LOW-ΔP-FLOW

Mass Flow Meters/Controllers for low pressure drop or corrosive gas service

Bronkhorst®

Introduction

Bronkhorst High-Tech B.V., the European market leader in thermal Mass Flow Meters/Controllers and Electronic Pressure Controllers, has more than 40 years experience in designing and manufacturing precise and reliable measurement and control devices. With a wide range of instruments, Bronkhorst offers innovative solutions for many different applications in many different markets.

The instruments are made to customers' specification, in various styles, suitable for use in laboratory, industrial and hazardous areas, in such diverse applications as semiconductor and analytical installations, to name but two.

LOW-ΔP-FLOW series for low pressure drop or corrosive gases

In a number of applications for measuring and controlling gas flows there is only little differential pressure available and/or allowable. These are the applications for which Bronkhorst developed the LOW-ΔP-FLOW series, in which the flow resistance is minimised by using a large bore capillary (thermal bypass sensor) in combination with a cylindrical flow splitter (laminar flow element). Based on this concept, mass flow capacities between 0…10 ml_n/min and 0…1000 m^3_n/h can be measured. At a flow up to 2 l_n/min a pressure drop of less than 1 mbar is required.

Furthermore the larger flow channels minimise the risk of clogging and facilitate the cleaning and purging of these LOW-ΔP-FLOW instruments, which will contribute to a significantly longer lifetime when the instruments are used on corrosive gas service. All fluid wetted parts are of stainless steel with high surface quality. Optionally the flow meter body, sensor and flow element can be supplied in Hastelloy or Monel.

For laboratory or industrial conditions

The LOW-ΔP-FLOW series are derived from the laboratory style EL-FLOW series, however they can also be supplied with a rugged IP65 (dust and waterproof) IN-FLOW housing, suitable for industrial environments. The latter are also ATEX Category 3, approved for use in Zone 2 hazardous areas.

In addition to the standard analog I/O-signals and the RS232 connection, there is the possibility of integrating an interface board with DeviceNet™, CANopen®, PROFIBUS®DP, Modbus RTU/ASCII, FLOW-BUS, EtherCAT®, PROFINET, Modbus-TCP, EtherNet/IP or POWERLINK protocol.

Mass flow control with low differential pressure

The control of mass flow with small pressure difference comprises the LOW-ΔP-FLOW Mass Flow Controllers in compact construction (model series F-200/201/202).The integrated proportional, electromagnetic control valves of these MFC's have extremely fast and smooth control characteristics. Depending on the operating properties, the maximum flow in these models is 1…50 l_n/min air-equivalent.

For the control of higher flow rates at very low differential pressures Bronkhorst High-Tech have devised special control valves with pressure compensation bellows (series F-004). These control valves are close-coupled to the flow meter while the electric PI-control function is an integral part of the flow meter. This F-004 valve has proven to be an excellent alternative to large, slow and expensive servo driven valves.

LOW-ΔP-FLOW features

- very low pressure drop
- suitable for corrosive gases
- larger flow channels to minimize risk of clogging and to facilitate cleaning and purging
- also available with IP65 housing, ATEX approval Cat.3, Zone 2
- alarm and counter functions
- Fieldbus interfaces:
  - DeviceNet™, CANopen®
  - PROFIBUS DP, Modbus RTU/ASCII, FLOW-BUS
  - EtherCAT®, PROFINET, Modbus-TCP, EtherNet/IP, POWERLINK

Models F-004BI and F-004AC bellows operated control valves

Technical specifications

Measurement / control system

Accuracy (incl. linearity) (based on actual calibration)	± 1% FS (of Full Scale)
Turndown	1 : 50 (2…100%)
Repeatability	< 0,2% Rd (of Reading)
Settling time (controller)	standard: 2…3 seconds
Control stability	< ±0,1% FS (typical for 1 l_n/min N_2)
Operating temperature	-10…+70°C for ATEX Cat. 3 0… 50°C
Max. operating pressure	10 bar
Temperature sensitivity	0,1% FS/°C
Pressure sensitivity	0,1% Rd/bar typical N_2
Leak integrity	tested < 2 x 10^{-9} mbar l/s He
Mounting position	horizontal
Warm-up time	30 min. for optimum accuracy; 2 min for accuracy ± 2% FS

Mechanical parts

Material (wetted parts)	stainless steel, other on request
Process connections	compression type or face seal couplings; wafer type on series F-106; DIN or ANSI flanges on series F-107
Seals	standard: Viton® options: EPDM, Kalrez® (FFKM)
Ingress protection (housing)	IP40 or IP65

Electrical properties

Power supply	+15…24 Vdc		
Max. power consumption	Supply	at voltage I/O	at current I/O
Meter	15 V	95 mA	125 mA
	24 V	65 mA	85 mA
Controller	15 V	290 mA	320 mA
	24 V	200 mA	215 mA
Extra for fieldbus (if applicable)	15 V < 75 mA 24 V < 50 mA		
Analog output/command	0…5 (10) Vdc or 0 (4)…20 mA (sourcing output)		
Digital communication	standard: RS232 options: DeviceNet™, CANopen®, PROFIBUS®DP, Modbus RTU/ASCII, FLOW-BUS, EtherCAT®, PROFINET, Modbus-TCP, EtherNet/IP, POWERLINK		

Electrical connection IP40 configuration

Analog, RS232	9-pin D-connector (male)
PROFIBUS®DP	bus: 9-pin D-connector (female) power: 9-pin D-connector (male)
DeviceNet™, CANopen®	5-pin M12-connector (male)
FLOW-BUS, Modbus-RTU/ASCII	RJ45 modular jack
Modbus-TCP, EtherNet/IP, POWERLINK	2 x RJ45 modular jack (in/out)
EtherCAT®, PROFINET	2 x RJ45 modular jack (in/out)

Electrical connection IP65 configuration

Analog, RS232	8 DIN (male);
PROFIBUS®DP	bus: 5-pin M12 (female); power: 8 DIN (male)
Modbus-TCP, EtherNet/IP, POWERLINK, EtherCAT®, PROFINET	bus: 2 x 5-pin M12 (female) (in/out); power: 8 DIN (male)
DeviceNet™, CANopen®	5-pin M12 (male)
Modbus-RTU/ASCII, FLOW-BUS	5-pin M12 (male)

Technical specifications subject to change without notice.

Models and flow ranges (based on Air)

Mass Flow Meters (MFM)

Model	min. flow	max. flow
F-100D/F-100DI	0,2…10 ml_n/min	0,44…22 ml_n/min
F-101D/F-101DI	0,42…21 ml_n/min	0,042…2,1 l_n/min
F-101E/F-101EI	0,028…1,4 l_n/min	0,24…12 l_n/min
F-102D/F-102DI	0,28…14 l_n/min	0,5…25 l_n/min
F-102E/F-102EI	0,17…8,5 l_n/min	1…50 l_n/min
F-103E/F-103EI	0,9…45 l_n/min	4…200 l_n/min
F-106xD/F-106xD	0,2…10 m^3_n/h	20…1000 m^3_n/h

Mass Flow Controllers (MFC)

Model	min. flow	max. flow
F-200DV/F-200DI [1]	0,2…10 ml_n/min	0,44…22 ml_n/min
F-201DV/F-201DI [1]	0,42…21 ml_n/min	0,042…2,1 l_n/min
F-201EV/F-201EI [1]	0,028…1,4 l_n/min	0,24…12 l_n/min
F-202D/F-202DI	0,28…14 l_n/min	0,5…25 l_n/min
F-202EV/F-202EI [1]	0,17…8,5 l_n/min	1…50 l_n/min

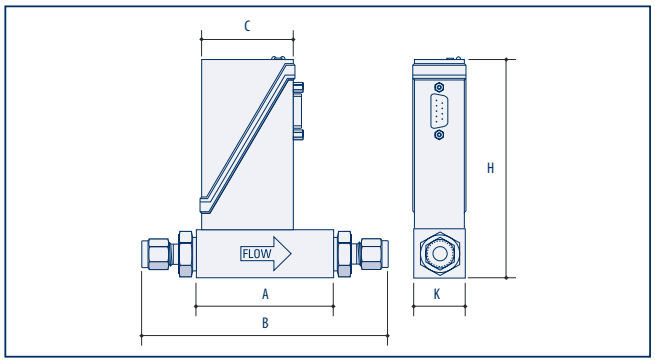
[1] *Kv-max = 6,6 x 10^{-2}*

Control Valve series F-004

	F-004AC/F-004AI	F-004BI
Kv-value	0,3	1,0
Max. operating press ure	10 bara	10 bara
Min. ΔP (approx.)	1 mbard	1 mbard
Max. ΔP	5 bard	5 bard
Max. power (at 15 Vdc)	3,5 Watt	3,5 Watt
Protection class	F-004AC: IP40 F-004AI: IP65	IP65

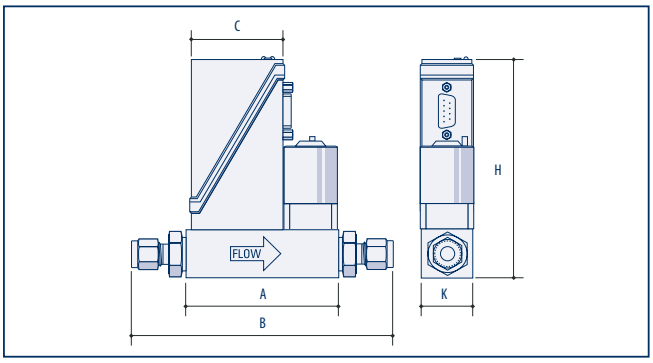
LOW-ΔP-FLOW F-202EI Mass Flow Controller, IP65 configuration

Dimensions (in mm) and weights (in kg)



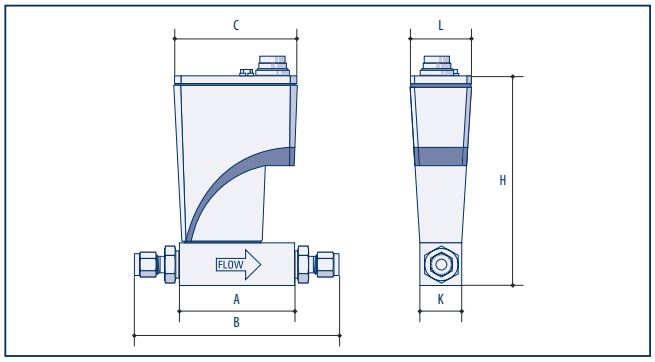
IP40 Mass Flow Meter

Model	A	B	C	H	K	Weight (kg)
F-100D (⅛" OD)	47	98	47	111	25	0,4
F-101D/F-101E (¼" OD)	69	126	47	111	25	0,5
F-102D/F-102E (½" OD)	69	134	47	123	26	0,6
F-103E (½" OD)	110	77	47	168	89	4,0



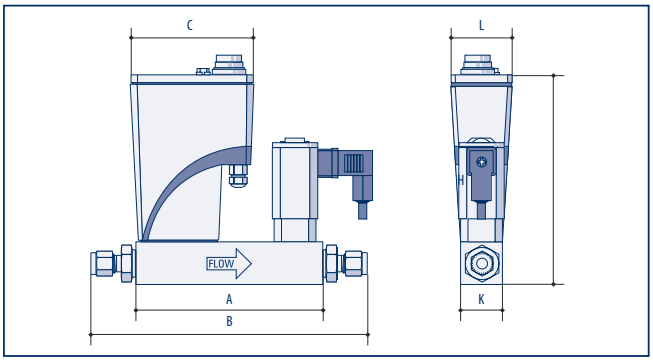
IP40 Mass Flow Controller

Model	A	B	C	H	K	Weight (kg)
F-200DV (⅛" OD)	77	128	47	111	25	0,6
F-201DV/F-201EV (¼" OD)	77	134	47	111	25	0,6
F-202DV/F-202EV (½" OD)	78	143	47	123	26	0,8



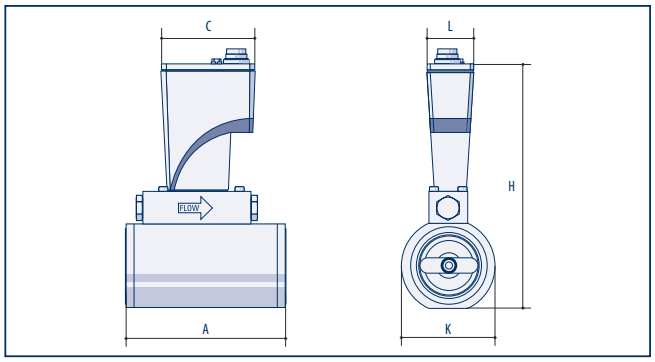
IP65 Mass Flow Meter, low/medium flow

Model	A	B	C	H	K	Weight (kg)
F-100DI (⅛" OD)	47	98	74	125	25	0,8
F-101DI/F-101EI (¼" OD)	69	126	74	125	25	0,9
F-102DI/F-102EI (½" OD)	69	134	74	137	26	1,0
F-103EI (½" OD)	110	177	74	182	89	4,4



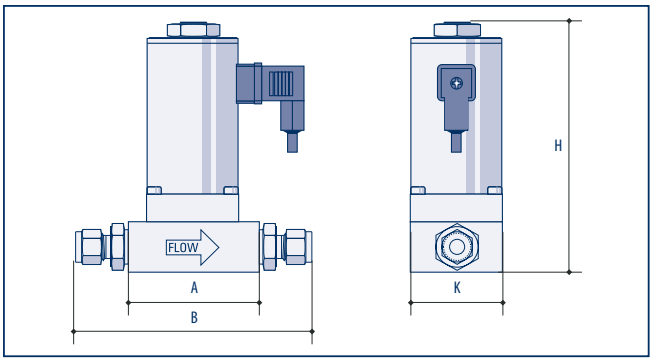
IP65 Mass Flow Controller

Model	A	B	C	H	K	L	Weight (kg)
F-200DI (⅛" OD)	112	164	74	125	25	36	1,3
F-201DI/F-201EI (¼" OD)	112	169	74	125	25	36	1,3
F-202DI/F-202EI (½" OD)	112	169	74	139	59	36	1,5



IP65 Mass Flow Meter, high flow, wafer type

Model	A	B	C	H	K	Weight (kg)
F-106AD	125	74	192	75	36	4,0
F-106BD	125	74	205	85	36	4,6
F-106CD	125	74	234	115	36	6,8
F-106DD	125	74	264	145	36	9,5
F-106ED	125	74	319	198	36	13,3



F-004 series Control Valves

Model	A	B	H	K	Weight (kg)
F-004AC/AI (¼" OD)	64	121	122	45	1,2
F-004BI (½" OD)	85	152	174	65	3,4

Dimensions subject to change without notice. For certified drawings and for dimensions of F-107Z series flanged type mass flow meters please contact factory.

Conversion factor calculations for model selection

To select the right model for other gases than Air, we have to carry out two calculations:

1. $$\varnothing_{vn}\ \text{Air} = \frac{\varnothing_{vn}\ \text{gas}}{\text{conversion factor}}$$

2. $$\varnothing_{vn}\ \text{Air} = \frac{\varnothing_{vn}\ \text{gas}}{\text{viscosity factor}}$$

The highest flow rate calculated determines the flow capacity.

Example: Freon-22, 1 l_n/min
Conversion factor = 0,49 (see table below)
Viscosity factor = 0,34 (see table below)

1. $\varnothing_{vn}$ Air = 1/0,49 = 2,04 l_n/min
2. $\varnothing_{vn}$ Air = 1/0,34 = 2,94 l_n/min

Highest flow rate = 2,94 ln/min so we can select model F-101E or F-101EI MFM resp. F-201EV or F-201EI MFC.

Conversion factors and viscosity factors

Name	A	B	C	Name	A	B	C	Name	A	B	C
Acetylene (ethyne)	C_2H_2	0,62	0,61	Ethylchloride	C_2H_5Cl	0,44	0,31	Molybdenum hexafluoride	MoF_6	0,23	0,16
Air	Air	1,00	1,00	Fluorine	F_2	0,93	0,96	Mono-ethylamine	C_2H_7N	0,38	0,32
Allene (Propadiene)	C_3H_4	0,46	0,38	Freon-11	CCl_3F	0,36	0,22	Monomethylamine	CH_5N	0,55	0,46
Ammonia	NH_3	0,79	0,87	Freon-113	$C_2Cl_3F_3$	0,22	0,14	Neon	Ne	1,40	1,86
Argon	Ar	1,40	1,12	Freon-1132A	$C_2H_2F_2$	0,47	0,39	Nitric oxide	NO	0,97	0,98
Arsine	AsH_3	0,72	0,48	Freon-114	$C_2Cl_2F_4$	0,24	0,16	Nitrogen	N_2	1,00	1,00
Boron trichloride	BCl_3	0,45	0,27	Freon-115	C_2ClF_5	0,25	0,18	Nitrogen dioxide	NO_2	0,75	0,57
Boron trifluoride	BF_3	0,56	0,47	Freon-116	C_2F_6	0,26	0,21	Nitrogen trifluoride	NF_3	0,53	0,47
Bromine pentafluoride	BrF_5	0,28	0,20	Freon-12	CCl_2F_2	0,38	0,25	Ntrosyl chloride	NOCl	0,62	0,42
Butadiene (1,3-)	C_4H_6	0,33	0,27	Freon-13	$CClF_3$	0,42	0,30	Nitrous oxide	N_2O	0,73	0,62
Butane	C_4H_{10}	0,27	0,23	Freon-13B1	$CBrF_3$	0,40	0,26	Oxygen	O_2	0,99	1,00
Butene (1-)	C_4H_8	0,38	0,30	Freon-14	CF_4	0,46	0,39	Oxygen difluoride	OF_2	0,66	0,62
Butene (2-) (cis)	C_4H_8	0,31	0,26	Freon-21	$CHCl_2F$	0,46	0,28	Ozone	O_3	0,72	0,59
Butene (2-) (trans)	C_4H_8	0,35	0,27	Freon-22	$CHClF_2$	0,49	0,34	Pentane	C_5H_{12}	0,23	0,19
Carbonylfluoride	COF_2	0,58	0,40	Freon-23	CHF_3	0,54	0,42	Perchlorylfluoride	ClO_3F	0,42	0,33
Carbonylsulfide	COS	0,67	0,46	Freon-C318	C_4F_8	0,16	0,12	Perfluoropropane	C_3F_8	0,18	0,14
Carbon dioxide	CO_2	0,76	0,63	Germane	GeH_4	0,61	0,44	Performa-ethylene	C_2F_4	0,35	0,27
Carbon disulfide	CS_2	0,63	0,36	Helium	He	1,40	3,35	Phosgene	$COCl_2$	0,48	0,30
Carbon monoxide	CO	1,00	0,97	Helium (3-)	3He	1,41	3,55	Phosphine	PH_3	0,76	0,65
Chlorine	Cl_2	0,82	0,50	Hydrogen	H_2	1,01	2,66	Phosphorous pentafluoride	PF_5	0,32	0,25
Chlorine trifluoride	ClF_3	0,44	0,33	Hydrogen bromide	HBr	0,98	0,59	Propane	C_3H_8	0,37	0,32
Cyanogen	C_2N_2	0,49	0,40	Hydrogen chloride	HCl	0,99	0,80	Propylene (Propene)	C_3H_6	0,43	0,37
Cyanogen chloride	ClCN	0,64	0,37	Hydrogen cyanide	HCN	0,75	0,22	Silane	SiH_4	0,65	0,61
Cyclopropane	C_3H_6	0,48	0,39	Hydrogen fluoride	HF	0,95	0,95	Silicon tetrafluoride	SiF_4	0,38	0,30
Deuterium	D_2	1,00	2,14	Hydrogen iodide	HI	0,97	0,46	Sulfurylfluoride	SO_2F_2	0,41	0,31
Diborane	B_2H_6	0,47	0,46	Hydrogen selenide	H_2Se	0,81	0,50	Sulfur dioxide	SO_2	0,69	0,46
Dibromo difluoromethane	CBr_2F_2	0,21	0,14	Hydrogen sulfide	H_2S	0,83	0,67	Sulfur hexafluoride	SF_6	0,28	0,22
Dichlorosilane	SiH_2Cl_2	0,44	0,28	Isobutane	C_4H_{10}	0,27	0,23	Sulfur tetrafluoride	SF_4	0,36	0,29
Dimethylamine	C_2H_7N	0,40	0,33	Isobutylene (Isobutene)	C_4H_8	0,30	0,25	Trichlorosilane	$SiHCl_3$	0,36	0,22
Dimethylpropane (2,2-)	C_5H_{12}	0,23	0,19	Kryton	Kr	1,42	0,83	Trimethylamine	C_3H_9N	0,30	0,24
Dimethylether	C_2H_6O	0,41	0,35	Methane	CH_4	0,80	0,93	Tungsten hexafluoride	WF_6	0,28	0,16
Disilane	Si_2H_6	0,33	0,28	Methylacetylene	C_3H_4	0,45	0,38	Vinylbromide	C_2H_3Br	0,50	0,30
Ethane	C_2H_6	0,53	0,50	Methylbromide	CH_3Br	0,64	0,37	Vinylchloride	C_2H_3Cl	0,50	0,36
Ethylene (Ethene)	C_2H_4	0,64	0,60	Methylchloride	CH_3Cl	0,67	0,48	Vinylfluoride	C_2H_3F	0,53	0,46
Ethylene oxide	C_2H_4O	0,56	0,44	Methylfluoride	CH_3F	0,74	0,70	Xenon	Xe	1,38	0,63
Ethylacetylene (1-Butyne)	C_4H_6	0,34	0,28	Methylmercaptan	CH_4S	0,56	0,42				

A = Symbol - B = conversion factor @ 20°C. 1 atm. - C = viscosity factor @ 20°C. 1 atm.

Ranges and pressure drop Mass Flow Meters

	Flow	ΔP (mbar) at atm.	
Model	**ml_n/min Air**	**⅛" tube**	**¼" tube**
F-100D/F-100DI	10	0,8	0,8
F-100D/F-100DI	15	0,8	0,8
F-101D/F-101DI	20	0,8	0,8
F-101D/F-101DI	50	0,8	0,8
F-101D/F-101DI	100	0,8	0,8
F-101D/F-101DI	200	0,8	0,8
F-101D/F-101DI	500	0,8	0,8
F-101D/F-101DI	1000	0,8	0,8
F-101D/F-101DI	2000	-	0,8

	Flow	ΔP (mbar) at atm.	
Model	**l_n/min Air**	**¼" tube**	**½" tube**
F-101E/F-101EI	5	5,5	5
F-101E/F-101EI	10	6	5,5
F-102D/F-102DI	20	4	2
F-102E/F-102EI	20	8,5	6,5
F-102E/F-102EI	50	-	15

	Flow	ΔP (mbar) at atm.	
Model	**l_n/min Air**	**½" tube**	**¾" tube**
F-103E/F-103EI	100	-	8
F-103E/F-103EI	200	-	15

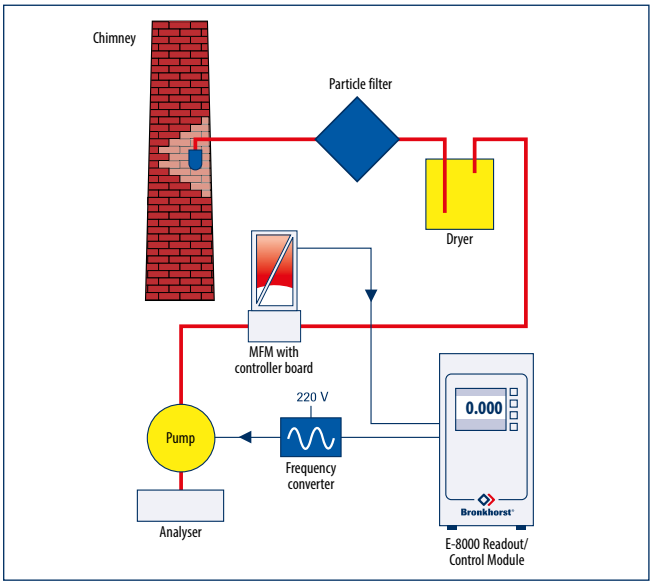
	Size		Flow	ΔP(mbar)
Model	**DIN**	**ANSI**	**m^3_n/h Air**	**at atm.**
F-106AD/F-107AD	DN40	1½"	10	7
F-106AD/F-107AD	DN40	1½"	20	13
F-106AD/F-107AD	DN40	1½"	50	35
F-106BD/F-107BD	DN50	2"	20	7
F-106BD/F-107BD	DN50	2"	50	18
F-106BD/F-107BD	DN50	2"	100	39
F-106CD/F-107CD	DN80	3"	50	7
F-106CD/F-107CD	DN80	3"	100	15
F-106CD/F-107CD	DN80	3"	200	32
F-106DD/F-107DD	DN100	4"	100	9
F-106DD/F-107DD	DN100	4"	200	17
F-106DD/F-107DD	DN100	4"	500	48
F-106ED/F-107ED	DN150	6"	200	7
F-106ED/F-107ED	DN150	6"	500	19
F-106ED/F-107ED	DN150	6"	1000	41

Fields of application

The LOW-ΔP-FLOW series have been successfully applied in a wide variety of both OEM and laboratory applications, e.g.:

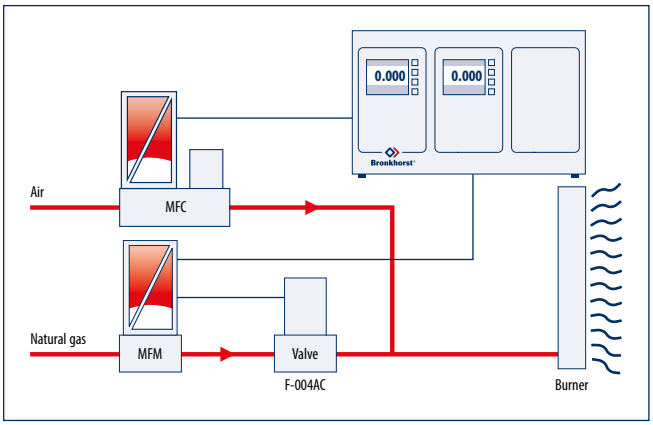
- Environmental air sampling at atmospheric conditions
- Leak rate and permeability measurements
- Burner control
- Measurement of gas consumption, for example of natural gas, in low pressure gas distribution systems

Air sampling



An interesting example to control a flow rate is using a LOW-ΔP-FLOW Mass Flow Meter in combination with a sampling pump. In this configuration the speed of the pump is controlled to obtain the required mass flow rate, determined by the setpoint value.

Burner control



Burner control using Mass Flow Controllers brings many advantages compared to conventional systems, where flow is adjusted through needle valves. When burner orifices get clogged or when gas supply pressure varies, an MFC will automatically adapt to the changed conditions. For the control of relatively large flows with low differential pressure, which is typical for natural gas or CH_4, LOW-ΔP-FLOW Mass Flow Meters in combination with F-004 pressure compensated bellow valves have proven to be a successful solution.

Model number identification

F	-	N	N	NAA	-	A	A	A	-	NN	-	A

Base

0	Valve only
1	Meter
2	Controller

Pressure rating

0	64 bar [1]

1) Max. operating pressure: 10 bar

Ranges

See page 3 of this leaflet, 'Models and flow ranges'. Model numbers F-106xD, F-107xD and ending with the letter "I" are IP65 rated. Other models are IP40 rated.

Communication (I/O)

A	RS232 + analog (n/c control)
B	RS232 + analog (n/o control)
C	RS232 + POWERLINK (n/c control)
D	RS232 + DeviceNet™ (n/c control)
E	RS232 + DeviceNet™ (n/o control)
I	RS232 + EtherNet/IP (n/c control)
J	RS232 + EtherNet/IP (n/o control)
K	RS232 + CANopen® (n/c control)
L	RS232 + CANopen® (n/o control)
M	RS232 + Modbus (n/c control)
N	RS232 + Modbus (n/o control)
O	RS232 + POWERLINK (n/o control)
P	RS232 + PROFIBUS (n/c control)
Q	RS232 + PROFIBUS (n/o control)
R	RS232 + FLOW-BUS (n/c control)
S	RS232 + FLOW-BUS (n/o control)
T	RS232 + EtherCAT® (n/c control)
U	RS232 + EtherCAT® (n/o control)
V	RS232 + PROFINET (n/c control)
W	RS232 + PROFINET (n/o control)
X	RS232 + Modbus-TCP (n/c control)
Y	RS232 + Modbus-TCP (n/o control)

Analog output

A	0…5 Vdc
B	0…10 Vdc
F	0…20 mA sourcing
G	4…20 mA sourcing

Supply voltage

D	+15…24 Vdc

Connections (in/out)

compression type couplings

11	⅛" OD compression type
22	¼" OD compression type
33	6 mm OD compression type
44	12 mm OD compression type
55	½" OD compression type
66	20 mm OD compression type
88	¼" Face seal male
99	other

mounting between flanges

01	mounting betw. flange, DIN PN10
02	mounting betw. flange, DIN PN16
03	mounting betw. flange, DIN PN40
06	mounting betw. flange, ANSI 150
07	mounting betw. flange, ANSI 300
13	Flanged connection, DIN PN40
26	Flanged connection, ANSI 150
99	other

Internal seals

V	FKM/Viton® (factory standard)
E	EPDM
K	FFKM/Kalrez®

F-101DI Mass Flow Meter, IP65 configuration

F-102E Mass Flow Meter, IP40 configuration

Bronkhorst®

Bronkhorst High-Tech designs and manufactures innovative instruments and subsystems for low-flow measurement and control for use in laboratories, machinery and industry. Driven by a strong sense of sustainability and with many years of experience, we offer an extensive range of (mass) flow meters and controllers for gases and liquids, based on thermal, Coriolis and ultrasonic measuring principles. Our global sales and service network provides local support in more than 40 countries. Discover Bronkhorst®!

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