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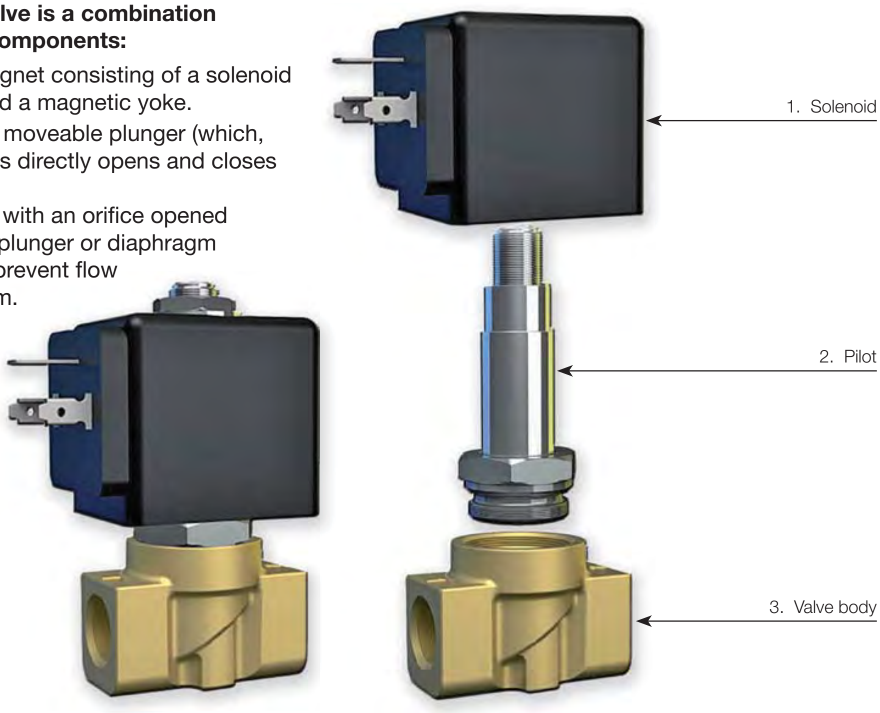
TECHNICAL INFORMATION ABOUT SOLENOID VALVES

General Information

Solenoid valves are electro-mechanical devices used for interrupting or diverting the flow of fluids by opening or closing one or more orifices.

The solenoid valve is a combination of three basic components:

1. An electromagnet consisting of a solenoid (windings) and a magnetic yoke.
2. A pilot with a moveable plunger (which, in some cases directly opens and closes the valve).
3. A valve body with an orifice opened or closed by plunger or diaphragm to enable or prevent flow of the medium.



Operating principles

The term solenoid refers to operator and coil, also known as pilot or magnetic actuator.

The coil consists of copper wire wound on a support reel. When electric current is applied into the coil, magnetic flow lines are generated which are stronger in the coil center.

This magnetic flow raises the moveable plunger in the coil until it brings it into contact with the pole piece. The valve body has an orifice through which the fluid flows when the valve is open.

The moveable plunger has an integral seat which when the solenoid coil is energised, moves off the valve (direct operated) orifice or diaphragm (pilot operated) orifice opening the valve.

When the coil is de-energised, a return spring brings the plunger back to the original closing position, thus cutting off the flow of the fluid.

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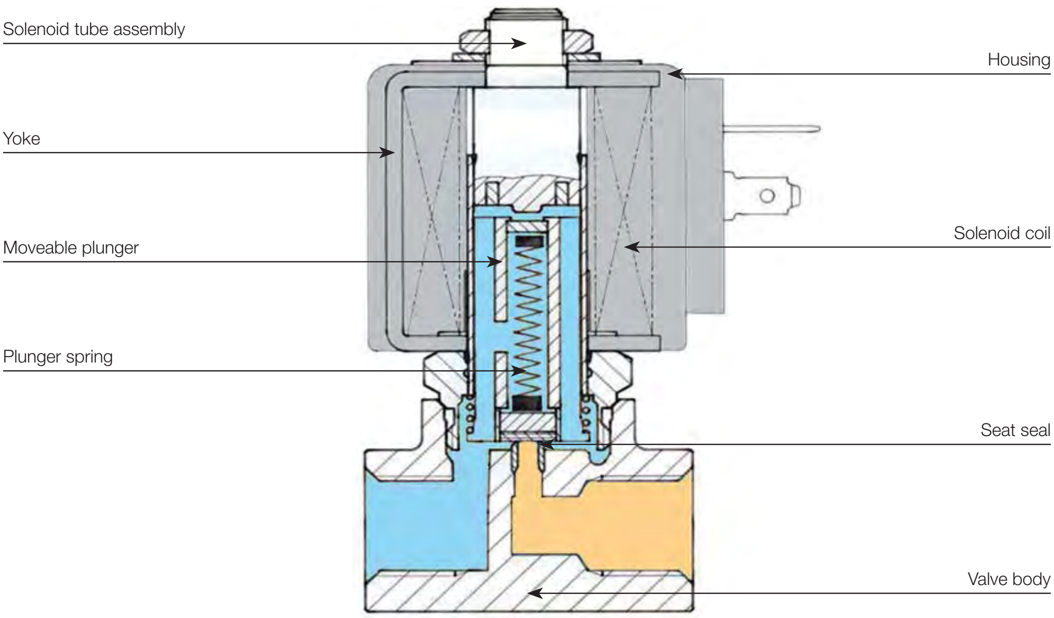
BASIC COMPONENTS OF A SOLENOID VALVE

Valve body:	Main part of the solenoid valve including ports, seat and orifices.
Solenoid tube assembly:	Cylinder, in stainless steel, hermetically sealed and closed at one extremity. It is the guide channel of the moveable plunger which is moved magnetically. The solenoid coil is fitted on the external side of the enclosing tube.
Moveable plunger:	Made by ferritic stainless steel, it is attracted by the solenoid magnetic field and slides inside the tube.
Plunger spring (or return spring):	Used to hold the moveable plunger in position and to return it when de-energized.
Seat seal:	Part of the moveable plunger, it is used to close a valves main orifice or pilot orifice.
Electromagnet (or solenoid coil):	Electrical part consisting of a copper windings (solenoid) along, with a magnetic yoke (armature), when electric current flows through, it generates a magnetic field atracting the moveable plunger.
Housing:	Part that contains and protects the coil.
Yoke:	Metalic case surounding the coil and concentring electro-magnetic force on the moveable plunger.



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Solenoid valves are highly engineered products that can be used in many diverse applications.

In addition to operational functionality, media compatibility and suitability for the operating environement when selecting the best product for a given application.

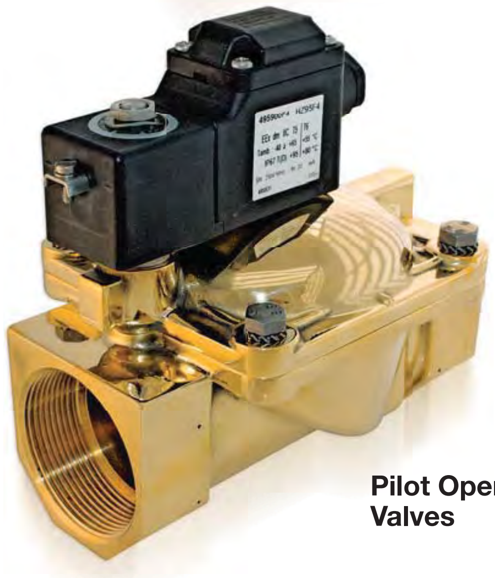
This section provides a brief overview of the components, actuation and function modes of solenoid valves avaible from Parker Hanninfin - FCDE.

Different Technologies:

Solenoid valves are electrically operated devices used to control flow.
The most common types of solenoid valve are:

Direct Operated Valves

Magnalift Valves



Pilot Operated Valves

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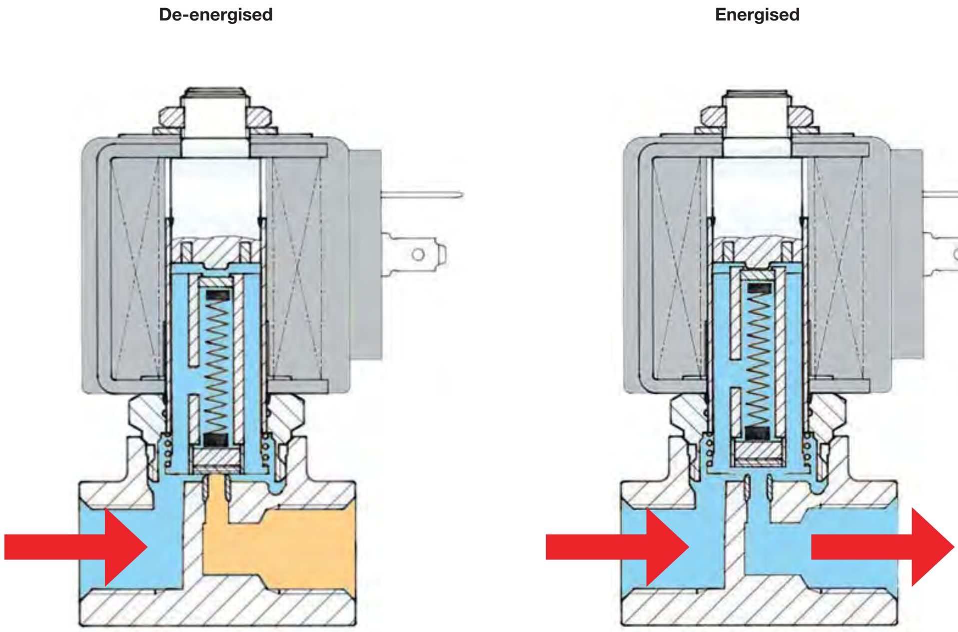
DIRECT OPERATED VALVE

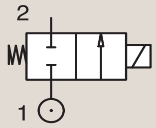
Magnetic force is used directly to open or close the plunger which controls the passage of the fluid. Performances are limited by the coil, the pressure, and the valve orifice size. For direct operated valves, the minimum working pressure is 0 bar and the maximum pressure relies on the combination (valve/coil) chosen.

Direct Operated Valve



Example:

- 121 Series
- 146 Series
- N74 Series



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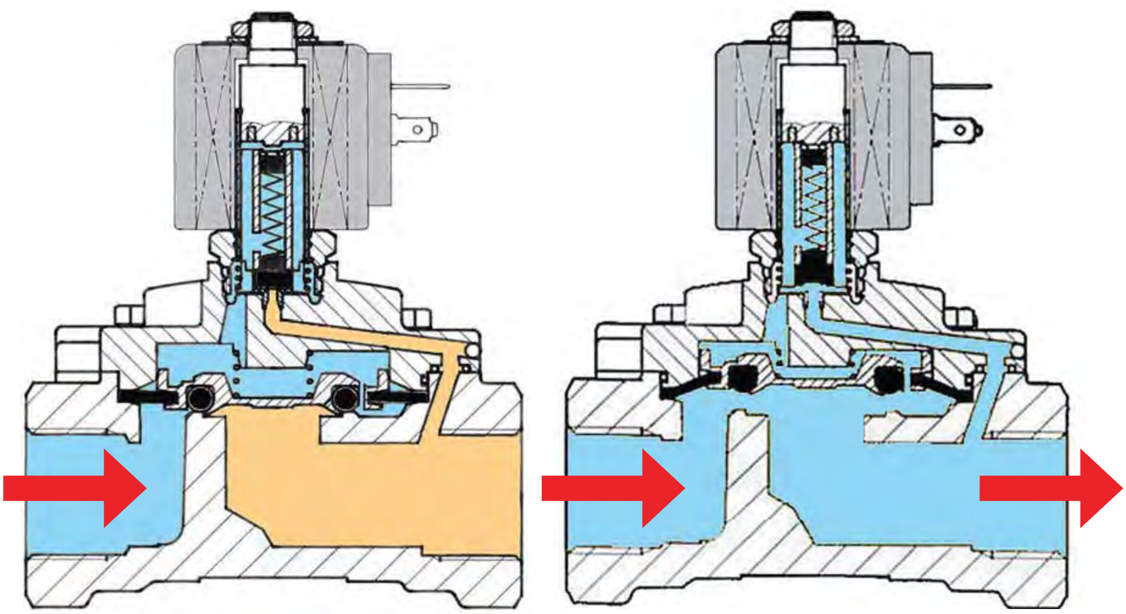
PILOT OPERATED VALVE

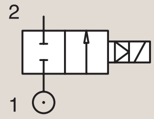
To control a higher flow, it is necessary to use pilot operated valves. The supply pressure enters the direct operated "pilot stage" which directs the flow to a "pilot chamber" which,in turn, applies the pilot pressure over a large area (generally a diaphragm or piston). Therefore, a large force is generated to move the main sealing elements against higher pressure or over a large orifice.
One condition of operation is to have a minimum pressure available to shift the valve (indicated in the catalogue). In most applications, this presents no particular problems (refer to magnalift valve section). The pressure rating of the valve starts between 0.1 to 0.5 bar (depending on the valve).
(NB. Pilote Operated Valves are also called Servo Operated Valves).

Pilot Operated Valve

De-energised **Energised**



Example:
- 321 Series
- 7321B Series
- 168.1 Series



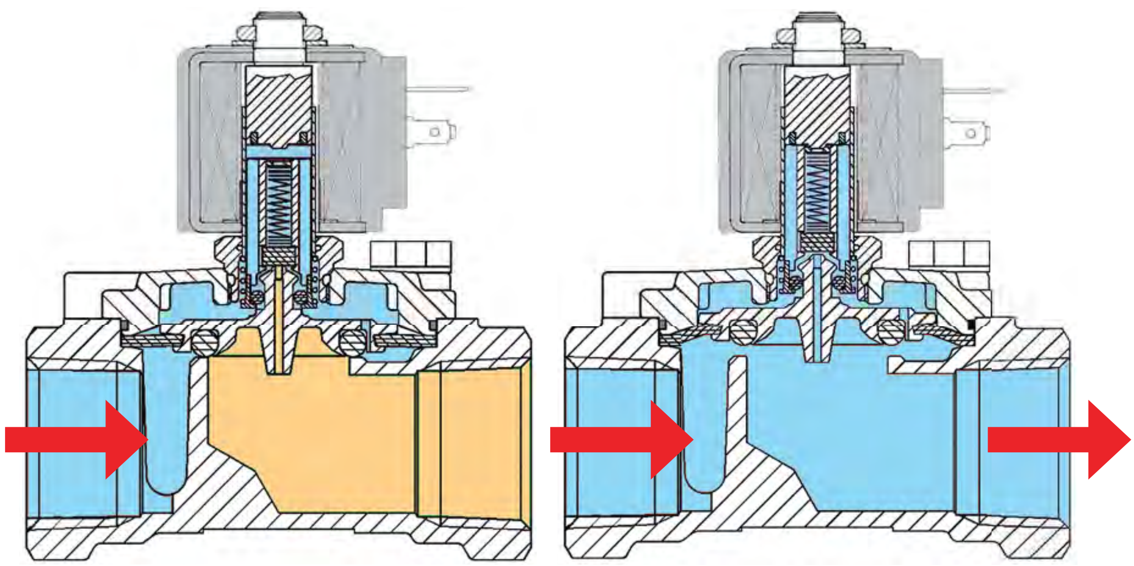
MAGNALIFT VALVE

The magnalift valves combine the features of the direct operated and pilot operated valves. A mechanical link between the plunger and diaphragm retainer allows the valve to operate as a direct operated valve at low pressures and as a pilot operated valve at higher pressures. Magnalift valves are specially designed for applications where 0 pressure is needed to operate the valve, as well as bigger flow than a direct operated valve.

Magnalift Operated Valve

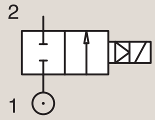
De-energised

Energised



Example:

- 221 Series
- 123 Series



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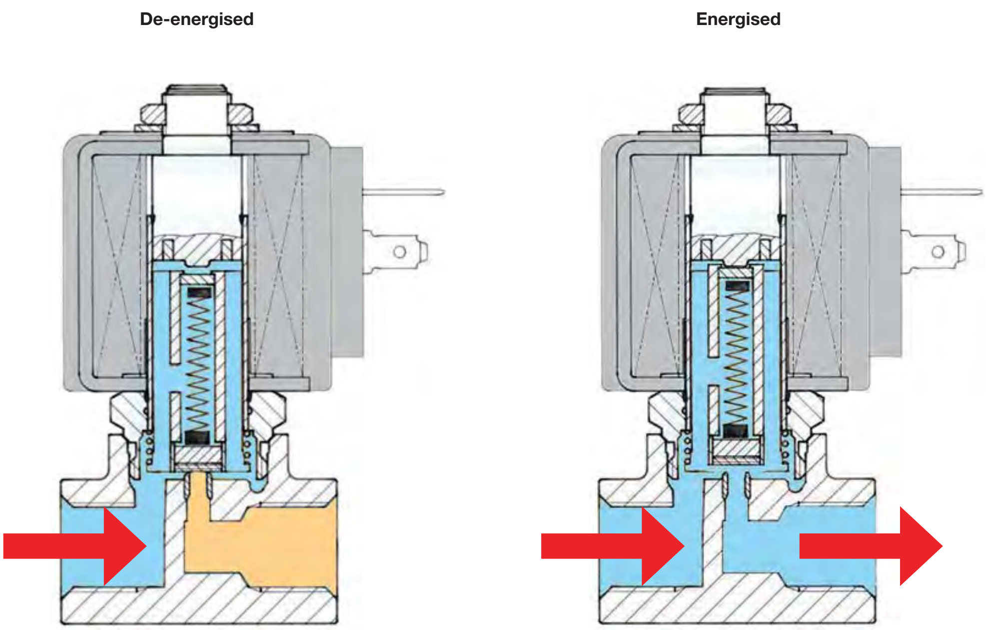
NORMALLY CLOSED VALVE

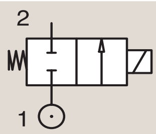
Most of our valves are available in normally closed and normally open configuration when not energized. In certain applications, you may require a normally open valve (open function in case of current failure). The differentiating factor of design of this technology, is based upon the design of the seat seal, which is reversed in comparaison to a normally closed valve.

Normally Closed Valve



Example:

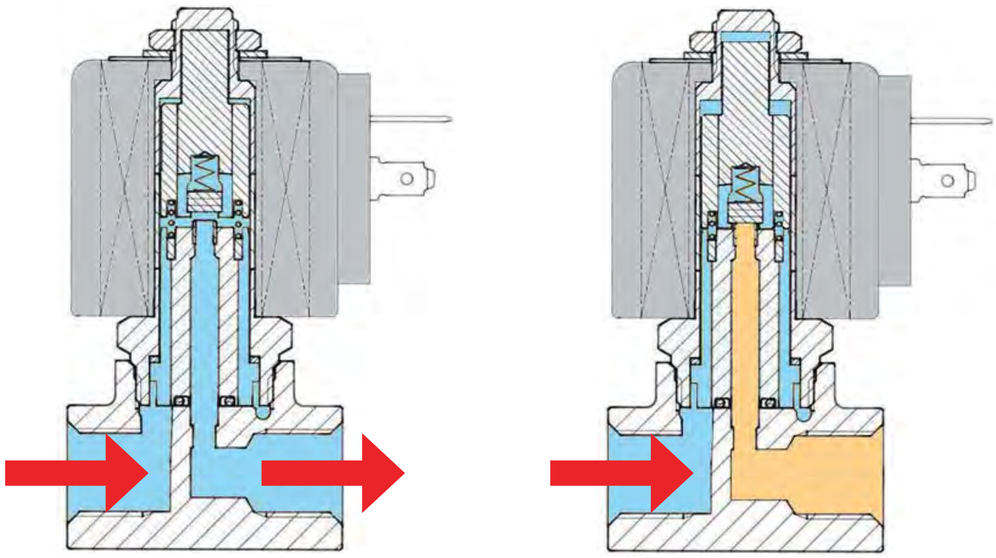
- 121 Series
- 146 Series
- N74 Series



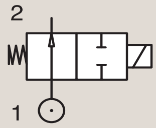
NORMALLY OPEN VALVE

Normally Open Valve

De-energised | Energised



Example:
- 122 Series
- 136 Series
- 7322B Series



FLOW AND PRESSURE RANGES

Area of operation:

Each valve principle, as described in the previous pages, has a defined area of operation related to its pressure and flow capabilities. The following graph shows which type of valve is suitable for a certain situation.

Areas of operation of Parker solenoid valves.

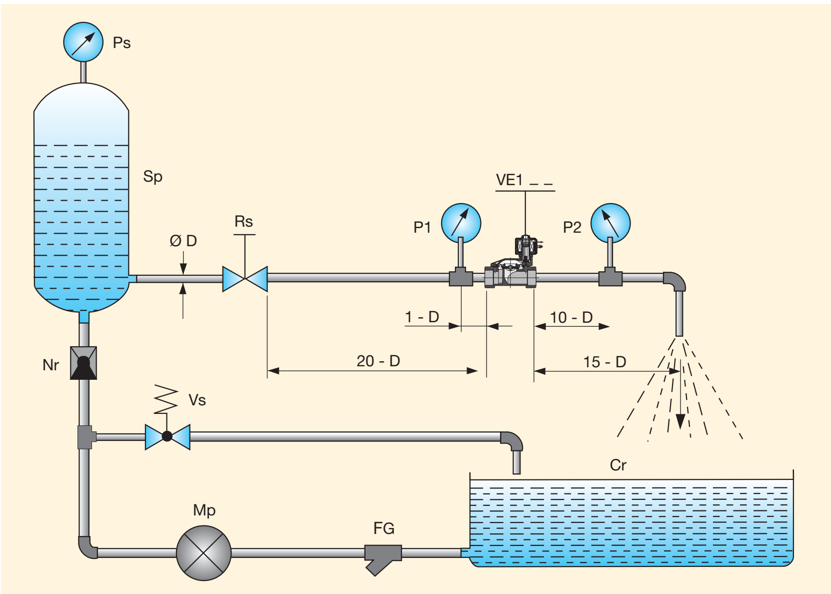
SIZING SOLENOID VALVES

The correct choice of solenoid valve is essential as it determines the regulation and performance required for practical application on a system. In order to decide on the exact type of solenoid valve, various parameters have to be known.

However the calculation method, based on the flow coefficient Kv, has proved highly practical as it can be determined on the basis of:

- Required flow rate
- Flow resistance
- Type of fluid and relative viscosity
- Specific gravity and temperature

This flow coefficient Kv is determined as defined in the VDI/VDE 2173 standards.
It represents the flow of water in m3/h or L/min with a temperature from 5 to 30°C which passes through the solenoid valve with a pressure drop of 1 bar.



Note:

The flow coefficient used in the USA is known as Cv and represents the water flow rate in US gallons per minute with a pressure drop ΔP of 1 psi.

To convert **C_V** in **K_V** and vice versa use:

$1\ K_V = 0.862\ C_V$
$1\ C_V = 1.16\ K_V$

FG = Grid Filter **Mp** = Pump **Vs** = Safety Valve **Nr** = Check Valve **Sp** = Pressure Tank **Ps** = Static Pressure Manometer

After existing conditions have been converted into this factor Kv, the type of valve is found by referring to the pages in the related sections in this catalogue.

Parameters used for selecting the solenoid valve are in the table next page.

Consult conversion tables of the various units of measurement as defined by the ISO (International Standards Organisation) - I.S. (International System) set out in this catalogue.

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FLOW AND PRESSURE RANGES

Pressure
symbol **(P)**
unit of measurement **[bar]**
Working pressure

Pressure drop
symbol **(ΔP)**
unit of measurement **[bar]**
Pressure difference between inlet (P_1) and outlet (P_2) of the solenoid valve when a medium is flowing through the valve ($\Delta P = P_1 - P_2$).

Flow cœfficient
symbol **(Kv)**
unit of measurement **[m³/h]**

Specific gravity of the medium
symbol **(γ)**
unit of measurement **[Kg/dm³]**

Temperature of the medium
symbol **(t)**
unit of measurement **[°C]**

Flow rate
- for liquids
  symbol **(Q)**
  unit of measurement **[m³/h]**
- for gases
  symbol **(Qn)**
  unit of measurement **[Nm³/h]**
- for steam
  symbol **(Qv)**
  unit of measurement **[Kg/h]**

Specific volume
symbol **(Vs)**
unit of measurement **[m³/Kg]**

a) Solenoid valves for liquids:

Flow rate: $Q = Kv \cdot \sqrt{\frac{\Delta P}{\gamma}}$ where: $Q = m^3/h$, $\Delta P = bar$, $\gamma = Kg/dm^3$

Flow coefficient:

$$Kv = Q \cdot \sqrt{\frac{\gamma}{\Delta P}}$$

In the case of liquids with viscosity greater than 3°E (22 cStokes) the Kv is modified according to the formula:

$$Kv_1 = Kv + C \qquad C = \frac{\delta \cdot \sqrt{Kv}}{200 \cdot Q} + 1$$

where C is the viscosity correction factor calculated by means of the formula:
where:
δ = kinematic viscosity of the fluid expressed in centistokes
Kv = flow rate factor of the solenoid valve
Q = flow rate in m³/h.

Pressure drop:

$$\Delta P = \gamma \cdot \left(\frac{Q}{Kv}\right)^2$$

b) Solenoid valves for gases:

If $\Delta P \leq 1/2\ P_1$ use the following formulae:

Flow rate: $Qn = 514 \cdot Kv \cdot \sqrt{\frac{\Delta P \cdot P_2}{\gamma n \cdot (273 + t)}}$

where: $Qn = Nm^3/h$ $\quad P_1 = bar$ $\quad P_2 = bar$

Flow coefficient: $Kv = \frac{Qn}{514} \cdot \sqrt{\frac{(273+t) \cdot \gamma n}{\Delta P \cdot P_2}}$

t = °C
γn = Kg/m^3

Pressure drop: $\Delta P = \frac{(273 + t) \cdot \gamma n}{P_2} \cdot \frac{Qn^2}{(514 \cdot Kv)^2}$

If $\Delta P > 1/2\ P_1$ use the following formula:

$$Qn = 757 \cdot Kv \cdot \sqrt{\frac{\Delta P \cdot P_2}{(273 + t) \cdot \gamma n}}$$

c) Solenoid valves for steam:

If $\Delta P \leq 1/2\ P_1$ use the following formulae:

Flow rate: $Qv = 31{,}7 \cdot Kv \cdot \sqrt{\frac{\Delta P}{Vs}}$

where: $Qv = Kg/h$ $\quad \Delta P = bar$ $\quad Vs = m^3/Kg$

Flow coefficient: $Kv = \frac{Qv}{31{,}7} \cdot \sqrt{\frac{Vs}{\Delta P}}$

Pressure drop: $\Delta P = Vs \cdot \frac{Qv^2}{(31{,}7 \times Kv)^2}$

If $\Delta P > 1/2\ P_1$ use the following formula:

$$Qv = 22{,}4 \cdot Kv \cdot \sqrt{\frac{P_1}{Vs}}$$

Notes:

1) Should the value ΔP not be specified, use the following, which is based on experience:

- For liquids only in the case of free discharge ΔP = 90% of the input pressure (P_1).
- For gases never use a ΔP of more than 50% of the absolute inlet pressure, since the excessive pressure drop may cause an irregular flow rate. In most cases, ΔP can be considered as 10% of the input pressure.

2) Specific volume value (Vs) for dry saturated steam, see the table in diagram 3.

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FLOW RATE FOR LIQUIDS

The liquid flow through a pipe or a valve is given by:

$$Q = Kv \cdot \sqrt{\frac{\Delta P}{\gamma}}$$

Where
- Q = Flow **[l/min]**
- ΔP = Differential Pressure **[bar]**
- γ = Density of the fluid **[kg/dm³]** (water γ = **1 [kg/d m³]**)
- kv = Flow Factor **[m³/h]**

Flow factor kv:

The kv flow factor of a valve is defined as the flow rate of water in litres per minute with a pressure drop of 1 bar across the valve.

Valve manufactuerers use different definitions for kv. It may be expressed in l/h or m³/h.

Care should therefore be taken when comparing values.

Maximum flow rate Qmax.

For particular 2-way valves the maximum flow must be limited for reasons of mechanical resistance and durability.

A very high flow velocity may dislocate a popet sealing or a diaphragm.

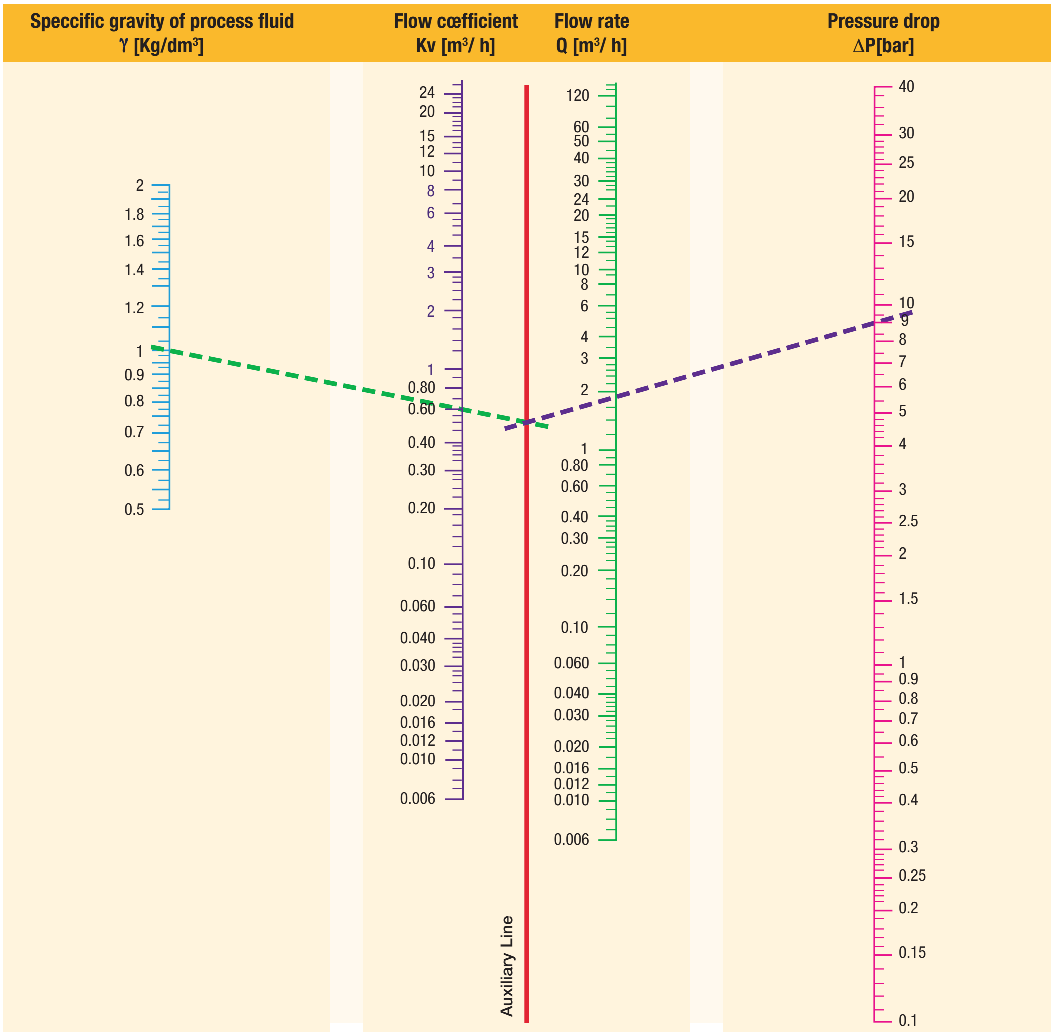
Maximum flow rates are indicated in the catalogue.

Flow factors

Kv l/min	KV m³/h	Qn l/min

NORMALLY CLOSED

Port size	Orifice Ø	Flow factors			Operating Pressure Differential			Fluid Temp.		Seat Seal	Parker LUCIFER® Valves			Power		Coil Group	Dwg. No.
					Min	Max(MOPD)		Min	Max		Valve Ref.	Housing Ref.	Coil Ref.				
BSP	mm	Kv l/min	KV m³/h	Qn l/min	bar	AC bar	DC bar	°C	°C					AC W	DC W		



Monogram for liquid flow calculation

Specific gravity of the most common fluids (ɤ = Kg/dm³) - (t = 15°C - P = 760 mm Hg)					
Acetone	0.76	**Benzenol**	0.90	**Naphtha**	0.76
Water	1.00	**Beer**	1.02	**Pentane**	0.63
Sea water	1.02	**Hexane**	0.66	**Vegetable oil**	0.92
Ethyl alcohol	0.79	**Ethane**	0.68	**Hydraulic oil**	0.92
Methyl alcohol	0.81	**Diesel oil**	0.70	**Wine**	0.95
Petrol	0.68	**Milk**	1.03		

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FLOW RATE FOR GASES

The gas flow through a valve is given by:

$$Q = C \cdot P_1 \cdot k_T \cdot \omega \cdot \gamma_{air} / \gamma_{gas}$$

Where
- **Q** = Flow Rate **[dm³/s]**
- **C** = Conductance **[dm³/s.bar]**
- P_1 = Inlet Pressure **[bar abs]**
- γ = Specific Weight **[kg/m³]**
- k_T = Temperature Correction Factor

$$\omega = \sqrt{1 - \frac{P_2/P_1 - b}{1 - b}} \qquad k_T = \sqrt{\frac{293}{273 + \text{Temp. °C}}}$$

Nominal Flow Qn:

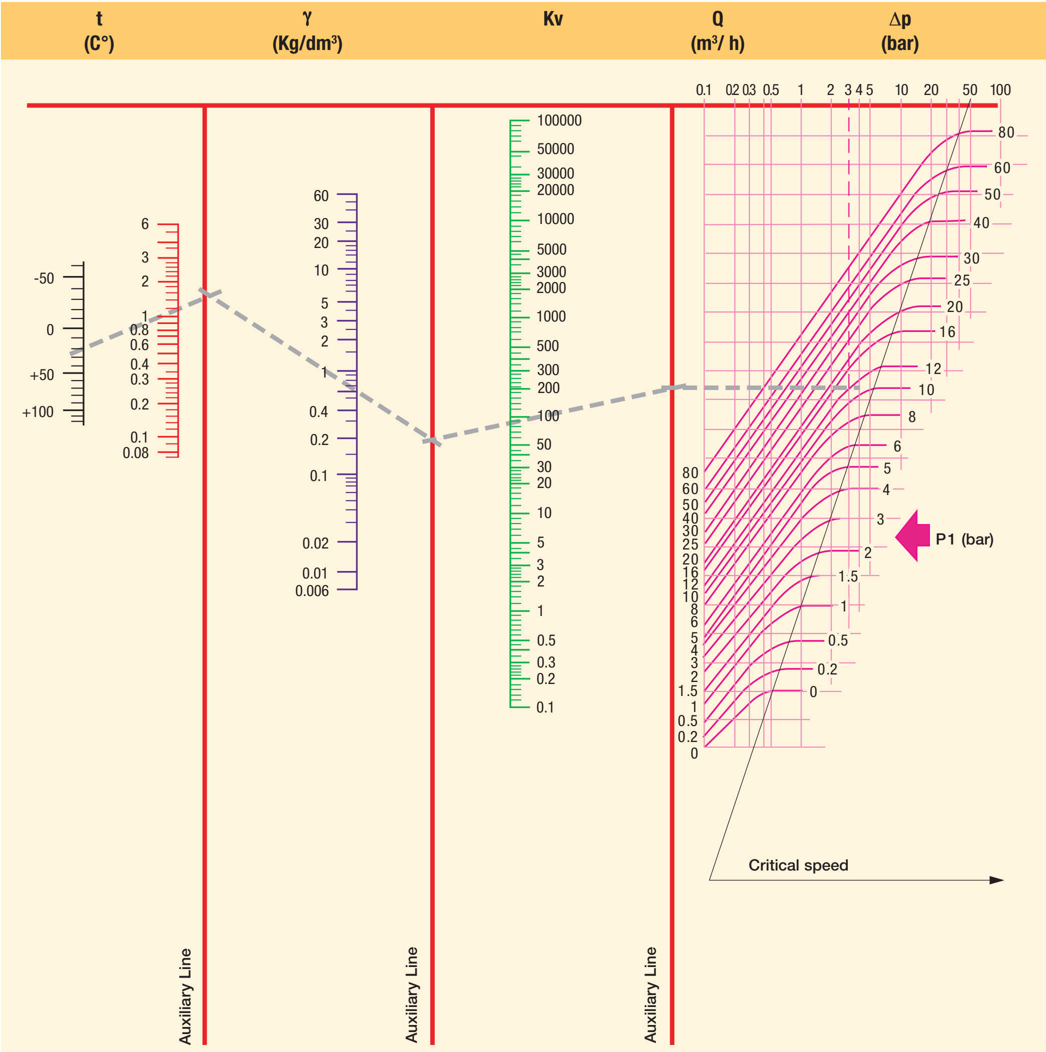
Calculations can be made with specific flow factors based on the CETOP RP 50P standard.
For practical purposes and ease of valve selection the catalogue shows the nominal flow Qn.
The nominal flow Qn is defined as the flow rate (L/min) of air across the valve when the inlet pressure P_1 = 6 bar and the pressure drop ΔP = 1 bar.

N.B.
The values of the flow factors and flow rates mentioned in catalogues are subjet to +/-15% tolerances.

Pneumatic application: $\gamma_{air} / \gamma_{gas} = 1$

a) Choked flow conditions $P_2 \leq b.P_1$
in this case $\omega = 1$ --> $Q = C . P_1 . kT$

b) Free flow conditions $P_2 > b.P_1$
in this case --> $Q = C . P_1 . kT . \omega$



t = Fluid Temperature **γN** = Specific Gravity **Kv** = Flow Cœfficient **Qn** = Flow Rate **Δp** = Pressure Drop $\mathbf{P_1}$ = Inlet Pressure

Specific gravity of the most common gases (γ = Kg/m³) - (t = 0°C - P = 760mm Hg)					
Acetylene	1.176	**Helium**	0.179	**Natural gas**	0.723
Carbon dioxide	1.965	**Ethane**	1.035	**Methane**	0.722
Air	1.293	**Ethylene**	1.259	**Carbon monoxide**	1.250
Argon	1.780	**Hydrogen**	0.089	**Oxygen**	1.429
Nitrogen	1.255			**Propane**	1.520
Butane	2.000			**Steam**	0.805

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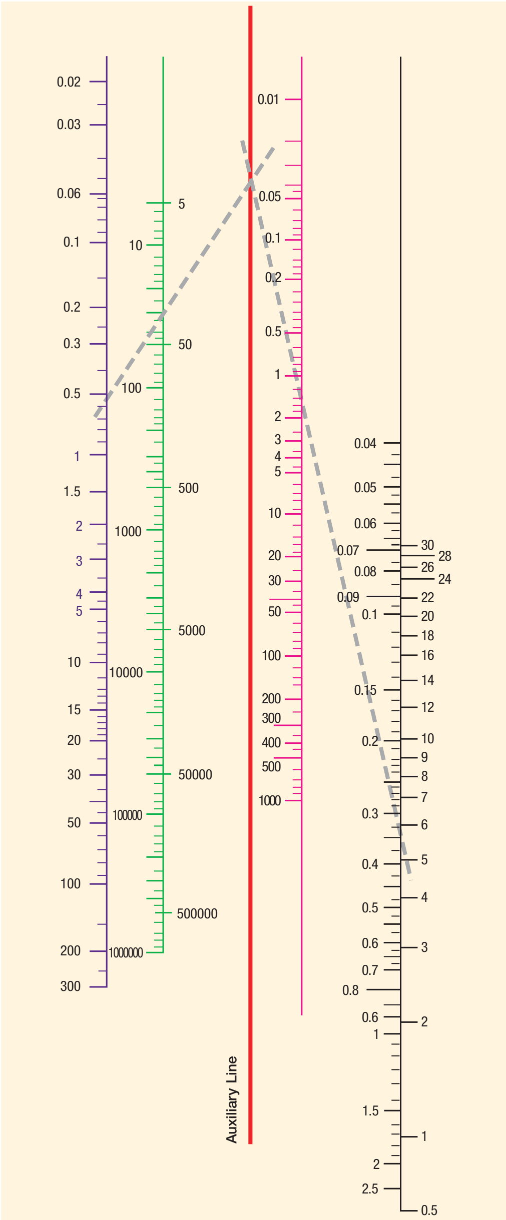
Diagram 3 for Dry Satured Steam



Steam (Dry Satured) Data

P_2 bar	Temp. °C	Vs m³/Kg	P_2 bar	Temp. °C	Vs m³/Kg
0.01	6.6	131.600	10.00	179.0	0.200
0.02	17.1	68.300	110.00	183.2	0.181
0.03	23.7	46.500	120.00	187.1	0.176
0.04	28.6	35.500	13.00	190.7	0.155
0.05	32.5	28.700	14.00	194.1	0.144
0.06	35.8	24.200	15.00	197.4	0.135
0.08	41.1	18.500	16.00	200.4	0.126
0.10	45.4	15.000	17.00	203.4	0.119
0.20	5 9.7	7.800	18.00	206.2	0.113
0.30	68.7	5.330	19.00	208.8	0.107
0.40	75.4	4.070	20.00	211.4	0.102
0.50	80.9	3.300	22.00	216.2	0.093
0.60	85.5	2.790	24.00	220.8	0.085
0.70	89.5	2.410	26.00	225.0	0.079
0.80	93.0	2.130	28.00	229.0	0.073
0.90	96.2	1.910	30.00	232.8	0.068
1.00	99.1	1.730	32.00	236.4	0.064
1.50	110.8	1.180	34.00	239.8	0.060
2.00	119.6	0.900	36.00	243.1	0.057
2.50	126.8	0.730	38.00	246.2	0.053
3.00	132.9	0.620	40.00	249.2	0.051
3.50	138.2	0.530	45.00	256.2	0.045
4.00	142.9	0.470	50.00	262.7	0.040
4.50	147.2	0.420	55.00	268.7	0.036
5.00	151.1	0.380	60.00	274.3	0.033
5.50	154.7	0.350	65.00	279.6	0.030
6.00	158.1	0.320	70.00	284.5	0.028
6.50	161.2	0.300	80.00	293.6	0.024
7.00	164.2	0.280	90.00	301.9	0.021
7.50	167.0	0.260	100.00	309.5	0.018
8.00	169.6	0.250	150.00	340.5	0.011
8.50	172.1	0.230	200.00	364.2	0.006
9.00	174.5	0.220	225.00	374.0	0.003
9.50	176.8	0.210			

Kv = Flow Coefficient **Qv** = Flow Rate **Δp** = Pressure Drop **Vs** = Specific Volume **P_2** = Outlet Pressure

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VISCOSITY CONVERSION TABLE

Centistokes cStokes mm²/S	°Engler °E	Saybolt Universal Second SSU	Rewood Second N°1 SRW N°1
1	1	-	-
12	2	65	55
22	3	100	90
30	4	140	120
28	5	175	155
45	6	210	185
60	8	275	245
75	10	345	305
90	12	415	370
115	15	525	465
150	20	685	610
200	26	910	810
300	39	1 385	1 215
400	53	1 820	1 620
500	66	2 275	2 025
750	97	3 365	2 995
1 500	197	6 820	6 075

OTHER USEFUL FORMULAS

Formulas:

°C	=	(°F - 32) x 5/9
°F	=	(°C x 9/5) + 32
m³/h	=	l/min x 0.06
l/min	=	m³/h x 16,67
m³/sec	=	m³/h x 2,778 x 10^{-4}
m³/sec	=	l/min x 1,667 x 10^{-5}

Examples:

(**167°F**-32) x 5/9	=	**75°C**
(**30°C** x 9/5) + 32	=	**86°F**
100 l/min x 0.06	=	**6 m³/h**
9 m³/h x 16,67	=	**150 l/min**
18.000 m³/h x 2.778 x 10 -4	=	**5 m³/sec**
479.904 l/min x 1.667 x 10-5	=	**8 m³/sec**