2/3 Port Valves for Fluid Control
Model Selection 1

For product specifications such as maximum operating pressure differentials and operating temperature ranges, refer to the relevent pages of each product.

Air, Inert gas

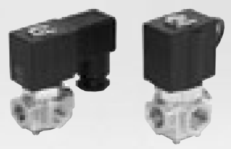
Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Air, Inert gas	Direct operated	VDW		●	●	●												P.241
		VCA			●	●		●	●	●								P.317
		VX2			●	●		●	●									P.29
		VXE	Only low wattage, DC type		●	●		●	●									P.93
		VX3			●	●		●	●									P.179
	Pilot operated	VXD				●		●	●	●	●				●	●	●	P.59
		VXZ	Zero pressure differential operation			●		●	●	●	●							P.77
		VXP				●		●	●	●	●	●	●	●	●	●	●	P.145
		VQ20/30	For dry air, built-in One-touch Fittings	ø6, ø8, ø10, ø12														P.267
	External pilot piston	VNA			●	●		●	●	●	●	●	●	●				P.357
		VNB			●	●		●	●	●	●	●	●	●	●	●	●	P.365


Series VDW


Series VCA

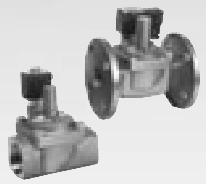

Series VX2

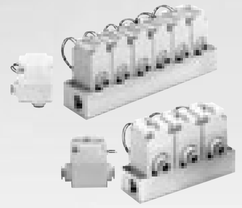

Series VXE


Series VX3

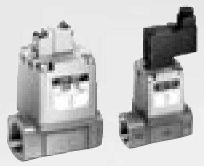

Series VXD


Series VXZ


Series VXP


Series VQ20/30


Series VNA


Series VNB

Vacuum

Fluid		Action	Series	Remarks	Applicable port size											Flange			Page
					—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
					M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Vacuum	Low vacuum	Direct operated	VDW		●	●	●												P.241
			VX2			●	●		●	●									P.29
			VX3, VXV3			●	●		●										P.179
	Medium vacuum	Direct operated	VX2	Option: V, M		●	●		●	●									P.29
			VCW	Made to Order available		●	●		●	●	●								P.345
			VX3	Option: V, M		●	●		●										P.196
		External pilot piston	VNB			●	●		●	●	●	●	●	●	●	●	●	●	P.365
	High vacuum	External pilot piston	XL		Vacuum KF: 16, 25, 40, 50, 63, 80; K: 63, 80														Best Pneumatics No. 8
			XM, XY		Vacuum KF: 16, 25, 40, 50, 63, 80; K: 63, 80														
			XVD	Flow rate adjustment	For VCR: 1/4; For swage lock: 1/4														

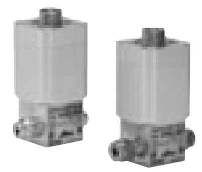

Series VDW


Series VCW


Series VXV3


Series XL


Series XM/XY


Series XVD

2/3 Port Valves for Fluid Control
Model Selection 2

For product specifications such as maximum operating pressure differentials and operating temperature ranges, refer to the relevent pages of each product.

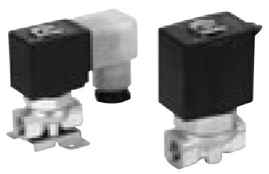
Water

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Water	Direct operated	**VDW**		●	●	●												P.241
		VX2			●	●		●	●									P.29
		VXE	Only low wattage, DC type		●	●		●	●									P.93
		VX3			●	●		●										P.179
		VCW			●	●		●	●	●								P.345
		VCB			●	●		●	●	●								P.329
	Pilot operated	**VXD**				●		●	●	●	●				●	●	●	P.59
		VXZ	Zero pressure differential operation			●		●	●	●	●							P.77
		VXP				●		●	●	●	●	●	●	●	●	●	●	P.145
		VXR	Water hammer relief					●	●	●	●	●	●	●				P.157
		VXH	Only AC type, 2 MPa			●		●	●									P.167
	External pilot piston	**VNB**			●	●		●	●	●	●	●	●	●	●	●	●	P.365

Heated water

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Heated water	Direct operated	**VX2**	Option: E, P		●	●												P.29
		VX3	Option: E, P		●	●		●										P.179
		VCB			●	●		●	●	●								P.329
	Pilot operated	**VXD**	Option: E, P			●		●	●	●	●				●	●	●	P.59
		VXZ	Zero pressure differential operation, Option: E, P			●		●	●	●	●							P.77
		VXP	Option: E, P			●		●	●	●	●	●	●	●	●	●	●	P.145
		VXR	Water hammer relief, Option: D						●	●	●	●	●	●				P.157
	External pilot piston	**VNB**			●	●		●	●	●	●	●	●	●	●	●	●	P.365


Series ***VDW***


Series ***VX2***

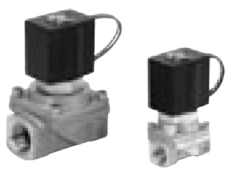

Series ***VXE***


Series ***VX3***


Series ***VCW***

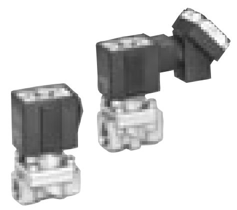

Series ***VCB***

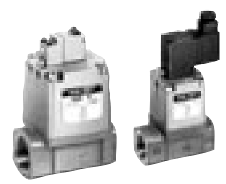

Series ***VXD***


Series ***VXZ***


Series ***VXP***


Series ***VXR***


Series ***VXH***


Series ***VNB***

2/3 Port Valves for Fluid Control
Model Selection 3

For product specifications such as maximum operating pressure differentials and operating temperature ranges, refer to the relevent pages of each product.

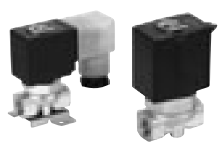
Oil

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Oil	Direct operated	**VDW**	Option: A, H	●	●	●												P.241
		VX2	Option: A, D, H, N		●	●		●	●									P.29
		VXE	Only low wattage, DC type, Option: A, H		●	●		●	●									P.93
		VX3	Option: A, D, H, N		●	●		●										P.179
		VCL			●	●		●	●	●								P.333
	Pilot operated	**VXH**	Only AC type, 1.5 MPa or less			●		●	●									P.167
		VXD	Option: A, D, H, N			●		●	●	●	●				●	●	●	P.59
		VXZ	Zero pressure differential operation, Option: A, D, H, N			●		●	●	●	●							P.77
		VXP	Option: A, D, H, N			●		●	●	●	●	●	●	●	●	●	●	P.145
		VXR	Water hammer relief, Option: A, D					●	●	●	●	●	●	●				P.157
	External pilot piston	**VNA**			●	●		●	●	●	●	●	●	●				P.357
		VNB			●	●		●	●	●	●	●	●	●	●	●	●	P.365

Steam

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A		10A	15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4		3/8	1/2	3/4	1	1 1/4	1 1/2	2				
Steam	Direct operated	**VCS**			●	●		●	●	●								P.339
		VX2	Option: S, Q		●	●		●	●									P.29
		VX3	Option: S, Q		●	●		●										P.179
	Pilot operated	**VXP**	Option: S			●		●	●	●	●	●	●	●	●	●	●	P.145
	External pilot piston	**VND**				●		●	●	●	●	●	●	●	●	●	●	P.415

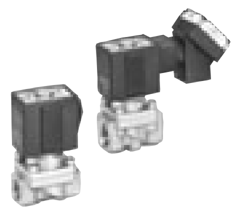

Series VDW


Series VX2

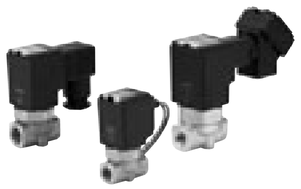

Series VXE


Series VX3


Series VCL


Series VXH

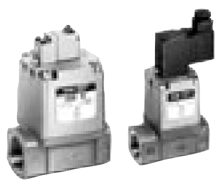

Series VXD


Series VXZ


Series VXP


Series VXR


Series VNA


Series VNB


Series VCS


Series VND

2/3 Port Valves for Fluid Control
Model Selection 4

For product specifications such as maximum operating pressure differentials and operating temperature ranges, refer to the relevent pages of each product.

High pressure compressed air

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A	10A		15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4	3/8		1/2	3/4	1	1 1/4	1 1/2	2				
High pressure compressed air	Direct operated	**VX2**	3 MPa or less		●													P.29
		VXE	Only low wattage, DC type, 3 MPa or less		●													P.93
	Pilot operated	**VXH**	Only AC type, 2 MPa or less			●	●		●									P.167
		VCH4	Only G thread type, 5 MPa or less								●*	●*						P.227

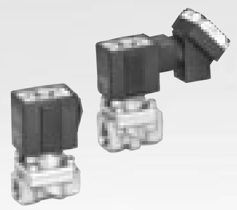
* Only G thread type

Coolant

Fluid	Action	Series	Remarks	Applicable port size											Flange					Page
				—	6A	8A	10A		15A	20A	25A	32A	40A	50A	32F	40F	50F	65A	80A	
				M5	1/8	1/4	3/8		1/2	3/4	1	1 1/4	1 1/2	2						
Coolant	External pilot piston	**SGC**					●		●	●	●									P.373
		VNC			●	●	●		●	●	●	●	●	●	●	●	●	●	●	P.399
		VNH					●		●	●	●									P.409

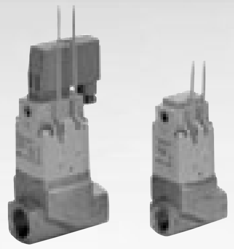
Series ***VX2***

Series ***VXE***



Series ***VXH***

Series ***VCH4***



Series ***SGC***

Series ***VNC***

Series ***VNH***

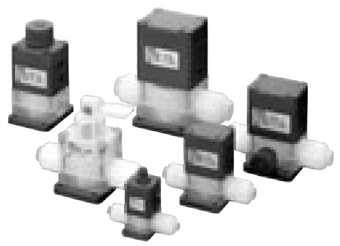
Chemicals, Pure water

Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A	10A		15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4	3/8		1/2	3/4	1	1 1/4	1 1/2	2				
Chemicals, Pure water	Pilot	**LV**	Female thread type, with fittings type available		●	●	●		●	●	●							P.457
	Direct operated	**LVM**	With fittings type, female thread type available	●*														P.281

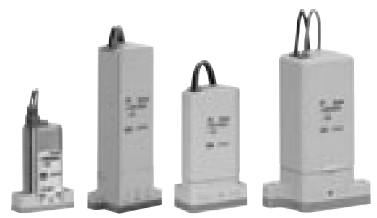
* Body ported: M5; Base mounted: M6

Dust collector

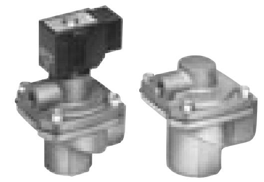
Fluid	Action	Series	Remarks	Applicable port size											Flange			Page
				—	6A	8A	10A		15A	20A	25A	32A	40A	50A	32F	40F	50F	
				M5	1/8	1/4	3/8		1/2	3/4	1	1 1/4	1 1/2	2				
Dust collector	Pilot operated	**VXF**	Dedicated for dust collector							●	●	●	●					P.169



Series ***LV***



Series ***LVM***



Series ***VXF***

Solenoid Valve Flow Characteristics
(How to indicate flow characteristics)

1. Indication of flow characteristics

The flow characteristics in equipment such as a solenoid valve, etc. are indicated in their specifications as shown in Table (1).

Table (1) Indication of Flow Characteristics

Corresponding equipment	Indication by international standard	Other indications	Conformed standard
Pneumatic equipment	*C*, *b*	—	ISO 6358: 1989 JIS B 8390: 2000
	—	*S*	JIS B 8390: 2000 Equipment: JIS B 8373, 8374, 8375, 8379, 8381
		Cv	ANSI/(NFPA)T3.21.3: 1990
Process fluid control equipment	*Av*	—	IEC60534-2-3: 1997 JIS B 2005: 1995 Equipment: JIS B 8471, 8472, 8473
	—	*Cv*	

2. Pneumatic equipment

2.1 Indication according to the international standards

(1) Conformed standard

ISO 6358: 1989 : Pneumatic fluid power—Components using compressible fluids—Determination of flow-rate characteristics

JIS B 8390: 2000 : Pneumatic fluid power—Components using compressible fluids—How to test flow-rate characteristics

(2) Definition of flow characteristics

The flow characteristics are indicated as a result of a comparison between sonic conductance ***C*** and critical pressure ratio ***b***.

Sonic conductance ***C*** : Value which divides the passing mass flow rate of an equipment in a choked flow condition by the product of the upstream absolute pressure and the density in a standard condition.

Critical pressure ratio ***b*** : Pressure ratio (downstream pressure/upstream pressure) which will turn to a choked flow when the value is smaller than this ratio.

Choked flow : The flow in which the upstream pressure is higher than the downstream pressure and where sonic speed in a certain part of an equipment is reached.
Gaseous mass flow rate is in proportion to the upstream pressure and not dependent on the downstream pressure.

Subsonic flow : Flow greater than the critical pressure ratio

Standard condition : Air in a temperature state of 20°C, absolute pressure 0.1 MPa (= 100 kPa = 1 bar), relative humidity 65%.
It is stipulated by adding the “(ANR)” after the unit depicting air volume.
(standard reference atmosphere)
Conformed standard: ISO 8778: 1990 Pneumatic fluid power—Standard reference atmosphere, JIS B 8393: 2000: Pneumatic fluid power—Standard reference atmosphere

(3) Formula for flow rate

It is described by the practical units as following.

When

$$\frac{P_2 + 0.1}{P_1 + 0.1} \leq b \text{, choked flow}$$

$$Q = 600 \times C (P_1 + 0.1)\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots(1)$$

When

$$\frac{P_2 + 0.1}{P_1 + 0.1} > b \text{, subsonic flow}$$

$$Q = 600 \times C (P_1 + 0.1)\sqrt{1 - \left[\frac{\frac{P_2 + 0.1}{P_1 + 0.1} - b}{1 - b}\right]^2}\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots(2)$$

Q : Air flow rate [dm^3 /min (ANR)], dm^3 (Cubic decimeter) of SI unit are also allowed to be described by ℓ (liter).
$1\ dm^3 = 1$ ℓ

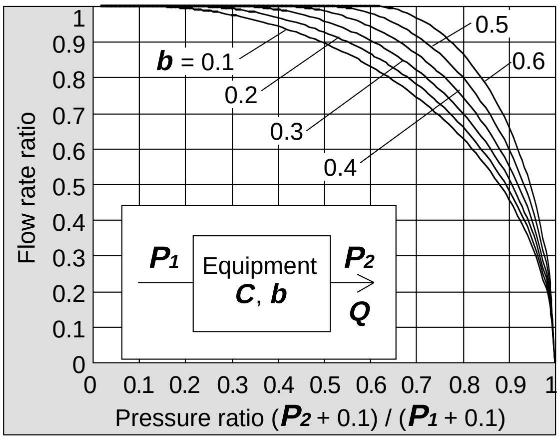
C : Sonic conductance [$dm^3/(s \cdot bar)$]
b : Critical pressure ratio [—]
P_1 : Upstream pressure [MPa]
P_2 : Downstream pressure [MPa]
t : Temperature [°C]
Note) Formula of subsonic flow is the elliptic analogous curve.
Flow characteristics are shown in Graph (1) For details, please make use of SMC's "Energy Saving Program".

Example)
Obtain the air flow rate for P_1 = 0.4 [MPa], P_2 = 0.3 [MPa], ***t*** = 20 [°C] when a solenoid valve is performed in ***C*** = 2 [$dm^3/(s \cdot bar)$] and ***b*** = 0.3.

According to formula 1, the maximum flow rate $= 600 \times 2 \times (0.4 + 0.1) \times \sqrt{\frac{293}{273 + 20}} = 600$ [dm^3/min (ANR)]

Pressure ratio $= \frac{0.3 + 0.1}{0.4 + 0.1} = 0.8$

Based on Graph (1), it is going to be 0.7 if it is read by the pressure ratio as 0.8 and the flow ratio to be ***b*** = 0.3.
Hence, flow rate = Max. flow x flow ratio = 600 x 0.7 = 420 [dm^3/min (ANR)]



Graph (1) Flow characteristics

(4) Test method

Attach a test equipment with the test circuit shown in Fig. (1) while maintaining the upstream pressure to a certain level which does not go below 0.3 MPa. Next, measure the maximum flow to be saturated in the first place, then measure this flow rate at 80%, 60%, 40%, 20% and the upstream and downstream pressure. And then, obtain the sonic conductance ***C*** from this maximum flow rate. Besides that, substitute each data of others for the subsonic flow formula to find ***b***, then obtain the critical pressure ratio ***b*** from that average.

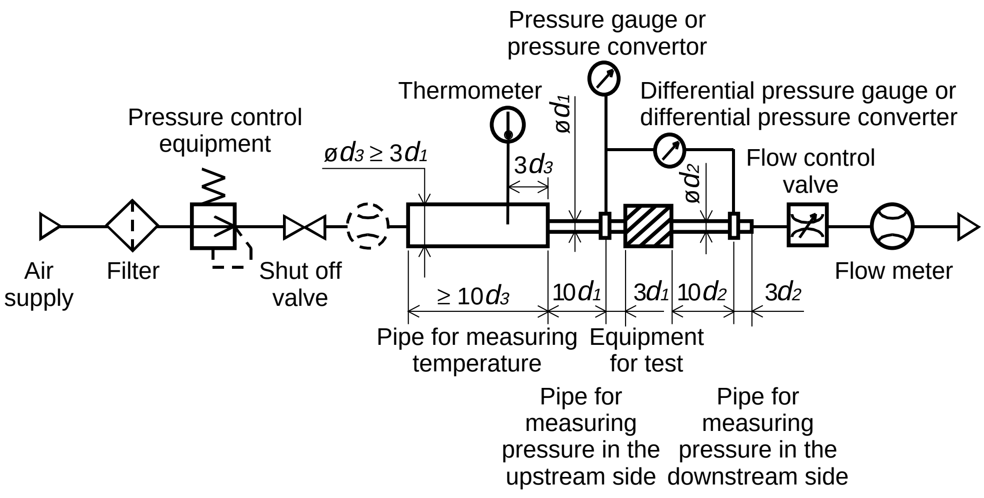


Fig. (1) Test circuit based on ISO 6358, JIS B 8390

Solenoid Valve Flow Characteristics

2.2 Effective area S

(1) Conformed standard

JIS B 8390: 2000: Pneumatic fluid power—Components using compressible fluids—Determination of flow rate characteristics

Equipment standards: JIS B 8373: 2 port solenoid valve for pneumatics
JIS B 8374: 3 port solenoid valve for pneumatics
JIS B 8375: 4 port, 5 port solenoid valve for pneumatics
JIS B 8379: Silencer for pneumatics
JIS B 8381: Fittings of flexible joint for pneumatics

(2) Definition of flow characteristics

Effective area S: The cross-sectional area having an ideal throttle without friction deduced from the calculation of the pressure changes inside an air tank or without reduced flow when discharging the compressed air in a choked flow, from an equipment attached to the air tank. This is the same concept representing the "easy to run through" as sonic conductance C.

(3) Formula for flow rate

When

$\frac{P_2 + 0.1}{P_1 + 0.1} \leq 0.5$, **choked flow**

$$Q = 120 \times S\,(P_1 + 0.1)\sqrt{\frac{293}{273 + t}} \qquad (3)$$

When

$\frac{P_2 + 0.1}{P_1 + 0.1} > 0.5$, **subsonic flow**

$$Q = 240 \times S\,\sqrt{(P_2 + 0.1)\,(P_1 - P_2)}\sqrt{\frac{293}{273 + t}} \qquad (4)$$

Conversion with sonic conductance C:

$$S = 5.0 \times C \qquad (5)$$

Q : Air flow rate[dm³/min(ANR)], dm³ (cubic decimeter) of SI unit are also allowed to be described by ℓ (liter) 1 dm³ = 1 ℓ
S : Effective area [mm²]
P_1 : Upstream pressure [MPa]
P_2 : Downstream pressure [MPa]
t : Temperature [°C]

Note) Formula for subsonic flow (4) is only applicable when the critical pressure ratio b is the unknown equipment. In the formula (2) by the sonic conductance C, it is the same formula as when b = 0.5.

(4) Test method

Attach a test equipment with the test circuit shown in Fig. (2) in order to discharge air into the atmosphere until the pressure inside the air tank goes down to 0.25 MPa (0.2 MPa) from an air tank filled with the compressed air at a certain pressure level (0.5 MPa) which does not go below 0.6 MPa. At this time, measure the discharging time and the residual pressure inside the air tank which had been left until it turned to be the normal values to determine the effective area S, using the following formula. The volume of an air tank should be selected within the specified range by corresponding to the effective area of an equipment for test. In the case of JIS B 8373, 8374, 8375, 8379, 8381, the pressure values are in parentheses and the coefficient of the formula is 12.9.

$$S = 12.1\,\frac{V}{t}\log_{10}\left(\frac{P_s + 0.1}{P + 0.1}\right)\sqrt{\frac{293}{T}} \qquad (6)$$

S : Effective area [mm²]
V : Air tank capacity [dm³]
t : Discharging time [s]
P_s : Pressure inside air tank before discharging [MPa]
P : Residual pressure inside air tank after discharging [MPa]
T : Temperature inside air tank before discharging [K]

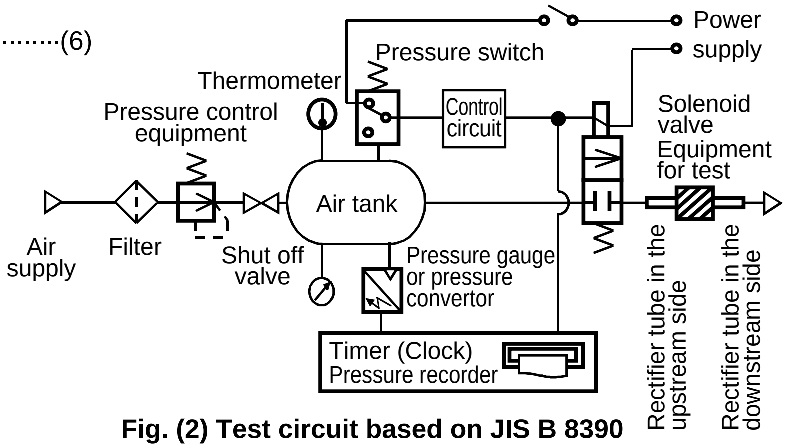


Fig. (2) Test circuit based on JIS B 8390

2.3 Flow coefficient *Cv* factor

The United States Standard ANSI/(NFPA)T3.21.3: 1990: Pneumatic fluid power—Flow rating test procedure and reporting method for fixed orifice components

Defines the *Cv* factor of flow coefficient by the following formula which is based on the test conducted by the test circuit analogous to ISO 6358.

$$Cv = \frac{Q}{114.5\sqrt{\frac{\Delta P\,(P_2 + P_a)}{T_1}}} \quad \cdots\cdots (7)$$

ΔP : Pressure drop between the static pressure tapping ports [bar]
P_1 : Pressure of the upstream tapping port [bar gauge]
P_2 : Pressure of the downstream tapping port [bar gauge]: $P_2 = P_1 - \Delta P$
Q : Flow rate [dm³/s standard condition]
P_a : Atmospheric pressure [bar absolute]
T_1 : Upstream absolute temperature [K]

Test conditions are < $P_1 + P_a = 6.5 \pm 0.2$ bar absolute, $T_1 = 297 \pm 5$K, 0.07 bar $\leq \Delta P \leq$ 0.14 bar.

This is the same concept as effective area *A* which ISO 6358 stipulates as being applicable only when the pressure drop is smaller than the upstream pressure and the compression of air does not become a problem.

3. Process fluid control equipment

(1) Conformed standard

IEC60534-2-3: 1997: Industrial process control valves. Part 2: Flow capacity, Section Three-Test procedures
JIS B 2005: 1995: Test method for the flow coefficient of a valve
Equipment standards: JIS B 8471: Solenoid valve for water
JIS B 8472: Solenoid valve for steam
JIS B 8473: Solenoid valve for fuel oil

(2) Definition of flow characteristics

Av factor: Value of the clean water flow rate represented by m³/s which runs through a valve (equipment for test) when the pressure difference is 1 Pa. It is calculated using the following formula.

$$Av = Q\sqrt{\frac{\rho}{\Delta P}} \quad \cdots\cdots (8)$$

Av : Flow coefficient [m²]
Q : Flow rate [m³/s]
ΔP : Pressure difference [Pa]
ρ : Density of fluid [kg/m³]

(3) Formula of flow rate

It is described by the practical units. Also, the flow characteristics are shown in Graph (2).

In the case of liquid:

$$Q = 1.9 \times 10^6 Av\sqrt{\frac{\Delta P}{G}} \quad \cdots\cdots (9)$$

Q : Flow rate [ℓ/min]
Av : Flow coefficient [m²]
ΔP : Pressure difference [MPa]
G : Relative density [water = 1]

In the case of saturated aqueous vapor:

$$Q = 8.3 \times 10^6 Av\sqrt{\Delta P(P_2 + 0.1)} \quad \cdots\cdots (10)$$

Q : Flow rate [kg/h]
Av : Flow coefficient [m²]
ΔP : Pressure difference [MPa]
P_1 : Upstream pressure [MPa]: $\Delta P = P_1 - P_2$
P_2 : Downstream pressure [MPa]

Solenoid Valve Flow Characteristics

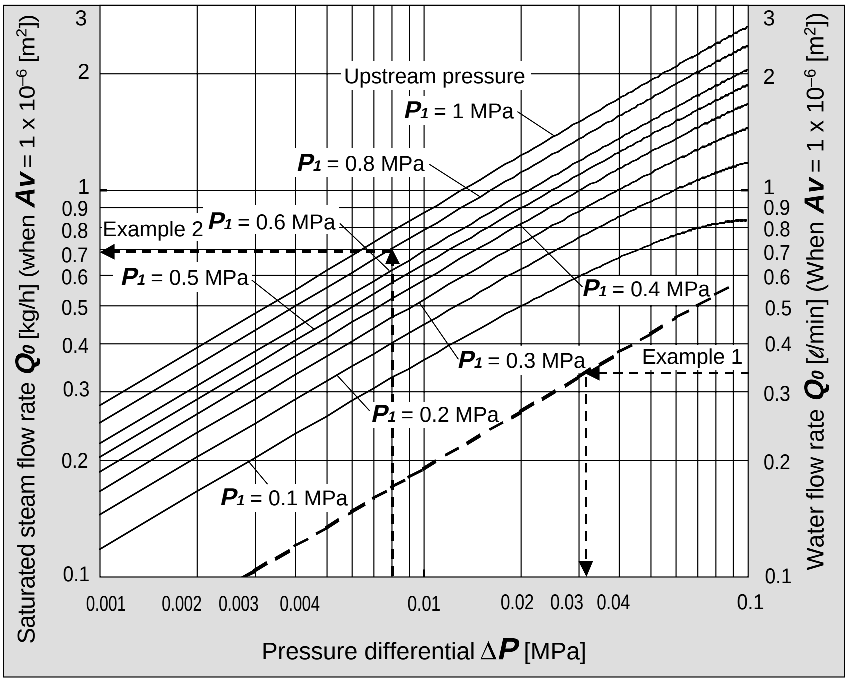
Conversion of flow coefficient:
$Av = 28 \times 10^{-6}\ Kv = 24 \times 10^{-6}\ Cv$ ··(11)

Here,

Kv factor : Value of the clean water flow rate represented by m^3/h which runs through a valve at 5 to 40°C, when the pressure difference is 1 bar.

Cv factor (Reference values): Figures representing the flow rate of clean water by US gal/min which runs through a valve at 60°F, when the pressure difference is 1 lbf/in^2 (psi).

Value is different from ***Kv*** and ***Cv*** factors for pneumatic purpose due to different test method.



Graph (2) Flow characteristics

Example 1)
Obtain the pressure difference when water 15 [ℓ/min] runs through a solenoid valve with an $Av = 45 \times 10^{-6}$ [m^2].
Since $Q_0 = 15/45 = 0.33$ [ℓ/min], according to Graph (2), if reading ΔP when Q_0 is 0.33, it will be 0.031 [MPa].

Example 2)
Obtain the saturated steam flow rate when $P_1 = 0.8$ [MPa], $\Delta P = 0.008$ [MPa] with a solenoid valve with an $Av = 1.5 \times 10^{-6}$ [m^2].
According to Graph (2), if reading Q_0 when P_1 is 0.8 and ΔP is 0.008, it is 0.7 [kg/h]. Hence, the flow rate $Q = 0.7 \times 1.5 = 1.05$ [kg/h].

(4) Test method
Attach a test equipment with the test circuit shown in Fig. (3). Next, pour water at 5 to 40°C, then measure the flow rate with a pressure difference of 0.075 MPa. However, the pressure difference needs to be set with a large enough difference so that the Reynolds number does not go below a range of 4×10^4 .
By substituting the measurement results for formula (8) to figure out ***Av***.

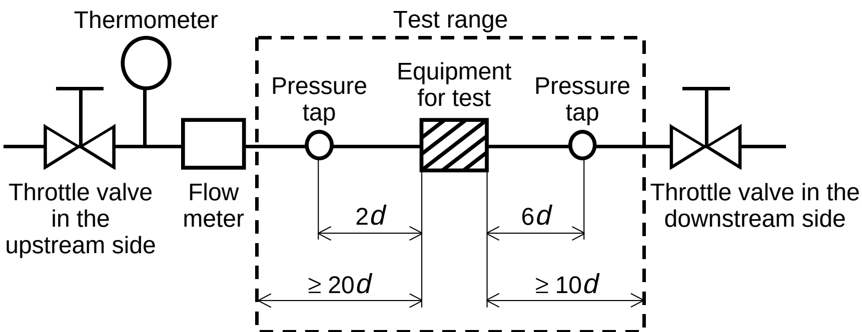
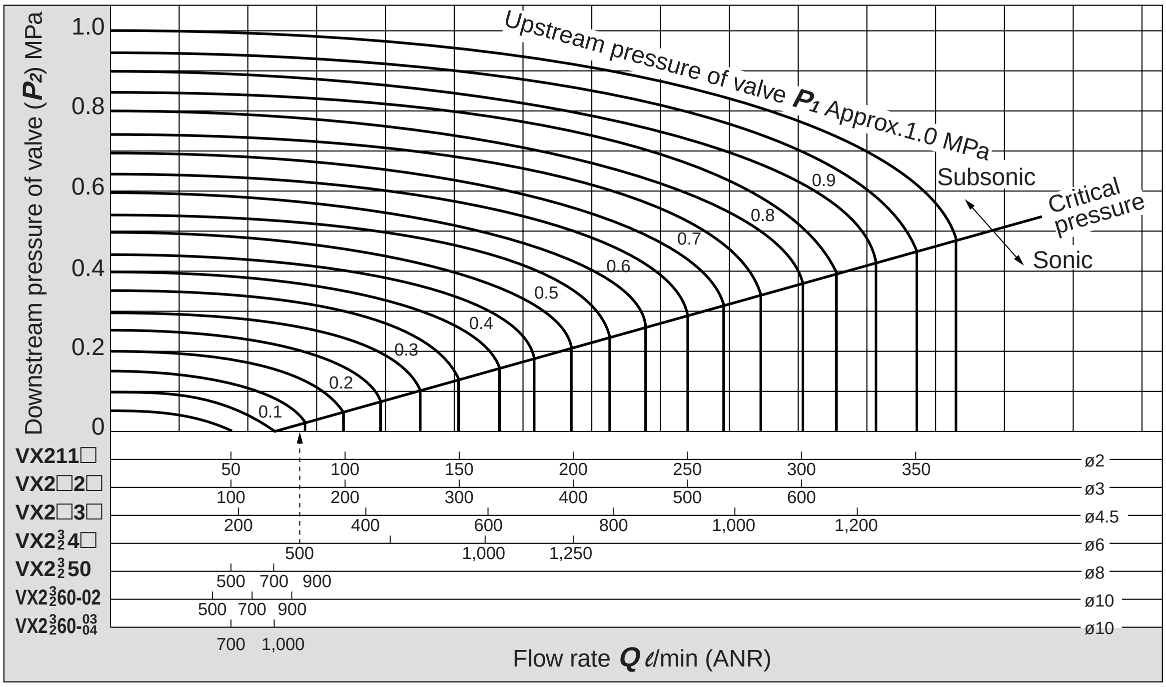


Fig. (3) Test circuit based on IEC60534-2-3, JIS B 2005

Flow Characteristics

Note) Use this graph as a guide. In the case of obtaining an accurate flow rate, refer to pages 10 through to 14.

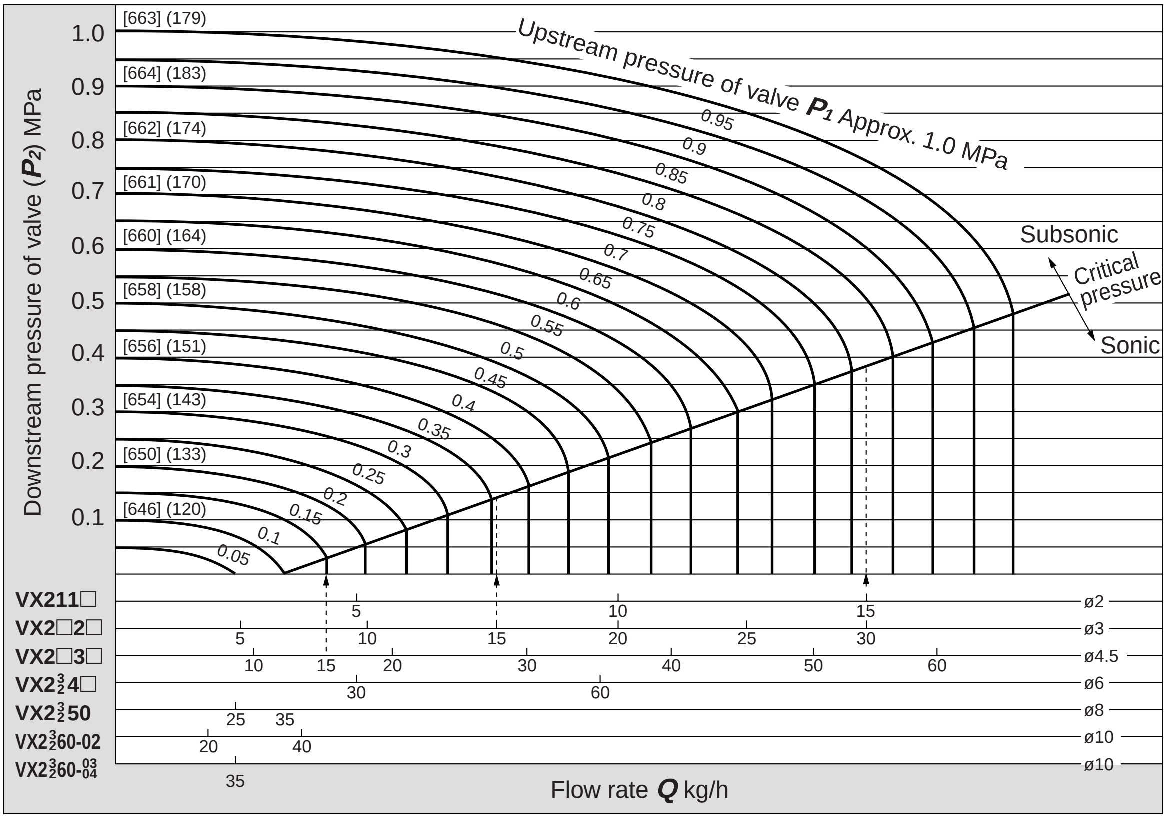
For Air



How to read the graph

The sonic range pressure to generate a flow rate of 500 ℓ/min (ANR) is
P_1 Approx. 0.14 MPa for a ø6 orifice (VX2 3/2 4□) and
P_1 Approx. 0.3 MPa for a ø4.5 orifice (VX2□3□).

For Saturated Steam



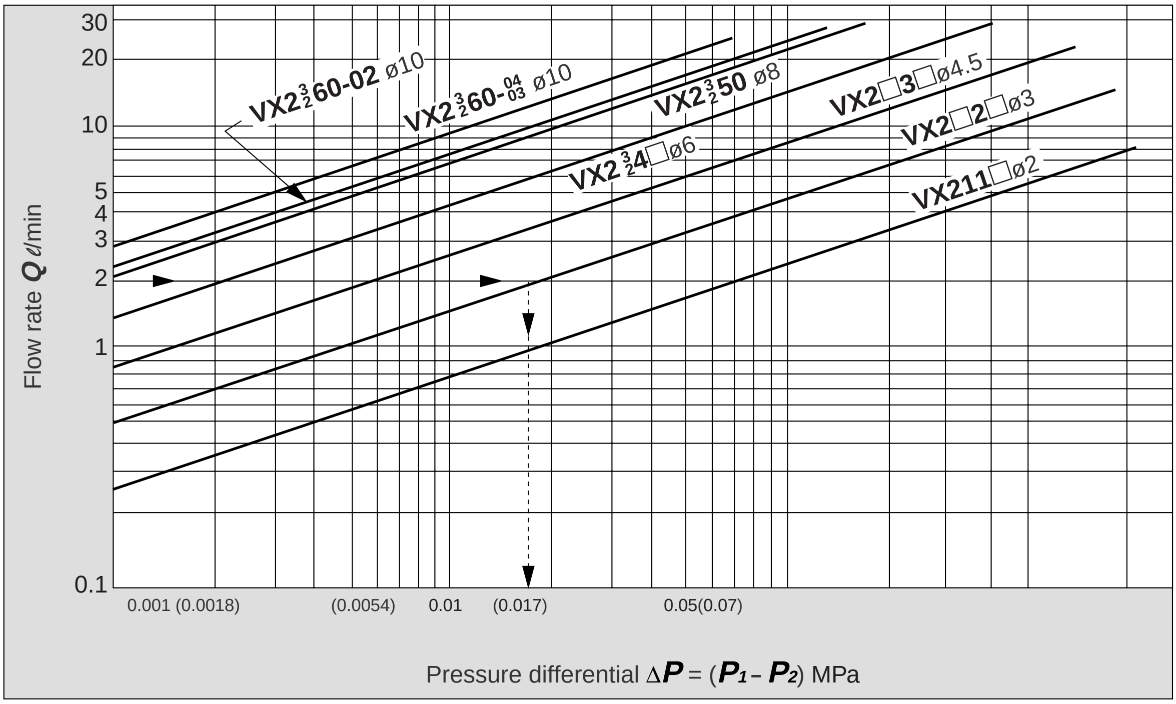
Figures inside [ ] indicate the saturated steam holding heat (kcal/kg). Figures inside ( ) indicate the saturation temperature (°C).

How to read the graph

The sonic range pressure to generate a flow rate of 15 kg/h is
P_1 Approx. 0.15 MPa for ø4.5 orifice (VX2□3□S), P_1 Approx. 0.37 MPa for ø3 orifice (VX2□2□S), and
P_1 Approx. 0.82 MPa for ø2 orifice (VX211□S). The holding heat slightly differs depending on the pressure P_1, but at 15 kg/h it is approximately 9700 kcal/h.

Flow Characteristics

For Water



How to read the graph

When a water flow of 2 ℓ/min is generated, ΔP Approx. 0.017 MPa for a valve with ø3 orifice (VX212□, 222□, 232□).

SMC