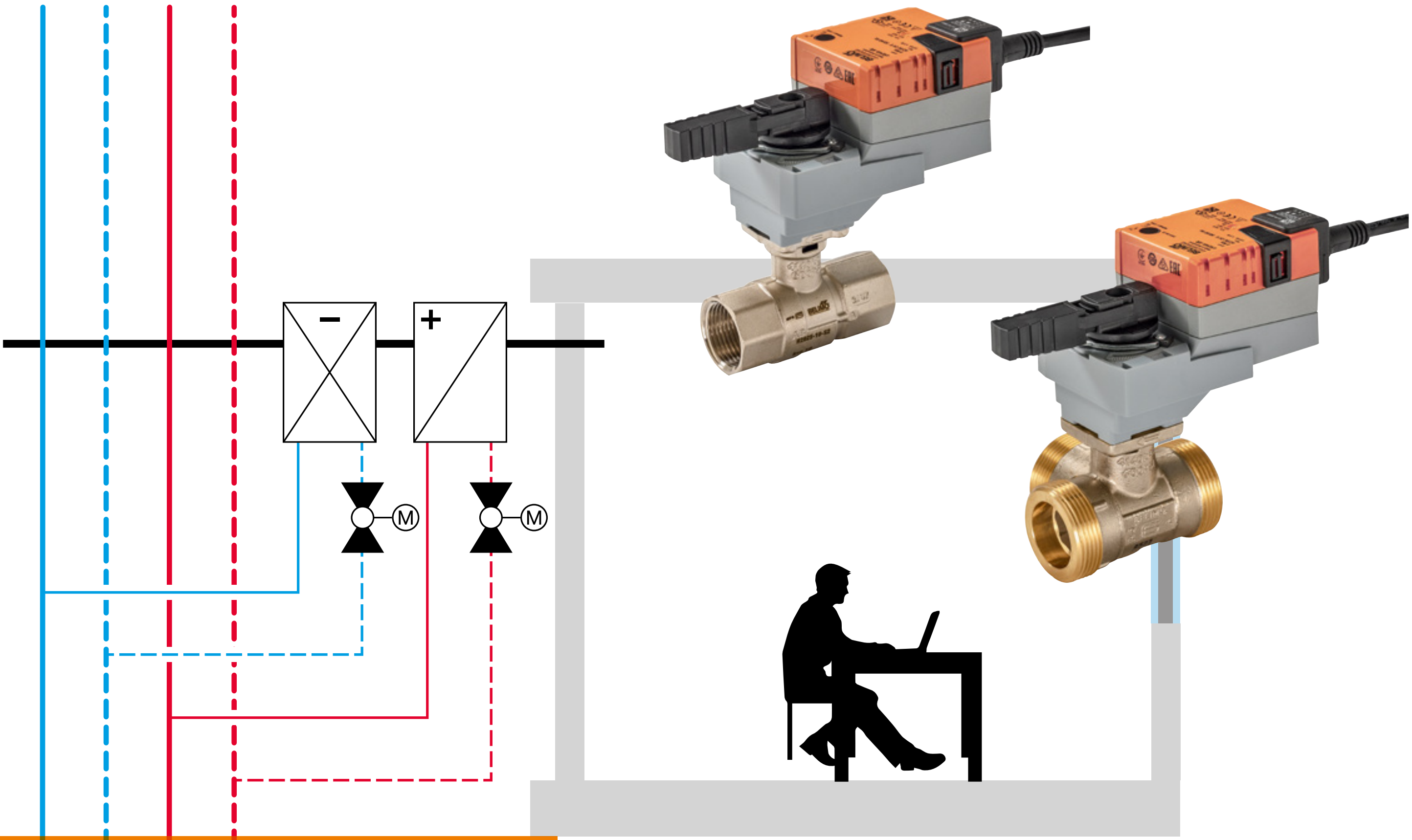

Notes for project planning

2-way and 3-way characterised control valves

Edition 2024-04/A

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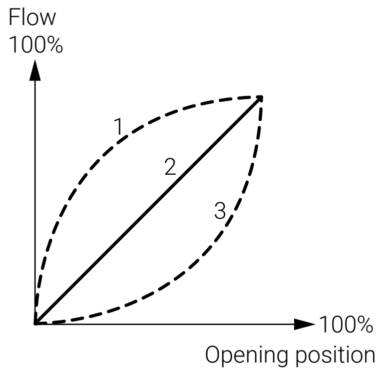
The Belimo characterised control valve

Valve characteristic curves

To enable high control stability, a hydronic control element must have a flow characteristic that complements the non-linear characteristic curve of the heat exchanger in the HVAC system.

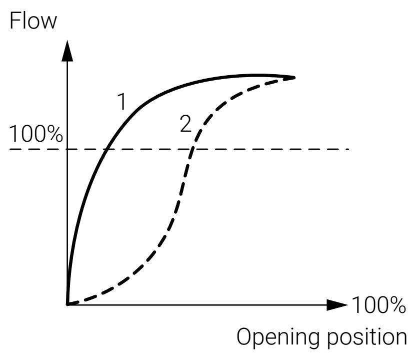
Characteristic curves of an ideal hydronic control element



1 Typical heat exchanger characteristic curve
2 Resultant thermal output
3 Equal-percentage valve characteristic curve

An equal-percentage valve characteristic curve is desired so that a linear behaviour of the heat dissipation will result, depending on the opening position of the control element (so-called path characteristic curve). The flow rate thus increases very slowly whilst the control element begins to open. This characteristic curve is extremely deformed with a standard ball valve.

Characteristic curves of an ideal hydronic control element



1 Resultant thermal output
2 Flow characteristic standard ball valve

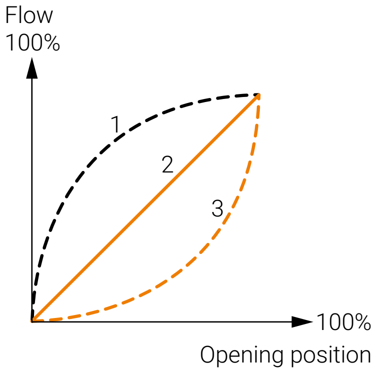
The reason for this is that a standard ball valve has an extremely high flow coefficient (K_{VS} value) compared to its nominal diameter, which is many times greater than that of a comparable globe valve. A standard ball valve is therefore poorly suited to control tasks:

– Flow coefficient too large for the model
– In the partial-load range, the flow rate cannot be sufficiently controlled

Advantages of the Belimo characterised control valve

Belimo has successfully solved the problem of the distorted path characteristic curve of the ball valve. A so-called characterised disc corrects the characteristic curve of the ball valve to make it an equal-percentage one. The flow rate is now influenced by the ball bore and the v-shaped opening in the characterised disc.

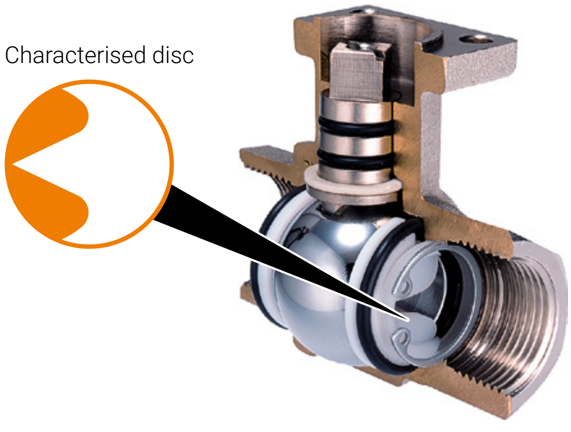
Characteristic curves of the Belimo characterised control valve



1 Heat exchanger characteristic curve
2 Resultant thermal output
3 Equal-percentage characteristic curve Belimo characterised control valve

The K_{VS} value is reduced and corresponds to that of a globe valve of the same nominal diameter. To eliminate the need to install pipe reducers in most cases, each nominal diameter is also available with a corresponding selection of different K_{VS} values.

The properties of the Belimo characterised control valve have many advantages:
– Equal-percentage characteristic curve
– No input jump upon opening
– Excellent control stability via characterised disc

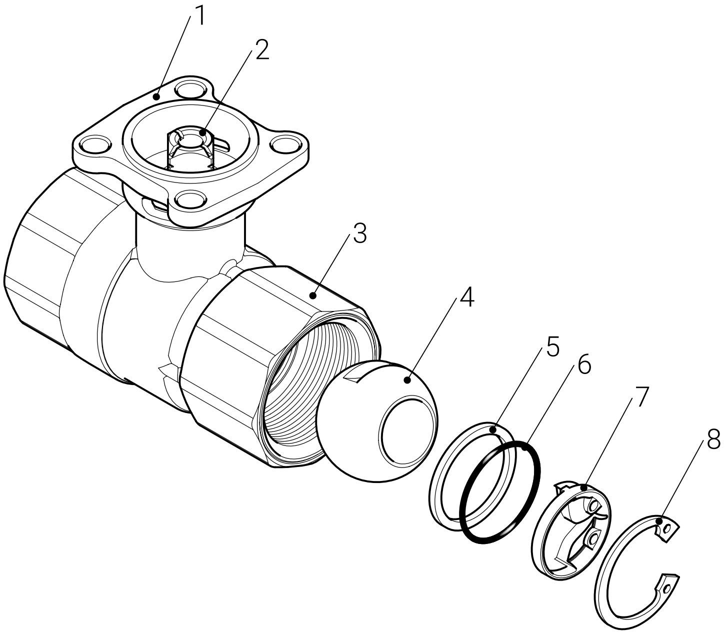


– Kvs value comparable with globe valve of the same nominal diameter
– Less pipe reduction required
– Better partial-load behaviour and higher control stability
– Tight-closing (2-way version)
– Prevention of the system's tendency to oscillate

Elements of the characterised control valve

1 Mounting flange
2 Spindle with flow marking
3 Valve body
4 Ball made of stainless steel
5 Gasket
6 O-ring
7 Characterised disc
8 Locking ring

Internal thread according to ISO 7-1
External thread according to ISO 228/1



Selection of K_{VS} values

The optimum selection of different K_{VS} values with the same nominal diameter leads to:
– Better controllability
– Lower installation costs
The Belimo characterised control valve product range includes 2-way and 3-way versions. These are offered in various nominal diameters with a selection of different K_{VS} values. Every characterised control valve is supplied together with the matching Belimo rotary actuator.

Project planning

Relevant information

The data, information and limit values on the data sheets of the Belimo characterised control valves must be observed and complied with.

Closing and differential pressures

Refer to the data sheets for the maximum permissible closing and differential pressures.

Pipeline clearances

The minimum clearances between the pipelines and the walls and ceilings required for project planning depend not only on the valve dimensions but also on the design. The dimensions can be found in the associated data sheets.

2-way characterised control valves

Characterised control valves are throttling devices. Installation in the return flow is recommended with high temperatures. This leads to a lower thermal load on the sealing elements in the valve. The prescribed direction of flow must be observed.

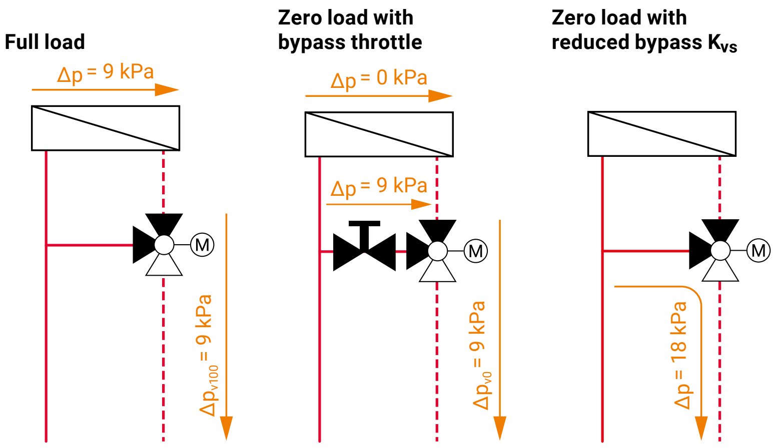
3-way characterised control valves

3-way characterised control valves are mixing devices. The direction of flow must be maintained under all loads. Installation in the supply or return is dependent on the hydronic circuit selected. The 3-way characterised control valve must not be used as a diverting valve.

Diverting circuit

Thanks to the reduced flow rate in the bypass, no balancing valve in the bypass line is required for the diverting circuit.

Bypass 70% K_{vs}



$$V' = K_{vs} \cdot \sqrt{\Delta p_{v100}} = x \cdot K_{vs} \cdot \sqrt{2 \cdot \Delta p_{v100}} \rightarrow x = \frac{1}{\sqrt{2}} = 0.7 \rightarrow 70\%$$

Water quality

Adhere to the water quality requirements specified in VDI 2035.

Strainer

The Belimo characterised control valve is a regulating device. Central strainers are recommended to ensure the control task in the long term.

Open/close valve

Make sure that sufficient open/close valves are installed on the plant for service purposes.

Design and dimensioning

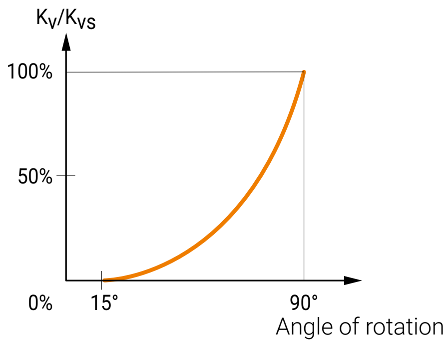
Control characteristics

To ensure a valve attains good control characteristics thus a long service life for the control element, it needs to be correctly designed with the correct valve authority. The valve authority P_V is the benchmark for the control characteristics of the valve in combination with the hydronic network. The valve authority is the relation between the differential pressure of the fully open valve at nominal flow and the total pressure drop in the variable-flow path or of the completely closed valve. The higher the valve authority, the better the control characteristics. The smaller the valve authority P_V becomes, the more the operational behaviour of the valve will deviate from the linearity, i.e. the poorer the flow control will be. A valve authority P_V of >0.5 is desired in everyday practice.

Design when using glycol

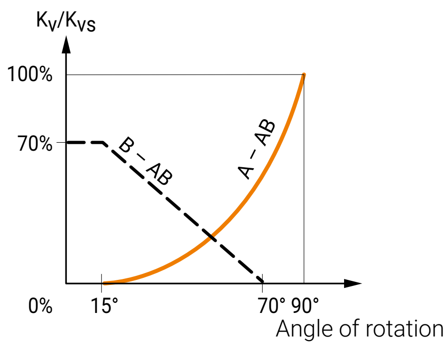
To reduce the freezing point of water, salt was added to the water in the past. These were called brine applications. Today glycol is used and we talk about cold agents. Depending on the concentration of the cold agent used (type of glycol) and the fluid temperature, the density of the water-glycol mixture varies between 1 and 9 percent. The resultant volume deviation is less than the permissible volume tolerance of the valve's K_{VS} value (by ±10 percent according to VDI/VDE 2173) and as a rule need not be taken into account, even if glycol mixtures require a slightly higher K_{VS} value. Depending on the type of glycol, compatibility with the valve materials used must be guaranteed and the permissible maximum concentration (50 percent) must not be exceeded. Furthermore, the specifications of the glycol manufacturer with respect to minimum concentration are to be taken into account.

Flow characteristics



2-way characterised control valve

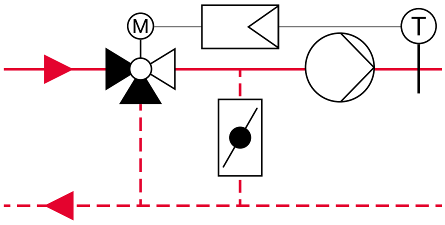
The characteristic curve is equal percentage with a characteristic curve factor n(gl) = 3.2 or 3.9. This guarantees stable control characteristics in the upper partial load range. The curve is linear in the lower opening range between 0…30% of the operating range. This ensures outstanding control characteristics, including in the lower partial load range. The operating range 0…100% corresponds to an angle of rotation of 15…90°.



3-way characterised control valve

3-way characterised control valves have the same behaviour as 2-way characterised control valves across the control path A – AB. The flow in the bypass B – AB is designed to be 70% of the K_{VS} value of the control path (A – AB). This compensates for the often low resistance in the bypass line. The characteristic curve in the bypass is linear.

Note



Due to the ball design, the 3-way characterised control valve is suitable only to a limited extent for conventional supply temperature control. When using these characterised control valves, it is therefore recommended that control of the supply temperature be designed as a double mixing circuit.

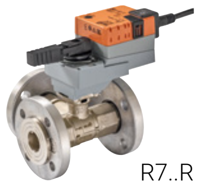
No limitations exist for mixing circuits in air heaters or for injection circuits.

Dimensional diagram for 2-way and 3-way characterised control valves R2/3.. / R6/7..R


R2..


R3..


R6..R


R7..R

Application

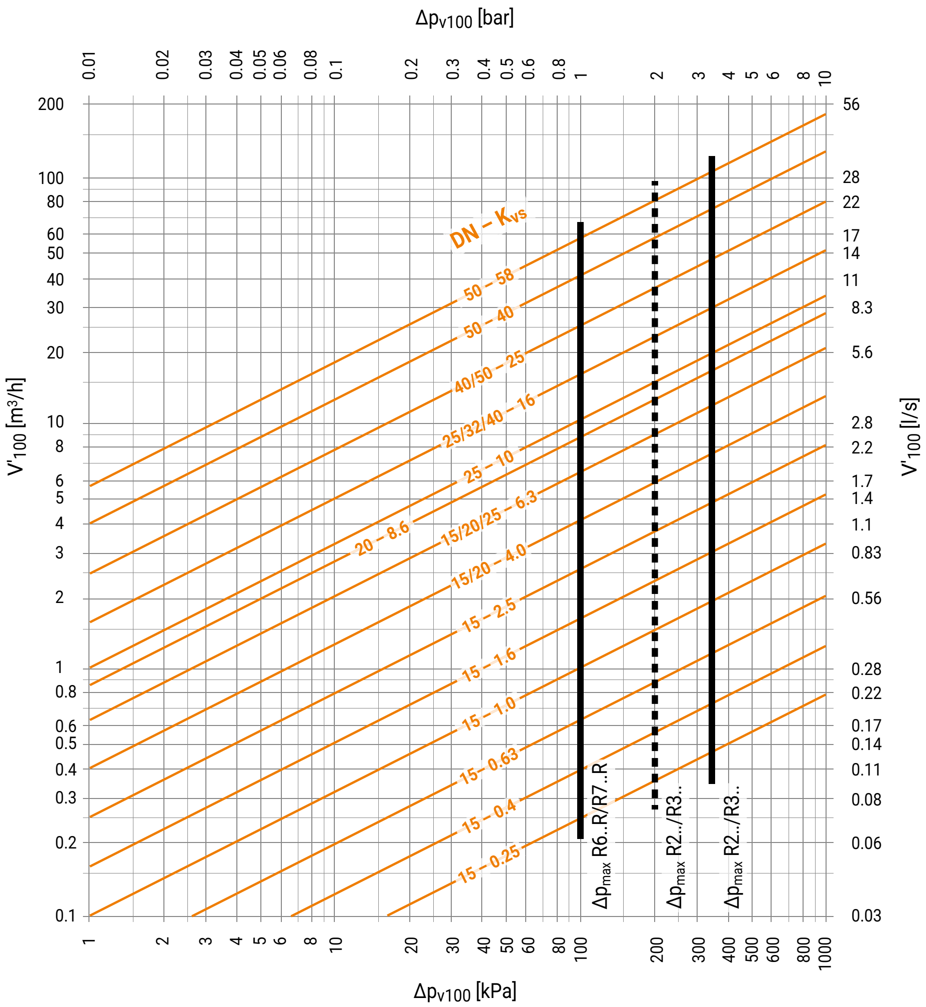
These characterised control valves are used in open (R2.. and R6..R) and closed chilled and warm water systems for modulating water-side control of air handling units and heating systems.

Media

Chilled and warm water, water with glycol up to max. 50% vol.

Fluid temperatures

The permissible fluid temperatures can be found in the corresponding valve and actuator data sheets.



Formula K_{vs}

$$K_{vs} = \frac{V'_{100}}{\sqrt{\frac{\Delta p_{v100}}{100}}}$$

Δp_{v100} : [kPa]
V'_{100} : [m³/h]
K_{vs} : [m³/h]

—— Δp_{max} Maximum permissible differential pressure for long service life across control path A – AB, with reference to the whole opening range

– – Δp_{max} Maximum permissible differential pressure for low noise operation

Dimensional diagram for 2-way and 3-way characterised control valves R4../R5..


R4..


R5..

Application

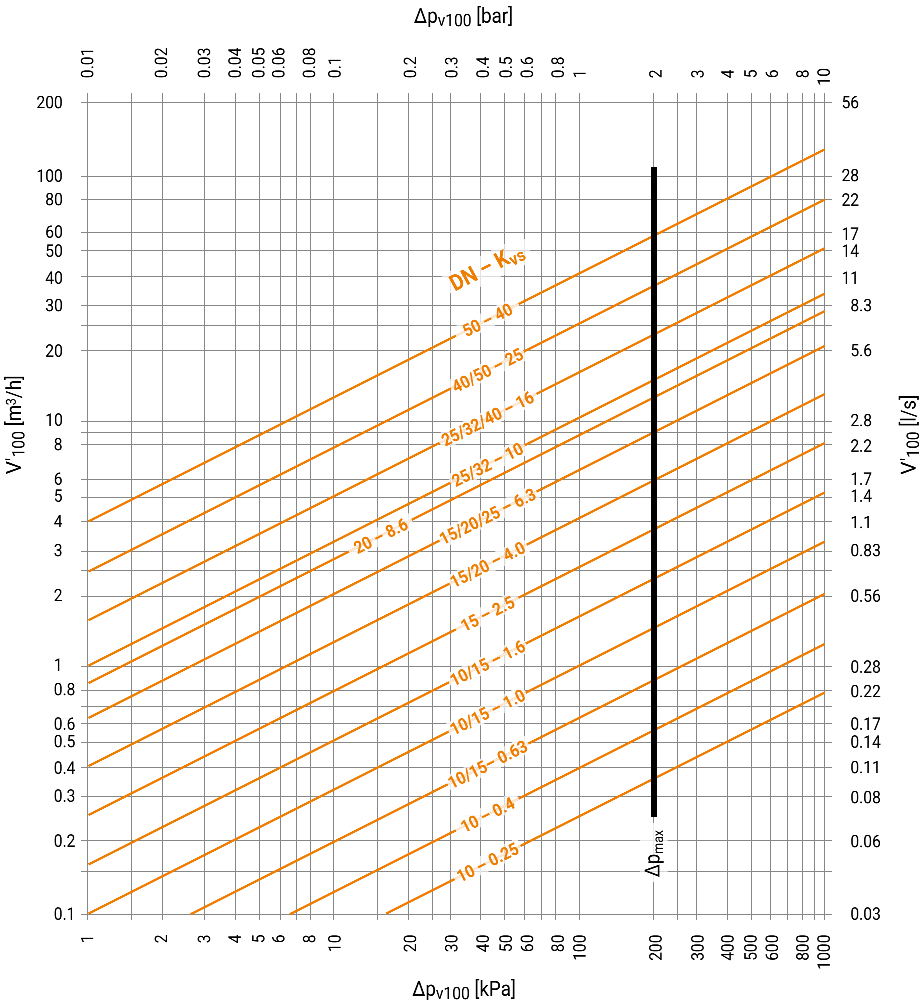
These characterised control valves are used in open and closed chilled and warm water systems for modulating water-side control of air handling units and heating systems.

Media

Chilled and warm water, water with glycol up to max. 50% vol.

Fluid temperatures

The permissible fluid temperatures can be found in the corresponding valve and actuator data sheets.



Formula K_{vs}

$$K_{vs} = \frac{V'_{100}}{\sqrt{\frac{\Delta p_{v100}}{100}}}$$

Δp_{v100} : [kPa]
V'_{100} : [m³/h]
K_{vs} : [m³/h]

Δp_{max} Maximum permissible differential pressure for long service life across control path A – AB, with reference to the whole opening range

Dimensional diagram for 2-way characterised control valves R6..W..-S8

R6..W..-S8

Application

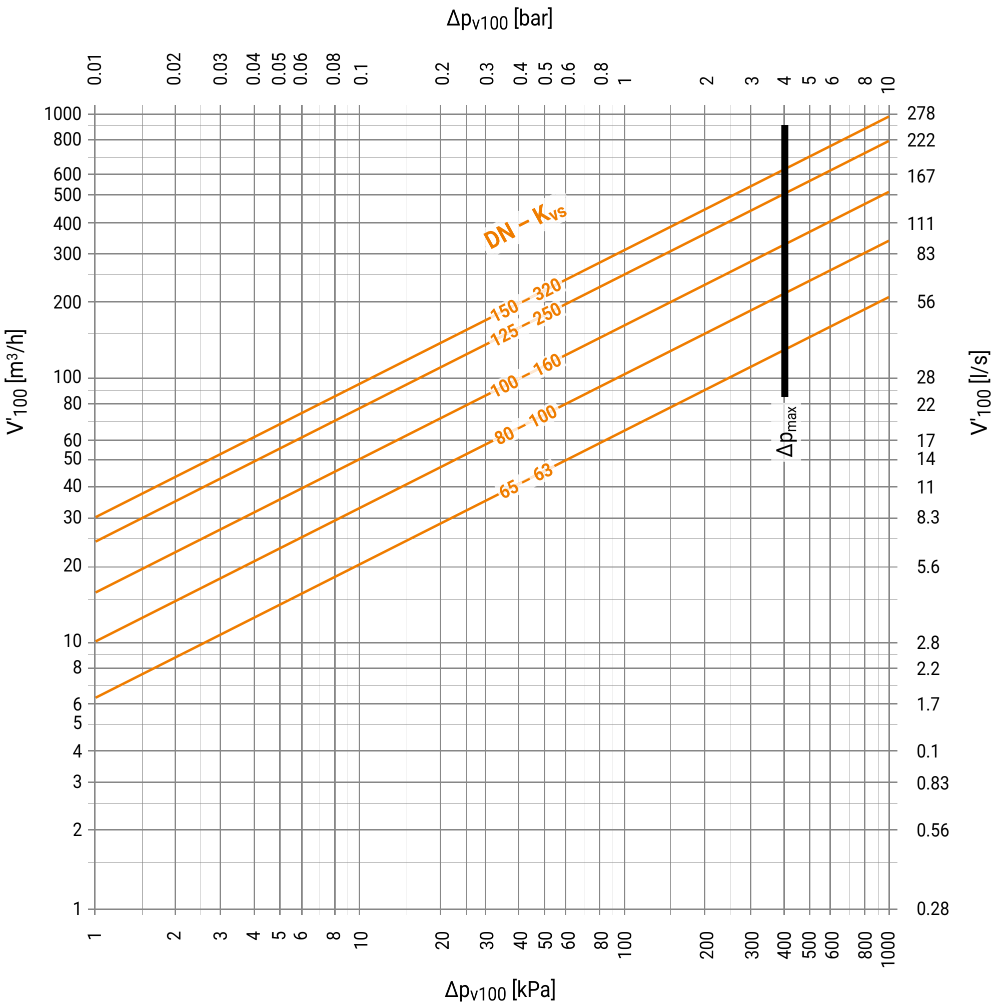
These characterised control valves are used in closed chilled and warm water systems for modulating water-side control of air handling units and heating systems.

Media

Chilled and warm water, water with glycol up to max. 50% vol.

Fluid temperatures

−10...120°C



Formula K_{vs}

$$K_{vs} = \frac{V'_{100}}{\sqrt{\frac{\Delta p_{v100}}{100}}}$$

Δp_{v100} : [kPa]
V'_{100} : [m³/h]
K_{vs} : [m³/h]

Δp_{max} Maximum permissible differential pressure for long service life across control path A – AB, with reference to the whole opening range

Dimensional diagram for 2-way characterised control valves R4..D(K)

R4..D(K)

Application

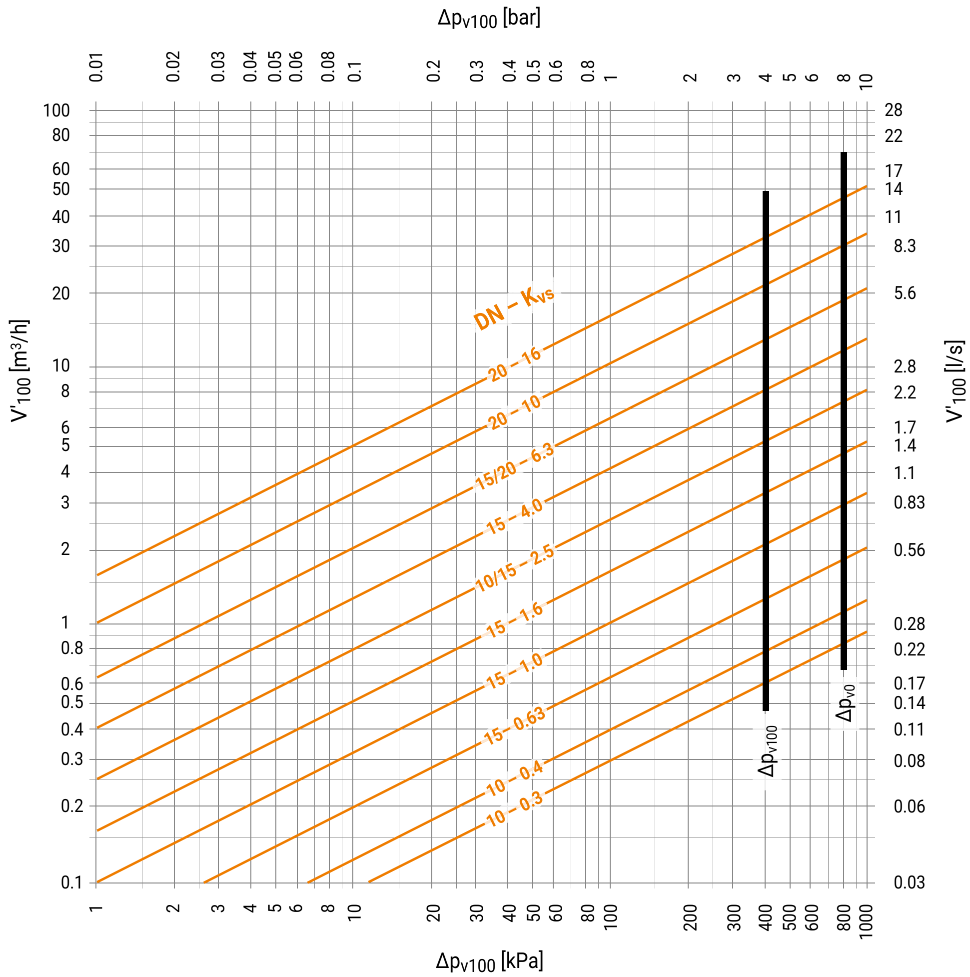
These characterised control valves are used in open and closed chilled, warm and hot water systems for modulating water-side control of water in district heating applications.

Media

Chilled, warm and hot water, potable water (upon request), water with glycol up to max. 50% vol.

Fluid temperatures

2...130°C



Formula K_{vs}

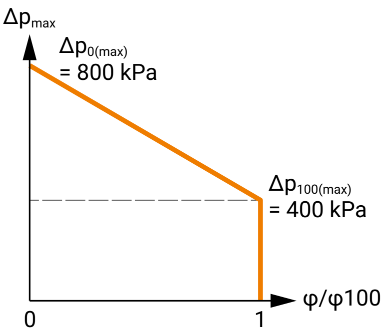
$$K_{vs} = \frac{V'_{100}}{\sqrt{\frac{\Delta p_{v100}}{100}}}$$

Δp_{v100} : [kPa]
V'_{100} : [m³/h]
K_{vs} : [m³/h]

Δp_{v0} Maximum permissible differential pressure for long service life with closed ball valve

Δp_{v100} Maximum permissible differential pressure for long service life with opened ball valve

Differential pressure

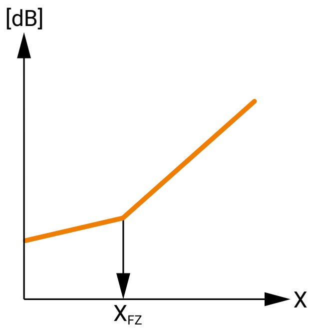


Δp_{max} = maximum permissible differential pressure
p_{v0} = maximum permissible differential pressure with closed valve
p_{v100} = maximum permissible differential pressure with valve completely open
φ = Delay angle
φ_{100} = Delay angle with valve completely open

Operating pressure ratio X_F

Formula:

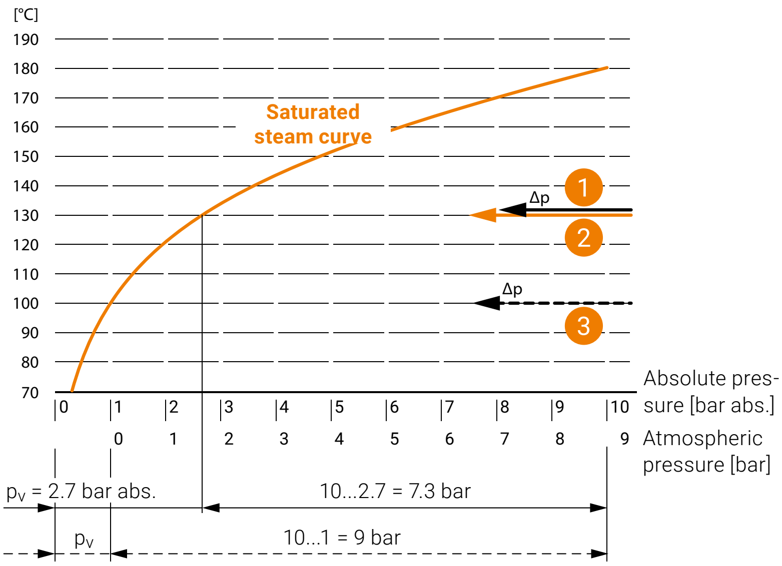
$$X_F = \frac{\Delta p}{p_1 - p_V} < X_F \quad \Delta p < X_{FZ}\,(p_1 - p_V) \quad X_F \leq Z = X_{FZ}$$



Δp = p1 – p2 = differential pressure via the valve [bar]
p_V = Steam pressure water [bar abs.]
X_F = Operating pressure ratio
X_{FZ} = Start cavitation of the valve
Z = Cavitation factor of the valve

Cavitation factor Z

Diagram:

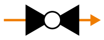


Example: Z = 0.3
1 No cavitation X_F = 2 / 7.3 = 0.27
2 Incipient cavitation X_F = 2.5 / 7.3 = 0.34
3 No cavitation X_F = 2.5 / 9 = 0.28

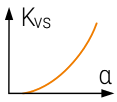
Selection table 2-way characterised control valve DN 10...50

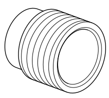
Pipe connection	**External thread** G (ISO 228-1)	**Flange** (EN 1092-1/4)
Fluid temperature	2...130°C	−10...100°C
Leakage rate	Air-bubble tight, leakage rate A (EN 12266-1)	Air-bubble tight, leakage rate A (EN 12266-1)
Max. differential pressure	**R4..D(K)** Δp_{max}: 400 kPa	**R6..R** Δp_{max}: 100 kPa
Permissible operating pressure	p_s: 2700 kPa	p_s: 600 kPa

Valve design



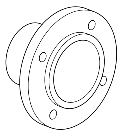
Valve characteristic curve





External thread

Valve type R4..D(K)	DN	K_{vs}	PN
R404DK	**10**	0.3	40
R405DK	**10**	0.4	40
R406DK	**10**	0.63	40
R407DK	**10**	1.0	40
R408DK	**10**	1.6	40
R409DK	**10**	2.5	40
R412D	**15**	2.5	40
R413D	**15**	4.0	40
R414D	**15**	6.3	40
R417D	**20**	6.3	40
R418D	**20**	10	40
R419D	**20**	16	40



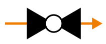
Flange

Valve type R6..R	DN	K_{vs}	PN
R6015RP63-B1	**15**	0.63	6
R6015R1-B1	**15**	1.0	6
R6015R1P6-B1	**15**	1.6	6
R6015R2P5-B1	**15**	2.5	6
R6015R4-B1	**15**	2.5	6
R6020R6P3-B1	**20**	6.3	6
R6025R10-B2	**25**	10	6
R6032R16-B3	**32**	16	6
R6040R25-B3	**40**	25	6
R6050R40-B3	**50**	40	6

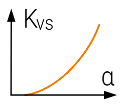
Selection table 2-way characterised control valve DN 15...150

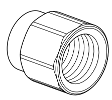
Pipe connection	**Internal thread** Rp (ISO 7-1)	**External thread** G (ISO 228-1)	**Flange** ISO 7005-1/2
Fluid temperature	−10...120°C	−10...120°C	−10...120°C
Leakage rate	Air-bubble tight, leakage rate A (EN 12266-1)	Air-bubble tight, leakage rate A (EN 12266-1)	Air-bubble tight, leakage rate A (EN 12266-1)
Flow characteristic	Equal percentage	Equal percentage	Equal percentage
Max. differential pressure	**R2..** Δp_{max}: 350 kPa (200 kPa for low-noise operation)	**R4..** Δp_{max}: 200 kPa	**R6..W..** Δp_{max}: 400 kPa
Permissible operating pressure	p_S: 1600 kPa	p_S: 1600 kPa	p_S: 1600 kPa

Valve design



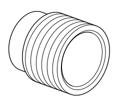
Valve characteristic curve





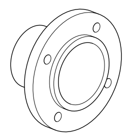
Internal thread

Valve type R2..	DN	K_{vs}	PN
R2015-P25-S1	**15**	0.25	40
R2015-P4-S1	**15**	0.40	40
R2015-P63-S1	**15**	0.63	40
R2015-1-S1	**15**	1.0	40
R2015-1P6-S1	**15**	1.6	40
R2015-2P5-S1	**15**	2.5	40
R2015-4-S1	**15**	4.0	40
R2015-6P3-S1	**15**	6.3	40
R2020-4-S2	**20**	4.0	40
R2020-6P3-S2	**20**	6.3	40
R2020-8P6-S2	**20**	8.6	40
R2025-6P3-S2	**25**	6.3	40
R2025-10-S2	**25**	10	40
R2025-16-S2	**25**	16	40
R2032-16-S3	**32**	16	25
R2040-16-S3	**40**	16	25
R2040-25-S3	**40**	25	25
R2050-25-S4	**50**	25	25
R2050-40-S4	**50**	40	25



External thread

Valve type R4..	DN	K_{vs}	PN
R409	**15**	0.63	40
R410	**15**	1.0	40
R411	**15**	1.6	40
R412	**15**	4.0	40
R413	**15**	6.3	40
R417	**20**	4.0	40
R418	**20**	6.3	40
R419	**20**	8.6	40
R422	**25**	6.3	40
R423	**25**	10	40
R424	**25**	16	40
R431	**32**	16	25
R438	**40**	16	25
R439	**40**	25	25
R448	**50**	25	25
R449	**50**	40	25



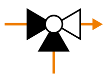
Flange

Valve type R6..W..	DN	K_{vs}	PN
R6065W63-S8	**65**	63	16
R6080W100-S8	**80**	100	16
R6100W160-S8	**100**	160	16
R6125W250-S8	**125**	250	16
R6150W320-S8	**150**	320	16

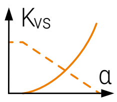
Selection table 3-way characterised control valves DN 15...50

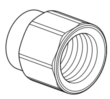
Pipe connection	**Internal thread** Rp (ISO 7-1)	**External thread** G (ISO 228-1)	**Flange** (EN 1092-1/4)
Fluid temperature	−10...120°C	−10...120°C	−10...100°C
Leakage rate	Control path A – AB: air-bubble tight, Leakage rate A (EN 12266-1) / Bypass B – AB: Leakage class I	Control path A – AB: air-bubble tight, Leakage rate A (EN 12266-1) / Bypass B – AB: Leakage class I	Control path A – AB: air-bubble tight, Leakage rate A (EN 12266-1) / Bypass B – AB: Leakage class I
Max. differential pressure	**R3..** Δp_{max}: 350 kPa (200 kPa for low-noise operation)	**R5..** Δp_{max}: 200 kPa	**R7..R** Δp_{max}: 100 kPa
Permissible operating pressure	p_s: 1600 kPa	p_s: 1600 kPa	p_s: 600 kPa

Valve design



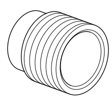
Valve characteristic curve





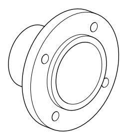
Internal thread

Valve type R3..	DN	K_{vs}	PN
R3015-P25-S1	**15**	0.25	40
R3015-P4-S1	**15**	0.40	40
R3015-P63-S1	**15**	0.63	40
R3015-1-S1	**15**	1.0	40
R3015-1P6-S1	**15**	1.6	40
R3015-2P5-S1	**15**	2.5	40
R3015-4-S1	**15**	4.0	40
R3020-4-S2	**20**	4.0	40
R3020-6P3-S2	**20**	6.3	40
R3025-6P3-S2	**25**	6.3	40
R3025-10-S2	**25**	10	40
R3032-16-S3	**32**	16	25
R3040-16-S3	**40**	16	25
R3040-25-S4	**40**	25	25
R3050-25-S4	**50**	25	25
R3050-40-S4	**50**	40	25
R3050-58-S4	**50**	58	25



External thread

Valve type R5..	DN	K_{vs}	PN
R509	**15**	0.63	40
R510	**15**	1.0	40
R511	**15**	1.6	40
R512	**15**	2.5	40
R513	**15**	4.0	40
R517	**20**	4.0	40
R518	**20**	6.3	40
R522	**25**	6.3	25
R523	**25**	10	25
R531	**32**	16	25
R538	**40**	16	25
R548	**50**	25	25



Flange

Valve type R7..R	DN	K_{vs}	PN
R7015RP63-B1	**15**	0.63	6
R7015R1P6-B1	**15**	1.6	6
R7015R4-B1	**15**	4.0	6
R7020R6P3-B1	**20**	6.3	6
R7025R10-B2	**25**	10	6
R7032R16-B3	**32**	16	6
R7040R16-B3	**40**	16	6
R7050R25-B3	**50**	25	6

Dimensional and selection table 2-way and 3-way open/close ball valves

Internal thread	External thread	Flange	Valve type R2.. / R4.. / R6	Valve type R3.. / R5.. / R7	Valve type R3..	DN	K_{vs}	Δp_{max} [kPa] 0.1	Δp_{max} [kPa] 1.0	Δp_{max} [kPa] 3.0	Δp_{max} [kPa] 10.0
	■		R410DK			10	4.0	0.13	0.40	0.69	1.3
■					R3015-BL1	15	5.5	0.17	0.55	1.0	1.7
	■		R415	R515		15	8.6	0.27	0.86	1.5	2.7
■					R3032-BL2	32	9.0	0.28	0.9	1.6	2.8
■					R3025-BL2	25	10	0.32	1.0	1.7	3.2
■					R3020-BL2	20	11	0.35	1.1	1.9	3.5
	■		R415D			15	12	0.38	1.2	2.1	3.8
■					R3040-BL3	40	14	0.44	1.4	2.4	4.4
■			R2015-S1	R3015-S1		15					
		■	R6015R-B1	R7015R-B1			15	0.47	1.5	2.6	4.7
■					R3032-BL3	32					
	■		R430	R530		32	16	0.51	1.6	2.8	5.1
	■		R420	R520		20	21	0.66	2.1	3.6	6.6
■					R3050-BL3	50	24	0.76	2.4	4.2	7.6
	■		R420D			20	25	0.79	2.5	4.3	7.9
■			R2025-S2	R3025-S2							
	■		R425	R525		25	26	0.82	2.6	4.5	8.2
		■	R6025R-B2	R7025R-B2							
■			R2040-S3	R3040-S3		40	31	1.0	3.1	5.4	9.8
		■	R6040R-B3	R7040R-B3							
■			R2020-S2	R3020-S2		20					
		■	R6020R-B1	R7020R-B1							
■			R2032-S3	R3032-S3			32	1.0	3.2	5.5	10.1
	■		R432	R532		32					
		■	R6032R-B3	R7032R-B3							
	■		R440	R540		40					
■					R3040-BL4	40	47	1.5	4.7	8.1	14.9
■			R2050-S4	R3050-S4							
	■		R450	R550		50	49	1.6	4.9	8.5	15.5
		■	R6050R-B3	R7050R-B3							
■					R3050-BL4	50	75	2.4	7.5	13.0	23.7

Formula K_{vs}

$$V'_{100} = K_{vs}\sqrt{\frac{\Delta p_{v100}}{100}}$$

Δp_{v100} : [kPa]
V'_{100} : [m^3/h]
K_{vs} : [m^3/h]

Definitions

Formula symbols

K_v	The flow coefficient K_v [m^3/h] is the specific flow of a valve with a defined delay angle with reference to 100 kPa (1 bar). The K_v value changes, depending on the valve position. The flow coefficient is determined for a water temperature of 5…40°C.
K_{vs}	The K_v value in reference to the nominal delay angle is referred to as the K_{vs} value. Flow coefficient at 100% valve opening (90° angle of rotation)
p_s	Permissible operating pressure kPa
V'_{100}	Nominal flow rate with Vp_{v100}
ΔT	Temperature difference between supply and return
Δp_{v0}	Maximum permissible differential pressure for long service life with closed ball valve
Δp_{v100}	Differential pressure across the completely opened valve at V'_{100}
Δp_{max}	Maximum permissible differential pressure across control path A – AB, with reference to the whole opening range
Δp_s	Close-off pressure: The specified tightness of the valve is ensured up to this value.
P_v	Valve authority: the benchmark for the control characteristics of the valve in combination with the hydronic network. The valve authority is the relation at nominal load between the differential pressure of the fully open valve (Δp_{v100}) at nominal flow and the total pressure drop in the variable-flow path or of the completely closed valve.

Further documentation

– Notes for project planning – general notes
– Technical data sheets
– Installation instructions
– Brochure – 8 reasons to use a characterised control valve
– Brochure – Energy efficiency and comfort in buildings

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Belimo as a global market leader develops innovative solutions for the controlling of heating, ventilation and air-conditioning systems. Damper actuators, control valves, sensors and meters represent our core business.

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