2, 22
- Option steam design up to max. +140 °C.

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time

Figure 49:
Proportional Valve, Type 2836

11.5. Type 2836

Direct-acting 2/2-way Proportional Valve; 1/2" or 3/4" (DN 3 – 12 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.25 to 2.5 m³/h
- Max. operating pressure depending on nominal diameter, 25 bar (DN 3, 360 psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 1 % F.S.
- Span 1:25
- Medium temperature – 10 to +90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 24 W
- Control signal pulse width modulated (PWM)
- Option steam design up to max. +140 °C.

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- Good repeatability
- PWM control reduces stick-slip risk
- Very short response time

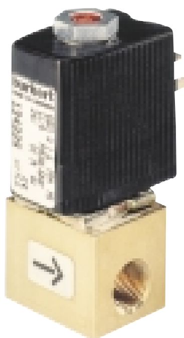


Figure 50:
Proportional Valve, Type 6021

11.6. Type 6021

Direct-acting 2/2-way Proportional Valve; 1/8" (DN 0.8 – 1.6 mm)

Data:

- For operation in closed control loops
- For neutral gases or liquids and vacuum
- k_{Vs} values 0.018 to 0.05 m³/h
- Max. operating pressure depending on nominal diameter, 12 bar (DN 0.8, 175 psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1:20
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 4 W
- Control signal pulse width modulated (PWM)

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of a power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time (20 – 30 ms)

Figure 51:
Proportional Valve, Type 6022

11.7. Type 6022

Direct-acting 2/2-way Proportional Valve; 1/8” or 1/4” (DN 0.8 – 4.0 mm)

Data:

- For neutral gases or liquids and vacuum
- k_{Vs} values 0.018 to 0.58 m³/h
- Max. operating pressure depending on nominal diameter, 16 bar (DN 0.8, 230 psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1:25
- Medium temperature − 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 8 W
- Control signal pulse width modulated (PWM)
- Option EEx m/em II T4, TU −30 to +60 °C/ATEX/ Zone 1, 21, 2, 22

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time (50 ms)

Figure 52:
Proportional Valve, Type 6023

11.8. Type 6023

Direct-acting 2/2-way Proportional Valve; 3/8” (DN 4 or 6 mm)

Data:

- For operation in closed control loops
- For neutral gases or liquids and vacuum
- k_{Vs} values 0.4 to 0.7 m³/h
- Max. operating pressure depending on nominal diameter, 4 bar (DN 4, 60 psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 0.5 % F.S.
- Span 1:10
- Medium temperature − 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 15 W
- Control signal pulse width modulated (PWM)

Characteristics:

- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time (50 ms)

Figure 53:
Proportional Valve, Type 6024

11.9.
Type 6024

Direct-acting 2/2-way low-Δp Proportional Valve; 1/2” or 3/4” (DN 8 – 12 mm)

Data:
- For applications with low operating pressures (< 700 mbar, e.g. natural gas)
- For neutral gases or liquids and vacuum
- k_{Vs} values 1.4 to 2.8 m^3/h
- Max. operating pressure depending on nominal diameter, 700 mbar (DN 8, 10psi)
- Stainless steel or brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 7 %
- Repeatability < 0.5 % F.S
- Span 1:25
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption 18 W
- Control signal pulse width modulated (PWM)

Characteristics:
- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Very short response time

Figure 54:
Proportional Valve, Type 6223

11.10.
Typ 6223

Servo-assisted 2/2-way high-flow Proportional Valve; 3/8” – 1” (DN 10 – 20 mm)

Data:
- For operation in closed control loops
- For neutral liquids
- k_{Vs} values 1.4 to 5.0 m^3/h
- Max. operating pressure 10 bar (145 psi)
- Minimum Δp = 0.5 bar
- Brass valve body
- FKM seals, EPDM or PTFE on request
- Hysteresis < 5 %
- Repeatability < 1 % F.S.
- Span 1:10
- Medium temperature – 10 to + 90 °C
- Type of protection IP 65
- Operating voltage 24 V DC
- Power consumption depending on nominal diameter, 15 W
- Control signal pulse width modulated (PWM)

Characteristics:
- Process and product optimization as a result of continuous control
- Tight-closing function in the event of power failure
- High repeatability
- PWM control reduces stick-slip risk
- Good response time (< 200 ms)

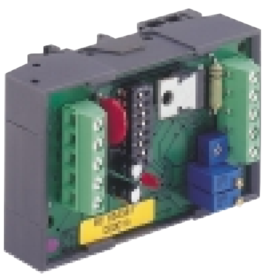


Figure 55: Control electronics, Type 1094 (top hat rail version)

Figure 56: Control electronics, Type 1094, mounted on a proportional valve

11.11. Type 1094

Control electronics for proportional valves

Data:

- Control electronics either as plug-on module or as a DIN-rail mounting version
- 1 standard signal input for set-point value
- 1 PWM signal output for valve control (max. 800 Hz, version for Type 2822 max. 6 kHz)
- Max. output current to valve 1.1 A
- Operating voltage 24 V DC
- Max. power consumption 0.5 W
- Max. ambient temperature 55 °C
- Dimensions:
  32 x 90 x 42 mm (plug-on module)
  46 x 76 x 31 mm (DIN-rail mounting version)
- Type of protection IP 65 (plug-on module)

Additional functions:

- Temperature compensation for heating of the coil by integrated current control
- Ramp function for damping sudden control signal changes
- Adjustment of minimum and maximum flow to the real pressure conditions
- Zero switch-off function

Figure 57:
Cable plug controller, Type 8623-2, mounted on a proportional valve

11.12. Type 8623-2

Compact flow controller for direct mounting
2 frequency inputs (actual value); 1 standard signal input (set-point value); 1 PWM signal output

Data:
- For liquids
- 2 frequency inputs for actual value (2 – 1000 Hz), e.g. for ratio control
- 1 standard signal input for set-point value
- 1 PWM signal output for valve control (max. 400 Hz)
- Accuracy 1 % F.S.
- Max. output current to valve 1 A
- Max. output current to sensor 0.5 A
- Operating voltage 24 V DC
- Max. power consumption 1.5 W
- Set-point value internal or external
- Input signals scalable
- Ambient temperature – 10 to + 60 °C
- Dimensions 54 x 54 x 61 mm, polyamide
- Type of protection IP 65
- Certified electromagnetic compatibility
- Optional field bus communication

Characteristics:
- Fast and easy installation
- High reliability due to decentralized intelligence
- Clear LCD display
- Programming of various
- functions
- Tight-closing function

Programming:
- Selection of internal or external set-point value
- Setting of control parameters
- Selection of inverted or non-inverted control
- Zero switch-off function
- Setting the unit and scaling

Figure 58:
Cable plug controller, Type 8624-2, mounted on a proportional valve

11.13. Type 8624-2

Compact flow pressure controller for direct mounting
1 standard signal input (actual value) and 1 standard signal input (set-point value); 1 PWM signal output

Data:
- For flowing gases or liquids
- Standard signal input for actual value
- Standard signal input for set-point value
- 1 PWM signal output for valve control (max. 400 Hz)
- Max. output current to valve 1 A
- Max. output current to sensor 0.5 A
- Operating voltage 24 V DC
- Max. power consumption 1.5 W
- Set-point value internal or external
- Input signals scalable 0 – 30 bar (435 psi)
- Ambient temperature – 10 to + 60 °C
- Dimensions 54 x 54 x 61 mm, polyamide
- Type of protection IP 65
- Certified electromagnetic compatibility
- Optional field bus communication

Characteristics:

- Fast and easy installation
- High reliability due to decentralized intelligence
- Clear LCD display
- Programming of various functions
- Tight-closing function
- Suitable for use as general-purpose controller for all controlled variables

Programming:

- Selection of internal or external set-point value
- Setting of control parameters
- Selection of inverted or non-inverted control
- Zero switch-off function
- Setting the unit and scaling

Figure 59:
Cable plug controller, Type 8625-2, mounted on a proportional valve

11.14. Type 8625-2

Compact temperature controller for direct mounting
1 Pt100 signal input (actual value); 1 standard signal input (set-point value); 1 PWM signal output

Data:

- 1 Pt100 signal sensor input
- 1 standard signal input for set-point value
- 1 PWM signal output for valve control (max. 400 Hz)
- Max. output current to valve 1 A
- 0.5 mA output for Pt100 sensor
- Operating voltage 24 V DC
- Max. power consumption 1.5 W
- Set-point value internal or external
- Input signals scalable – 50 to + 150 °C (– 58 to 302 °F)
- Resolution 0.25 °C
- Accuracy 1 °C
- Ambient temperature – 10 to + 60 °C
- Dimensions 54 x 54 x 61 mm, polyamide
- Type of protection IP 65
- Certified electromagnetic compatibility
- Optional field bus communication

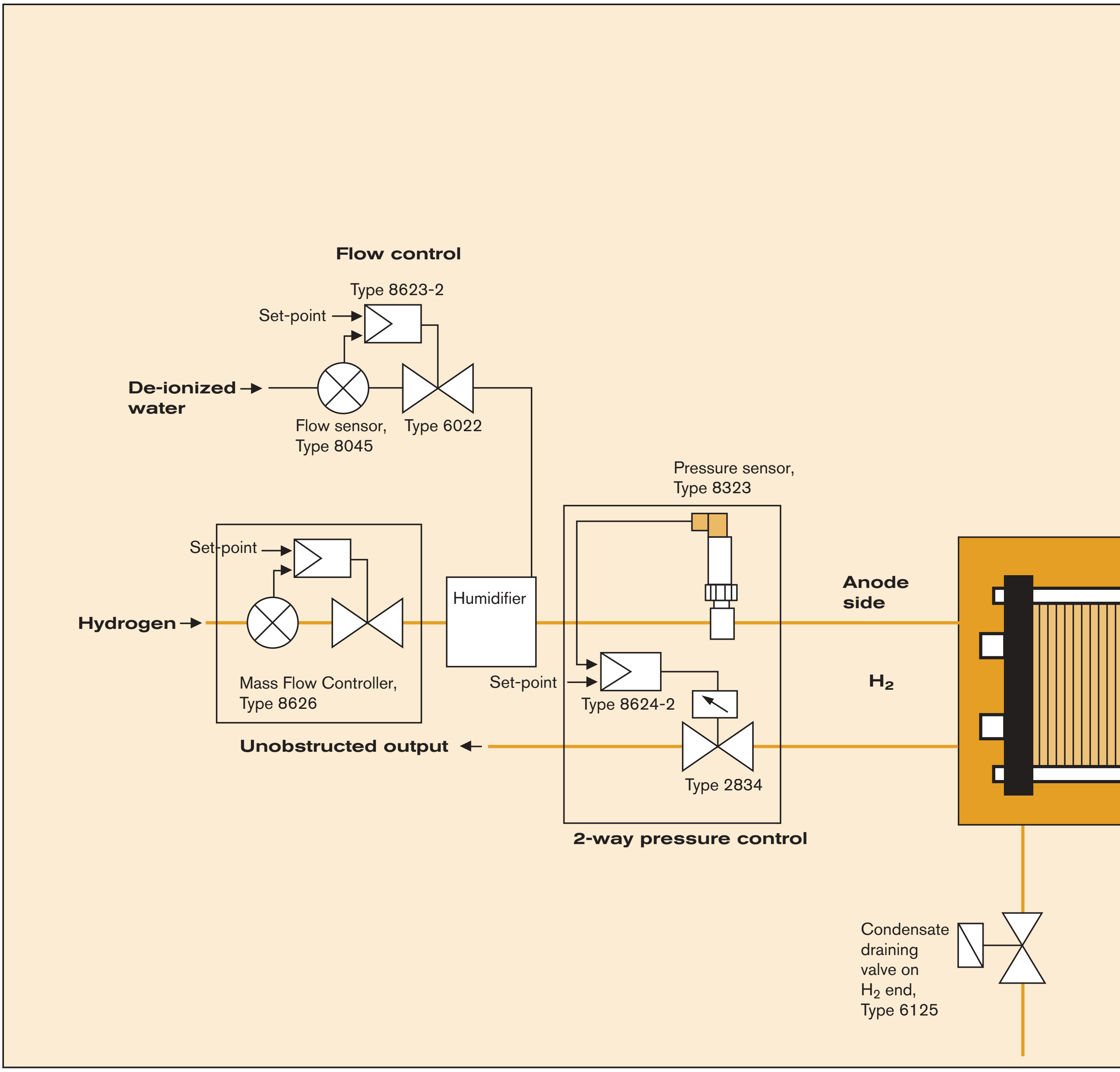
Characteristics:

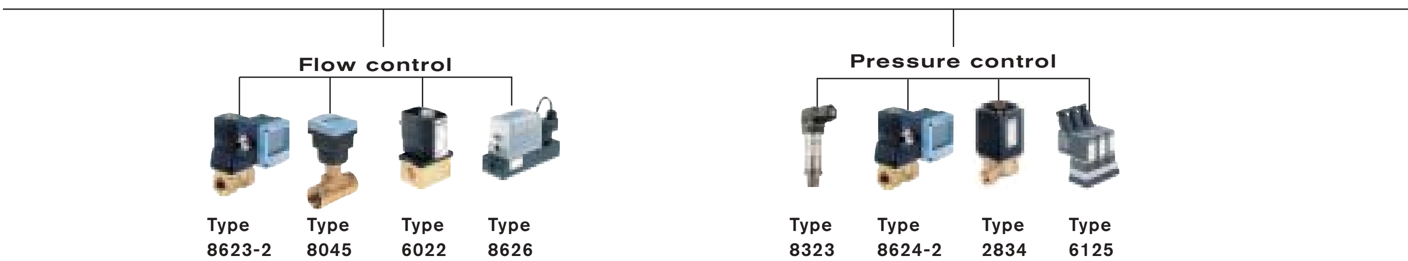
- Fast and easy installation
- High reliability due to decentralized intelligence
- Clear LCD display
- Programming of various functions
- Tight-closing function

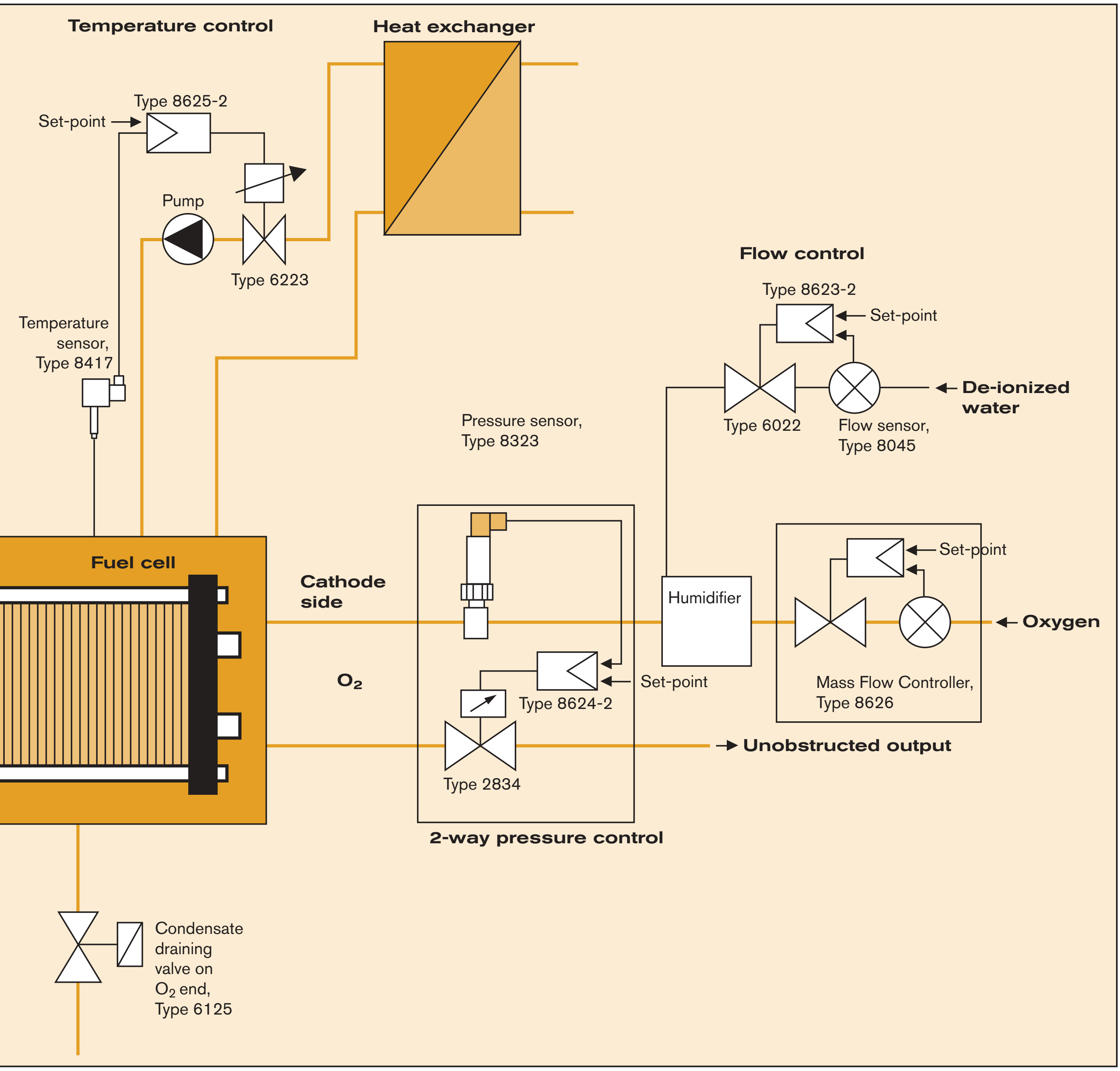
Programming:

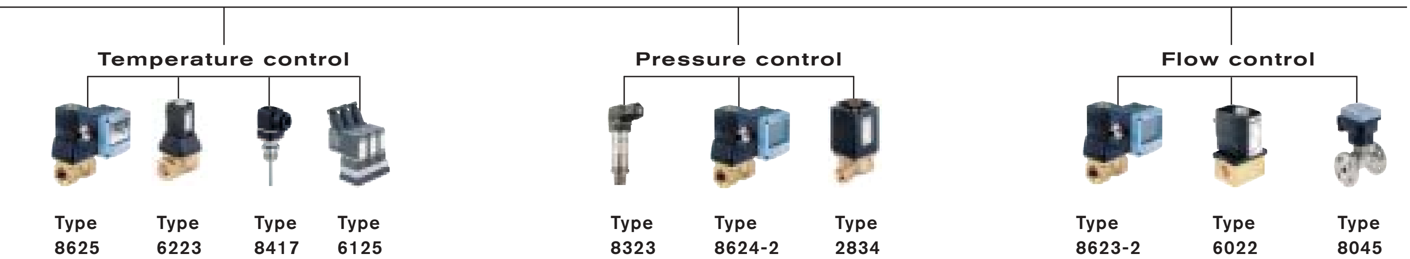
- Selection of internal or external set-point value
- Setting of control parameters
- Selection of inverted or non-inverted control
- Zero switch-off function
- Setting the unit and scaling

12. Application example






Temperature control
Heat exchanger
Type 8625-2
Set-point
Pump
Type 6223
Temperature sensor, Type 8417
Flow control
Type 8623-2
Set-point
De-ionized water
Type 6022
Flow sensor, Type 8045
Pressure sensor, Type 8323
Fuel cell
Cathode side
O_2
Set-point
Type 8624-2
Humidifier
Set-point
Oxygen
Mass Flow Controller, Type 8626
Unobstructed output
Type 2834
2-way pressure control
Condensate draining valve on O_2 end, Type 6125


Temperature control
Type 8625
Type 6223
Type 8417
Type 6125
Pressure control
Type 8323
Type 8624-2
Type 2834
Flow control
Type 8623-2
Type 6022
Type 8045

13. Conversion of various units

Pressure

	Pa	mWC	Torr	Inch H_2O	psi
1 bar	100000	10.20	750.1	401.6	14.505

mWC: meter water column
psi: pound per square inch

Flow rate

	sccm	slpm	scfm
1 l_N/min	1073.22	1.073	30.39
1 m_N^3/h	63.4	0.063	1.82

sccm: standard cubic centimeter per minute
slpm: standard liter per minute
scfm: standard cubic foot per minute

Temperature

	Celsius	Kelvin	Fahrenheit
x °C	–	= (x + 273.15) K	$= (\frac{9}{5}\, x + 32)$ °F
x K	= (x – 273.15) °C	–	$= (\frac{9}{5} \cdot [x - 273.15] + 32)$ °F
x °F	$= \frac{5}{9} \cdot (x - 32)$ °C	$= (\frac{5}{9} \cdot [x - 32] + 273.15)$ K	–

Reference conditions

- Standard (Index "N"):
  1013.25 mbar/273.15 K
- Normal (Index "s"):
  1013.25 mbar/293.15 K

Lengths

- 1 inch [in] = 2.54 cm = 0.0254 m
- 1 foot [ft] = 30.48 cm = 0.3048 m
- 1 yard [yd] = 0.9144 m

Volume

- 1 cubic inch = 16.387 cm^3
- 1 cubic foot = 28.317 dm^3
- 1 cubic yard = 0.76455 m^3
- 1 gallon (GBr) [gal]
  = 4.54609 dm^3 = 4.54609 l
- 1 gallon (USA) [gal]
  = 3.78543 dm^3

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Burkert Service and Distribution Network

Australia
Burkert Contromatic Australia Pty. Ltd.
2 Welder Road
Seven Hills, NSW 2147
Tel. +61 2 1300 888 868
Fax +61 2 1300 888 076

Victoria
Burkert Contromatic Australia Pty. Ltd.
Unit 11/26-30 Howleys Road
Notting Hill Victoria 3168
Tel. +61 1300 888 868
Fax +61 1300 888 076

Queensland
Burkert Contromatic Australia Pty. Ltd.
Unit 4/43 Sandgate Road
Albion Queensland 4010
Tel. +61 1300 888 868
Fax +61 1300 888 076

Western Australia
Burkert Contromatic Australia Pty. Ltd.
104 Westpoint,
396 Scarborough Beach Road
Osborne Park Western Australia 6017
Tel. +61 1300 888 868
Fax +61 1300 888 076

Austria
Bürkert-Contromatic G.m.b.H.
Diefenbachgasse 1-3
1150 Wien
Tel. +43 1 894 13 33
Fax +43 1 894 13 00

Belgium
Burkert Contromatic NV/SA
Bijkhoevelaan 3
2110 Wijnegem
Tel. +32 3 325 89 00
Fax +32 3 325 61 61

Brazil
Burkert-Contromatic Brasil Ltda.
Rua Américo Brasiliense
2171 cj. 1007
04715-005 São Paulo – SP
Tel. +55 11 5182 0011
Fax +55 11 5182 8899

Canada
Burkert Contromatic Inc.
760 Pacific Road, Unit 3
Oakville, Ontario L6L 6M5
Tel. +1 905 847 55 66
Fax +1 905 847 90 06

China
Burkert Contromatic (Shanghai) Co., Ltd.
Room J1, 3rd floor
207 Tai Gu Road
Wai Gao Qiao Free Trade Zone
Shanghai 200131
P.R. China
Tel. +86 21 5868 21 19
Fax +86 21 5868 21 20

Beijing
Burkert Contromatic (Shanghai) Co., Ltd.
Room 808, Jingtai Building
No. 24, Jian Guo Men Wai Da Jie
Beijing 100022
P.R. China
Tel. +86 10 6515 6508, 6515 6509
Fax +86 10 6515 6507

Chengdu
Burkert Contromatic (Shanghai) Co., Ltd.
Room 603-604, Fuji Building
26 Dongfeng Road, Shudu Dadao
Chengdu 610061
P.R. China
Tel. +86 28 8443 9064
Fax +86 28 8445 1341

Guangzhou
Burkert Contromatic (Shanghai) Co., Ltd.
Room 1502, Tower 4, Dong Jun Plaza
828-836 Dong Feng Road East
Guangzhou 510080
P.R. China
Tel. +86 20 8769 8379, 8767 8703
Fax +86 20 87671131

Shanghai
Burkert Contromatic (Shanghai) Co., Ltd.
Room 27 E, Shanghai Industry Building
No. 18 Caoxi Bei Road
Shanghai 200030
P.R. China
Tel. +86 21 6486 5110
Fax +86 21 6487 4815

Suzhou
Burkert Contromatic (Shanghai) Co., Ltd.
Room 5, #06-06
Block A, No. 5 Xinghan Street
SIP Suzhou 215021
P.R. China
Tel. +86 512 6761 1916
Fax +86 512 6761 1120

Czech Republic
Burkert-Contromatic G.m.b.H.
organizacni slozka
Krenova 35
602 00 Brno
Tel. +42 543 25 25 05
Fax +42 543 25 25 06

Denmark
Burkert-Contromatic A/S
Hørkær 24
2730 Herlev
Tel. +45 44 50 75 00
Fax +45 44 50 75 75

Estonia
Bürkert Oy Eesti
Laki 11 E
12915 Tallinn
Tel. +372 6440 698
Fax +372 6313 759

Finland
Burkert Oy
Atomitie 5
00370 Helsinki
Tel. +358 9 549 70 600
Fax +358 9 503 12 75

France
Burkert Contromatic SARL
Rue du Giessen
67220 Triembach au Val
Tel. +33 3 88 58 91 11
Fax +33 3 88 57 20 08

Germany
Bürkert GmbH & Co. KG
Christian-Bürkert-Straße 13-17
74653 Ingelfingen
Tel. +49 7940 10 111
Fax +49 7940 10 448

Hong Kong
Burkert Contromatic (China/HK) Ltd.
Unit 708 Prosperity Centre
77-81 Container Port Road
Kwai Chung, N.T.
Tel. +852 2480 1202
Fax +852 2418 1945

India
Burkert Contromatic PVT Ltd.
Apex Towers
1st Floor, No. 54 II Main Road
RA Puram
Chennai 600 028
Tel. +91 44 5230 3456
Fax +91 44 5230 3232

Italy
Burkert Contromatic Italiana S.p.A.
Centro Direzionale „Colombirolo“
Via Roma, 74
20060 Cassina De´Pecchi (MI)
Tel. +39 02 95 90 71
Fax +39 02 95 90 72 51

Japan
Burkert Ltd.
1-8-5 Asagaya Minami
Suginami-ku
Tokyo 166-0004
Tel. +81 3 5305 3610
Fax +81 3 5305 3611

Korea
Burkert Contromatic Korea Co., Ltd.
C-401, Micro Office Bldg. 554-2
Gasan-Dong, Keumcheon-Gu
Seoul 153-803
Tel. +82 2 3462 5592
Fax +82 2 3462 5594

Malaysia
Burkert Contromatic Singapore Pte Ltd
2F-1, Tingkat Kenari 6
Sungai Ara
11960 Penang
Tel. +60 4 643 5008
Fax +60 4 643 7010

Netherlands
Burkert-Contromatic BV
Computerweg 9
3542 DP Utrecht
Tel. +31 346 58 10 10
Fax +31 346 56 37 17

New Zealand
Burkert Contromatic
New Zealand Ltd.
2A, Unit L, Edinburgh Street
Penrose, Auckland
Tel. +64 9 622 28 40
Fax +64 9 622 28 47

Norway
Burkert-Contromatic A/S
Hvamstubben 17
2013 Skjetten
Tel. +47 63 84 44 10
Fax +47 63 84 44 55

Philippines
Burkert Contromatic Philippines, Inc.
8467, West Service Road Km 14
South Superhighway, Sunvalley
Paranaque City, Metro Manilla
Tel. +63 2 776 43 84
Fax +63 2 776 43 82

Poland
Bürkert Contromatic G.m.b.H. Austria –
Oddzial w Polsce
Bernardynska street 14a
02-904 Warszawa
Tel. +48 22 840 60 10
Fax +48 22 840 60 11

Portugal
Tel. +351 21 212 84 90
Fax +351 21 212 84 91

Singapore
Burkert Contromatic
Singapore Pte Ltd
51 Ubi Avenue 1, #03-14
Paya Ubi Industrial Park
Singapore 408933
Tel. +65 6844 2233
Fax +65 6844 3532

South Africa
Burkert Contromatic (Pty) Ltd.
P.O. Box 26260
East Rand 1462
Tel. +27 11 574 60 00
Fax +27 11 454 14 77

Spain
Burkert Contromatic S.A.
Avda. Barcelona, 40
08970 Sant Joan Despi (Barcelona)
Tel. +34 93 477 79 80
Fax +34 93 477 79 81

Sweden
Burkert-Contromatic AB
Skeppsbron 13 B
211 20 Malmö
Tel. +46 40 664 51 00
Fax +46 40 664 51 01

Switzerland
Bürkert-Contromatic AG Schweiz
Bösch 71
6331 Hünenberg ZG
Tel. +41 41 785 66 66
Fax +41 41 785 66 33

Taiwan
Burkert Contromatic Taiwan Ltd.
9F, No. 32, Chenggong Road
Sec. 1, Nangang District
Taipei 115
Taiwan, R.O.C.
Tel. +886 2 2653 7868
Fax +886 2 2653 7968

Turkey
Burkert Contromatic Akiskan
Kontrol Sistemleri Ticaret A.S.
1203/8 Sok. No 2-E
Yenisehir, Izmir
Tel. +90 232 459 53 95
Fax +90 232 459 76 94

United Kingdom
Burkert Contromatic Limited
Briscombe Port Business Park
Briscombe Stroud
Gloucestershire GL5 2QF
Tel. +44 1453 73 13 53
Fax +44 1453 73 13 43

USA
Burkert Contromatic Corp.
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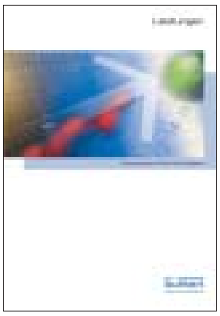

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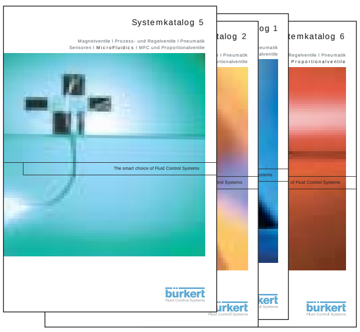
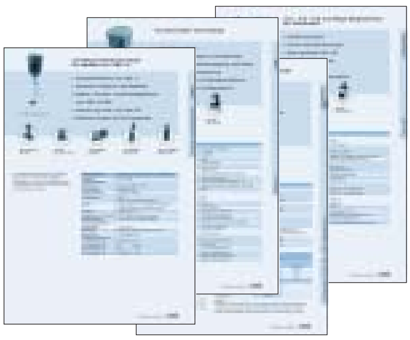


Technical data sheets

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



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Bürkert Fluid Control Systems, Christian-Bürkert-Straße 13–17, 74653 Ingelfingen, Germany
Tel. +49 (0) 79 40/10-0, Fax +49 (0) 79 40/10-204, info@de.buerkert.com, www.buerkert.com

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