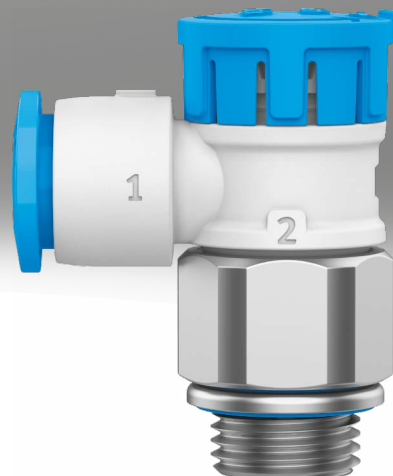


One-way flow control valves VFOE

FESTO



Festo Core Range
Solves the majority of your automation tasks

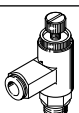
Worldwide:
Simply good:
Fast:

Quickest delivery – wherever, whenever
Expected high Festo quality
Easy and fast to select

With the Festo Core Range, we have selected the most important products and functions from our broad product catalogue, and added the quickest delivery.
The Core Range offers you the best value for your automation tasks.

Just look
for the
star!

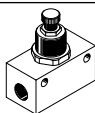
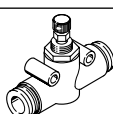
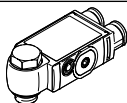
Product range overview – One-way flow control valves

Design	Valve function	Design	Type	Outlet direction of connection	Pneumatic connection 1	Pneumatic connection 2	q _N ¹⁾ [l/min]	Adjusting element	→ Page/ Internet
Standard	Polymer								
	Exhaust air one-way flow control function		VFOE-LE	L-Abgang	QS-4, QS-6, QS-8, QS-10, QS-12	M5, G1/8, G1/4, G3/8, G1/2, R1/8, R1/4, R3/8, R1/2	90 ... 1200	Rotary knob with detent	6
			GRLA	L-Abgang	QS-6, QS-8	G1/8, G1/4, G3/8	520 ... 650	Knurled screw	grla
	Supply air one-way flow control function		VFOE-LS	L-Abgang	QS-4, QS-6, QS-8	M5, M7, G1/8, R1/8	90 ... 180	Rotary knob with detent	6
	Metal								
	Exhaust air one-way flow control function		GRLA	Elbow outlet	QS-3, QS-4, QS-6, QS-8, QS-10, QS-12	M5, G1/8, G1/4, G3/8, G1/2	100 ... 1580	Slotted head screw	grla
								Knurled screw	
								Slotted head screw	grla
								Knurled screw	grla
	Supply air one-way flow control function		GRLSA	Elbow outlet	QS-6, QS-8	G1/8, G1/4	0 ... 450	Rotary knob with scale, internal hexagon	grlsa
			GRLZ	Elbow outlet	QS-3, QS-4, QS-6, QS-8	M5, G1/8	100 ... 215	Slotted head screw	grlz
								Slotted head screw	
								Knurled screw	grlz
			VFOC-S	Elbow outlet	QS-4, QS-6	Push-in sleeve ²⁾ QS-4, QS-6	0 ... 270	Slotted head screw	vfoc
	Nickel-plated metal								
	Exhaust air one-way flow control function		VFOH-LE	Elbow outlet	QS-4, QS-6, QS-8, QS-10	G1/8, G1/4	180 ... 530	External hex	vfoh

1) Standard nominal flow rate in flow control direction.

2) Only suitable for push-in connector QS.

Product range overview – One-way flow control valves

Design	Valve function	Design	Type	Outlet direction of connection	Pneumatic connection 1	Pneumatic connection 2	q _N ¹⁾ [l/min]	Adjusting element	→ Page/ Internet
Mini	Metal								
	Exhaust air one-way flow control function		GRLA	Elbow outlet	QS-3, QS-4	M3, M5	40 ... 41	Slotted head screw	grla
					M3	M3	0 ... 18	Slotted head screw	grla
	Supply air one-way flow control function		GRLZ	Elbow outlet	QS-3, QS-4	M3, M5	41 ... 48	Slotted head screw	grlz
					M3	M3	0 ... 18	Slotted head screw	grlz
In-line installation	Metal								
	One-way flow control function		GR/GRA	Straight	M3, M5, G1/8, G1/4, G3/8, G1/2, G3/4	M3, M5, G1/8, G1/4, G3/8, G1/2, G3/4	29.5 ... 3300	Knurled screw	gr
	Polymer								
	One-way flow control function		GR	Straight	QS-3, QS-4, QS-6, QS-8	QS-3, QS-4, QS-6, QS-8	85 ... 265	Knurled screw	gr
Corrosion-resistant	Stainless steel								
	Exhaust air one-way flow control function		CRGRLA	Elbow outlet	M5, G1/8, G1/4, G3/8, G1/2	M5, G1/8, G1/4, G3/8, G1/2	95 ... 2100	Slotted head screw	crgrla
Function combination	Polymer								
	Exhaust air one-way flow control function		VFOF	Elbow outlet	QS-6, QS-8	G1/8, G1/4	240 ... 590	Internal hex	vfof

1) Standard nominal flow rate in flow control direction.

Key features

Which fitting fits which thread?

Metric thread

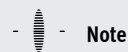
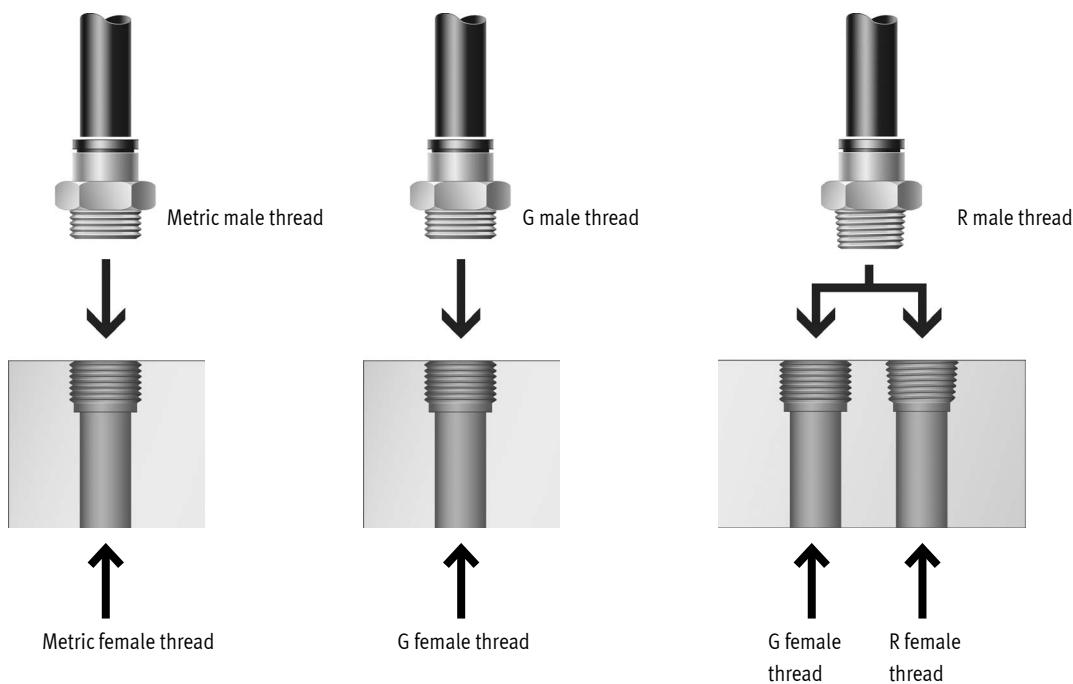
- Threads are comparable with G threads and are fitted as cylindrical metric thread
- The seal is guaranteed by a replaceable sealing ring.

G thread to ISO 228-1

- Shorter thread
- Consistent installation depth
- Replaceable sealing ring
- Sealing on the front
- Can be re-used a number of times thanks to replaceable sealing ring.

R thread to EN 10226-1 and ISO 7/1

- Self-sealing thread
- Sealing via coated threads
- No additional sealing surface required
- Smaller installation dimensions since there is no need for an offset for the sealing surface
- Can be reused up to 5 times
- Remove loose sealant remnants.



Note

Contact between the assembly tool and the housing should be avoided during assembly.



Note

When re-installing the one-way flow control valves with R thread, we recommend additionally using sealing band.

For manufacturing lithium-ion batteries (F1A)

Recommended for production facilities for manufacturing lithium-ion batteries.

Metals with copper, zinc or nickel as the main constituent are excluded from use.

Exceptions are nickel in steels, chemically nickel-plated surfaces, printed circuit boards, cables, electrical plug connectors and coils.



Note

Foreign objects may adhere to the product or arise during installation. Depending on the application, it may be necessary to blow out the product with clean compressed air, clean it after installation and operate it with ducted exhaust air.

Key features

For manufacturing lithium-ion batteries (F1A)

Recommended for production facilities for manufacturing lithium-ion batteries.

Metals with copper, zinc or nickel as the main constituent are excluded from use.

Exceptions are nickel in steels, chemically nickel-plated surfaces, printed circuit boards, cables, electrical plug connectors and coils.



Hinweis

Foreign particles may adhere to the product or arise during installation. Depending on the application, it may be necessary to blow out the product with clean compressed air, clean it after installation and operate it with ducted exhaust air.

Type codes

001	Series	
VFOE	One-way flow control valve	

002	Design	
L	L-shape	

003	Function	
E	One-way flow control valve for exhaust air	
S	One-way flow control valve for supply air	

004	Adjusting component	
T	Rotary knob with detent	

005	Pneumatic connection 2	
M5	M5	
M7	M7	
G18	G1/8	
G14	G1/4	
G38	G3/8	
G12	G1/2	
R18	R1/8	
R14	R1/4	
R38	R3/8	
R12	R1/2	

006	Pneumatic connection 1	
Q4	Push-in connector 4 mm	
Q6	Push-in connector 6 mm	
Q8	Push-in connector 8 mm	
Q10	Push-in connector 10 mm	
Q12	Push-in connector 12 mm	

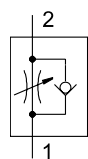
007	Special material properties	
	None	
F1A	Recommended for production facilities for the manufacture of lithium-ion batteries	

008	Package unit	
	Standard	
P20	20	
P50	50	

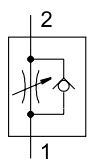
Technical data

One-way flow control function

Exhaust air



Supply air



- Flow rate
82 ... 1300 l/min
- Temperature range
-10 ... +60°C
- Operating pressure
0.02 ... 1 MPa



General technical data – VFOE-LE

General technical data – WSE LL									
Pneumatischer Anschluss 2	M5	G1/8	G1/4	G3/8	G1/2	R1/8	R1/4	R3/8	R1/2
Valve function	Exhaust air one-way flow control function								
Pneumatic connection 1	QS-4 QS-6	QS-4 QS-6 QS-8	QS-6 QS-8 QS-10	QS-8 QS-10	QS-12	QS-4 QS-6 QS-8	QS-6 QS-8 QS-10	QS-8 QS-10	QS-12
Actuation type	Manual								
Mounting position	Any								
Adjusting element	Rotary knob with detent, colour: blue								
Type of mounting	Screw-in								
Suitability for re-installation	max.	–				5			
Rotatability	Can be rotated 360° around the screw-in axis after mounting / not permitted for continuous rotation								
Nominal tightening torque	[Nm]	2 ±20%	5 ±20%	10 ±20%	13 ±20%	23 ±20%	Hand-tight + 1 to 2 revolutions		
Max. tightening torque	[Nm]	2,4	6	12	15,6	27,6	–		

General technical data – VFOE-LS

General technical data – WSE-L5					
Pneumatic connection 2		M5	M7	G1/8	R1/8
Valve function		Supply air one-way flow control function			
Pneumatic connection 1		QS-4, QS-6	QS-4, QS-6	QS-4, QS-6, QS-8	QS-4, QS-6, QS-8
Actuation type		Manual			
Mounting position		Any			
Adjusting element		Rotary knob with detent, colour: light blue			
Type of mounting		Screw-in			
Suitability for re-installation		max. –			5
Rotatability		Can be rotated 360° around the screw-in axis after mounting / not permitted for continuous rotation			
Nominal tightening torque		[Nm]	2 ±20%	3 ±20%	5 ±20%
Max. tightening torque		[Nm]	2.4	3.6	6
					Hand-tight + 1 to 2 revolutions
					–

Technical data

Operating and environmental conditions		
Material threaded bolt	Galvanised steel	Steel, chemically nickel-plated ¹⁾
Operating pressure for complete temperature range	[MPa]	0,02 ... 1
	[bar]	0,2 ... 10
	[psi]	2,9 ... 145
Operating medium	Compressed air to ISO 8573-1:2010 [7:4:4]	
PWIS conformity	VDMA24364 zone III	
Suitability for production of lithium-ion batteries	–	Metals with copper, zinc or nickel as the main constituent are excluded from use. Exceptions are nickel in steels, chemically nickel-plated surfaces, printed circuit boards, cables, electrical plug connectors and coils.
Cleanroom standard	–	Class 4 (ISO 14644-1)
Note on the operating/pilot medium	Lubricated operation possible (in which case lubricated operation will always be required)	
Ambient temperature	[°C]	–10 ... +60
Temperature of medium	[°C]	–10 ... +60
Corrosion resistance class CRC	1 - Low corrosion stress ²⁾	0 - No corrosion stress ³⁾

1) Steel, chemically nickel-plated: suitable for battery production (VFOE-...-F1A)

2) Corrosion resistance class CRC 1 to Festo standard FN 940070

Low corrosion stress. Dry indoor application or transport and storage protection. Also applies to parts behind coverings, in the non-visible interior area, and parts which are covered in the application (e.g. drive trunnions).

3) Corrosion resistance class CRC 0 to Festo standard FN 940070

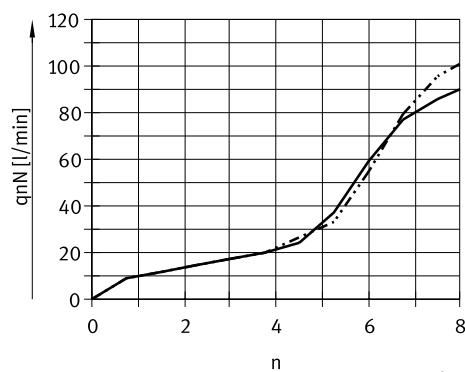
No corrosion stress. Gold-plated for small standard parts that are not visually relevant, such as set screws, circlips, clamping sleeves, etc., which are usually only available on the market in a phosphated or burnished version (if necessary oiled), as well as for ball bearings (for components < KBK3) and plain bearings.

Materials	
Housing	PBT
Cover, releasing ring	PBT
Threaded bolt	Galvanised steel
Static seals	NBR
Dynamic seals	HNBR
Note on materials	RoHS compliant

Technical data

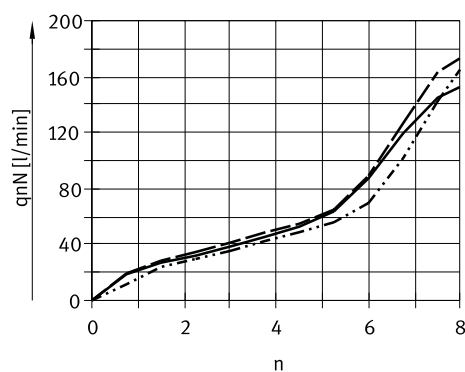
Standard nominal flow rate q_{nN} at 0.6 → 0.5 MPa as a function of spindle rotations n

Threaded connection M5 (exhaust)



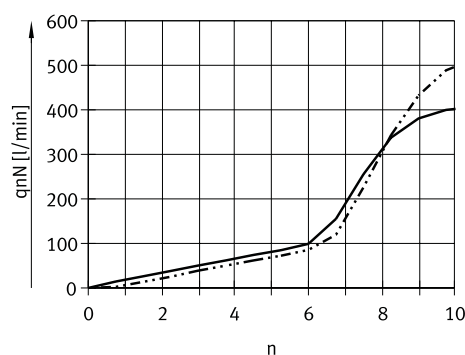
— Push-in connector 4 mm
 Push-in connector 6 mm

Threaded connection G1/8, R1/8 (exhaust)



— Push-in connector 4 mm
 Push-in connector 6 mm

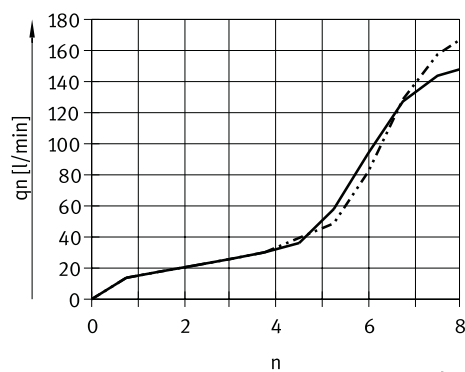
Threaded connection G1/4, R1/4 (exhaust)



— Push-in connector 6 mm
 Push-in connector 8 mm / 10 mm

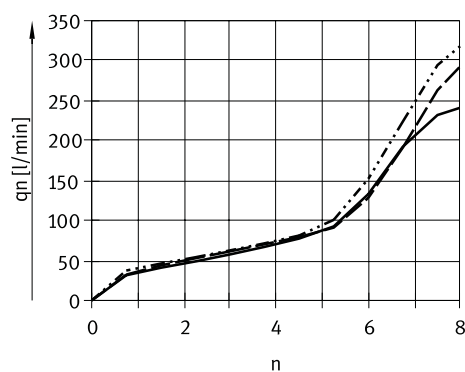
Standard flow rate q_n at 0.6 → 0 MPa as a function of spindle rotations n

Threaded connection M5 (exhaust)



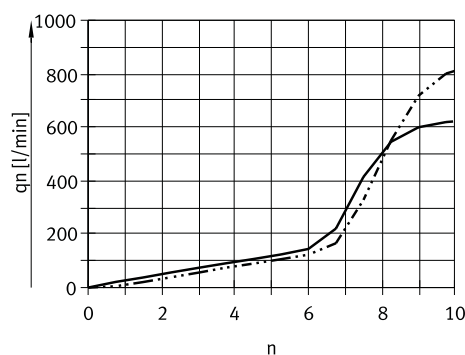
— Push-in connector 4 mm
 Push-in connector 6 mm

Threaded connection G1/8, R1/8 (exhaust)



— Push-in connector 4 mm
 Push-in connector 6 mm

Threaded connection G1/4, R1/4 (exhaust)

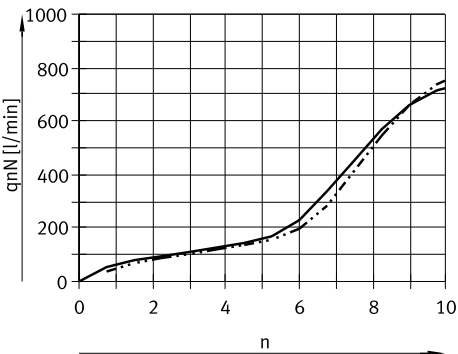


— Push-in connector 6 mm
 Push-in connector 8 mm / 10 mm

Technical data

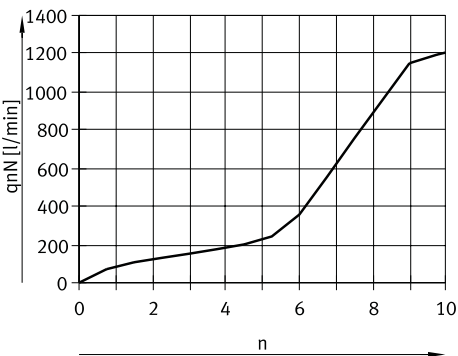
Standard nominal flow rate q_{nN} at 0.6 → 0.5 MPa as a function of spindle rotations n

Threaded connection G3/8, R3/8 (exhaust)



— Push-in connector 8 mm
- - - Push-in connector 10 mm

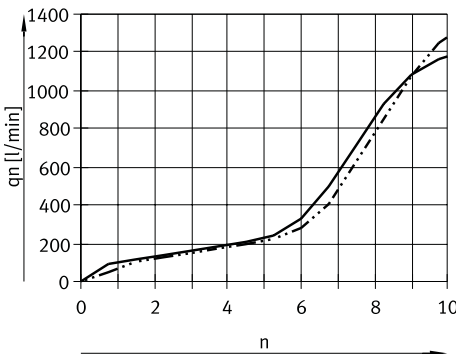
Threaded connection G1/2, R1/2 (exhaust)



— Push-in connector 12 mm

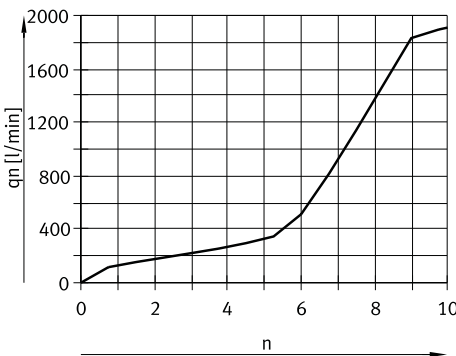
Standard flow rate q_n at 0.6 → 0 MPa as a function of spindle rotations n

Threaded connection G3/8, R3/8 (exhaust)



— Push-in connector 8 mm
- - - Push-in connector 10 mm

Threaded connection G1/2, R1/2 (exhaust)

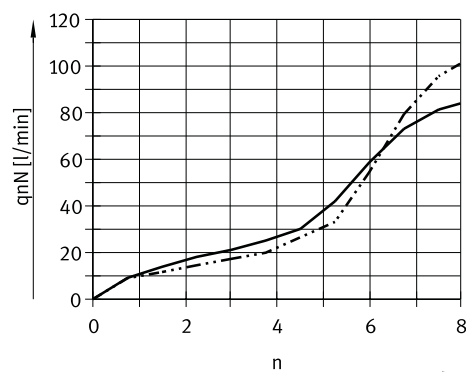


— Push-in connector 12 mm

Technical data

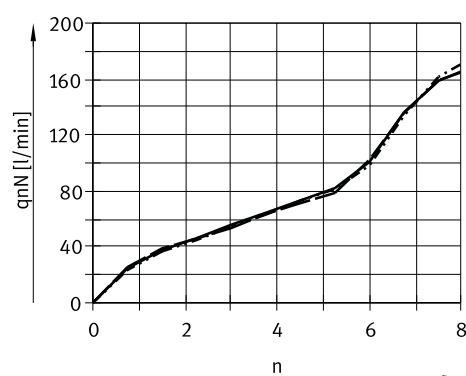
Standard nominal flow rate q_{nN} at 0.6 → 0.5 MPa as a function of spindle rotations n

Threaded connection M5, M7 (supply air)



— Push-in connector 4 mm
 - - - Push-in connector 6 mm

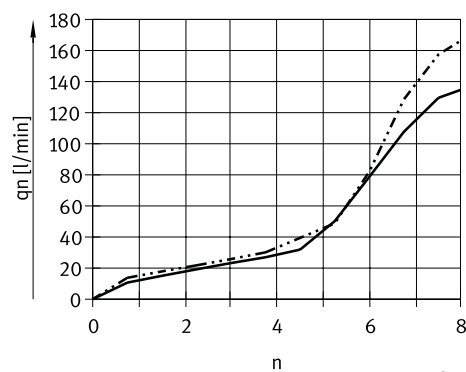
Threaded connection G1/8, R1/8 (supply air)



— Push-in connector 4 mm
 - - - Push-in connector 6 mm
 - · - Push-in connector 8 mm

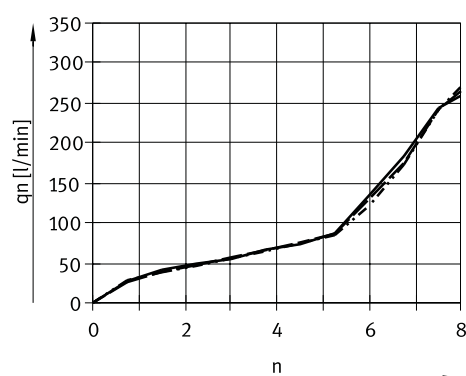
Standard flow rate q_n at 0.6 → 0 MPa as a function of spindle rotations n

Threaded connection M5, M7 (supply air)



— Push-in connector 4 mm
 - - - Push-in connector 6 mm

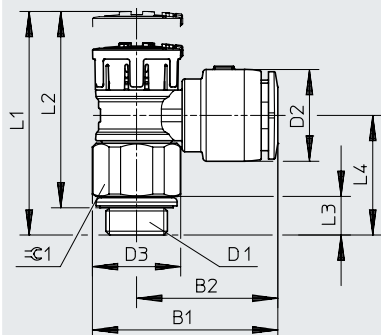
Threaded connection G1/8, R1/8 (supply air)



— Push-in connector 4 mm
 - - - Push-in connector 6 mm
 - · - Push-in connector 8 mm

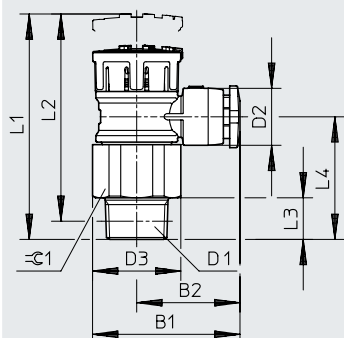
Technical data

Dimensions VFOE-...-M../G..

Download CAD data → www.festo.com

Type	B1	B2	D1	D2 ø	D3 ø	L1		L2		L3	L4	1/16
						Unlocked	Locked	Unlocked (max.)	Locked			
VFOE-...-M5-Q4	19,6	14,6	M5	9	10	27,6	26,6	25	24	4,1	13,9	9
VFOE-...-M5-Q6	22,6	17,6	M5	11	10	27,6	26,6	25	24	4,1	13,9	9
VFOE-...-M7-Q4	19,6	14,6	M7	9	10	29,5	28,5	25	24	6	15,8	9
VFOE-...-M7-Q6	22,6	17,6	M7	11	10	29,5	28,5	25	24	6	15,8	9
VFOE-...-G18-Q4	23,3	16,3	G1/8	9	14	31,7	30,3	27,4	26	6,1	18,9	13
VFOE-...-G18-Q6	24,4	17,4	G1/8	11	14	31,7	30,3	27,4	26	6,1	18,9	13
VFOE-...-G18-Q8	29,3	22,3	G1/8	14,5	14	31,7	30,3	27,4	26	6,1	18,9	13
VFOE-...-G14-Q6	28,3	19,3	G1/4	11	17,9	38,6	36,7	33,9	32	7	22	16
VFOE-...-G14-Q8	30	21	G1/4	14,5	17,9	38,6	36,7	33,9	32	7	22	16
VFOE-...-G14-Q10	35,1	26,2	G1/4	16,5	17,9	38,6	36,7	33,9	32	7	22	16
VFOE-...-G38-Q8	34,5	23,3	G3/8	14,5	22,4	44,1	41,9	38,2	36	8,5	26,2	21
VFOE-...-G38-Q10	39,6	28,4	G3/8	17,5	22,4	44,1	41,9	38,2	36	8,5	26,2	21
VFOE-...-G12-Q12	46,8	33,3	G1/2	20,8	27	53,7	50,8	46,8	43,9	9,5	31	24

Dimensions VFOE-...-R..

Download CAD data → www.festo.com

Type	B1	B2	D1	D2 ø	D3 ø	L1		L2		L3	L4	1/16
						Unlocked	Locked	Unlocked (max.)	Locked			
VFOE-...-R18-Q4	23,3	16,3	R1/8	9	14	32,2	30,8	29,2	27,8	6,6	19,4	13
VFOE-...-R18-Q6	24,4	17,4	R1/8	11	14	32,2	30,8	29,2	27,8	6,6	19,4	13
VFOE-...-R18-Q8	29,3	22,3	R1/8	14,5	14	32,2	30,8	29,2	27,8	6,6	19,4	13
VFOE-...-R14-Q6	28,3	19,3	R1/4	11	17,9	41,2	39,3	36,7	34,8	10,1	25,1	16
VFOE-...-R14-Q8	30	21	R1/4	14,5	17,9	41,2	39,3	36,7	34,8	10,1	25,1	16
VFOE-...-R14-Q10	35,1	26,2	R1/4	17,5	17,9	41,2	39,3	36,7	34,8	10,1	25,1	16
VFOE-...-R38-Q8	34,5	23,3	R3/8	14,5	22,4	45,2	43	40,7	38,5	10,1	27,8	21
VFOE-...-R38-Q10	39,6	28,4	R3/8	17,5	22,4	45,2	43	40,7	38,8	10,1	27,8	21
VFOE-...-R12-Q12	46,8	33,3	R1/2	20,8	27	55,8	52,9	50,8	47,9	12,1	33,6	24

Technical data

★ Core Range

Ordering data									
Pneumatic connection		Standard nominal flow rate qnN At 0.6 MPa → 0.5 MPa		Standard flow rate qn At 0.6 MPa → 0 MPa		Weight	Part No.	Type	PU ¹⁾
		In flow control direction	In non-return direction	In flow control direction	In non-return direction				
2	1	[l/min]	[l/min]	[l/min]	[l/min]	[g]			
Exhaust air one-way flow control function									
M5	QS-4	90	50 ... 90	150	130 ... 160	3,3	8068723	VFOE-LE-T-M5-Q4	1
							8095432	VFOE-LE-T-M5-Q4-P50	50
	QS-6	105	60 ... 105	160	150 ... 180		8068724	VFOE-LE-T-M5-Q6	1
G1/8	QS-4	150	90 ... 150	250	240 ... 300	9,5	★ 8068725	VFOE-LE-T-G18-Q4	1
	QS-6	165	110 ... 200	280	300 ... 360		★ 8068726	VFOE-LE-T-G18-Q6	1
							8095433	VFOE-LE-T-G18-Q6-P50	50
G1/4	QS-8	170	130 ... 200	320	320 ... 390	16	★ 8068727	VFOE-LE-T-G18-Q8	1
	QS-6	400	350 ... 450	610	700 ... 800		8068728	VFOE-LE-T-G14-Q6	1
	QS-8	500	370 ... 500	810	750 ... 900		8068729	VFOE-LE-T-G14-Q8	1
G3/8						29,5	8095434	VFOE-LE-T-G14-Q8-P50	50
	QS-10	500	370 ... 500	810	750 ... 900		8068730	VFOE-LE-T-G14-Q10	1
	QS-8	720	600 ... 900	1150	1300 ... 1500		8068731	VFOE-LE-T-G38-Q8	1
G1/2	QS-10	750	700 ... 1000	1280	1400 ... 1600	49,5	8068732	VFOE-LE-T-G38-Q10	1
							8095435	VFOE-LE-T-G38-Q10-P20	20
	QS-12	1200	600 ... 1200	1900	1400 ... 2000		8068733	VFOE-LE-T-G12-Q12	1
R1/8						9,5	8095436	VFOE-LE-T-G12-Q12-P20	20
	QS-4	150	90 ... 150	250	240 ... 300		★ 8068734	VFOE-LE-T-R18-Q4	1
	QS-6	165	110 ... 200	280	300 ... 360		★ 8068735	VFOE-LE-T-R18-Q6	1
R1/4	QS-8	170	130 ... 200	320	320 ... 390	16	★ 8068736	VFOE-LE-T-R18-Q8	1
	QS-6	400	350 ... 450	610	700 ... 800		8068737	VFOE-LE-T-R14-Q6	1
	QS-8	500	370 ... 500	810	750 ... 900		8068738	VFOE-LE-T-R14-Q8	1
R3/8	QS-10	500	370 ... 500	810	750 ... 900	29,5	8068739	VFOE-LE-T-R14-Q10	1
	QS-8	720	600 ... 900	1150	1300 ... 1500		8068740	VFOE-LE-T-R38-Q8	1
	QS-10	750	700 ... 1000	1280	1400 ... 1600		8068741	VFOE-LE-T-R38-Q10	1
R1/2	QS-12	1200	600 ... 1200	1900	1400 ... 2000	49,5	8068742	VFOE-LE-T-R12-Q12	1
Supply air one-way flow control function									
M5	QS-4	85	50 ... 90	150	130 ... 160	3,3	8068743	VFOE-LS-T-M5-Q4	1
	QS-6	100	60 ... 100	160	150 ... 180		8068744	VFOE-LS-T-M5-Q6	1
M7	QS-4	85	50 ... 90	150	130 ... 160	4	8068745	VFOE-LS-T-M7-Q4	1
	QS-6	100	60 ... 100	160	150 ... 180		8068746	VFOE-LS-T-M7-Q6	1
G1/8	QS-4	165	90 ... 165	260	240 ... 300	9,5	★ 8068747	VFOE-LS-T-G18-Q4	1
	QS-6	170	110 ... 200	270	300 ... 360		★ 8068748	VFOE-LS-T-G18-Q6	1
	QS-8	170	130 ... 200	270	320 ... 390		★ 8068749	VFOE-LS-T-G18-Q8	1
R1/8	QS-4	165	90 ... 165	260	240 ... 300	9,5	★ 8068750	VFOE-LS-T-R18-Q4	1
	QS-6	170	110 ... 200	270	300 ... 360		★ 8068751	VFOE-LS-T-R18-Q6	1
	QS-8	170	130 ... 200	270	320 ... 390		★ 8068752	VFOE-LS-T-R18-Q8	1

1) Packaging unit

Technical data

★ Core Range

Ordering data - Products for battery production										
Pneumatic connection		Standard nominal flow rate q _N At 0.6 MPa → 0.5 MPa		Standard flow rate q _N At 0.6 MPa → 0 MPa		Weight [g]	Part No.	Type		PU ¹⁾
		In flow control direction [l/min]	In non-return direction [l/min]	In flow control direction [l/min]	In non-return direction [l/min]					
2	1									
Exhaust air one-way flow control function										
M5	QS-4	90	50 ... 90	150	130 ... 160	3,3	8157642	VFOE-LE-T-M5-Q4-F1A ²⁾		1
	QS-6	105	60 ... 105	160	150 ... 180		8157641	VFOE-LE-T-M5-Q6-F1A ²⁾		1
R1/8	QS-4	150	90 ... 150	250	240 ... 300	9,5	8157640	VFOE-LE-T-R18-Q4-F1A ²⁾		1
	QS-6	165	110 ... 200	280	300 ... 360		8157639	VFOE-LE-T-R18-Q6-F1A ²⁾		1
	QS-8	170	130 ... 200	320	320 ... 390		8157638	VFOE-LE-T-R18-Q8-F1A ²⁾		1
R1/4	QS-6	400	350 ... 450	610	700 ... 800	16	8157637	VFOE-LE-T-R14-Q6-F1A ²⁾		1
	QS-8	500	370 ... 500	810	750 ... 900		8157636	VFOE-LE-T-R14-Q8-F1A ²⁾		1
	QS-10	500	370 ... 500	810	750 ... 900		8157635	VFOE-LE-T-R14-Q10-F1A ²⁾		1
R3/8	QS-8	720	600 ... 900	1150	1300 ... 1500	29,5	8157634	VFOE-LE-T-R38-Q8-F1A ²⁾		1
	QS-10	750	700 ... 1000	1280	1400 ... 1600		8157633	VFOE-LE-T-R38-Q10-F1A ²⁾		1
R1/2	QS-12	1200	600 ... 1200	1900	1400 ... 2000	49,5	8157631	VFOE-LE-T-R12-Q12-F1A ²⁾		1
Supply air one-way flow control function										
M5	QS-4	85	50 ... 90	150	130 ... 160	3,3	8157630	VFOE-LS-T-M5-Q4-F1A ²⁾		1
	QS-6	100	60 ... 100	160	150 ... 180		8157629	VFOE-LS-T-M5-Q6-F1A ²⁾		1
R1/8	QS-4	165	90 ... 165	260	240 ... 300	9,5	8157628	VFOE-LS-T-R18-Q4-F1A ²⁾		1
	QS-6	170	110 ... 200	270	300 ... 360		8157627	VFOE-LS-T-R18-Q6-F1A ²⁾		1
	QS-8	170	130 ... 200	270	320 ... 390		8157626	VFOE-LS-T-R18-Q8-F1A ²⁾		1

1) Packaging unit

2) Recommended for production facilities for manufacturing lithium-ion batteries