qualiflow

AFC 50
MASS FLOW
CONTROLLER

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SECTION 1 - INTRODUCTION

The QUALIFLOW mass flow controller model AFC 50.00 offers the highest degree of accuracy and reliability in controlling gas flows.
It has been designed specifically to prevent contamination and particle deposition, and is therefore ideal for use in semiconductor and optical fibre manufacturing processes.

1.0. SPECIFICATIONS

Ratings

Flow Range (equivalent N2) :from 10 sccm to 30 slm
Control Range : ....between 2 and 100% F..S.
Valve Type : .... Electromagnetic
Valve Rest Position : ....Normally Open or Close
Accuracy : ....+/- 1.0% of F.S
Linearity :..................................+/- 0.5% of F.S.
Repeatability : ....+/- 0.2% of F.S.
Sensibility to Mounting Position :+/- 0.1% of F.S.
Step Response Time :<= 4 sec. typical (SEMI E17-91)
Temperature Range : .... between 5 and 50°C
Temperature Coefficient :..........< 0.1% F.S. /°C
Maximum Inlet Pressure :.........................10 bar
Minimum Differential Pressure : ..0.5 bar for FS less than 1slm, 1 bar for FS less than 10 slm, 1.5 bar for FS larger
Maximum Differential Pressure : ....3 bar
Pressure Coefficient : ....< 0.1% F.S./bar
Wetted Materials : stainless steel (316L austenitic, and EN1.4523 ferritic), PVDF Kynar® or PCTFE Kel-F® and seals
Seals : ....fluoro elastomer Viton®, perfluoroelastomer Kalrez® or polychloroprene Neoprene®
Surface finish : ....0.8 mm(16 minch) Ra max
Leak Integrity :..................< 2.10-8 scc/sec (He)
Fittings :.......................... ¼” VCR, Swagelok ¼”

Power Input Requirement :

Mass Flow Controller :........+/- 15 VDC, 150 mA
Mass Flow Meter : ....+/- 15 VDC, 25 mA
Set Point Signal :......................from 0 to 5 VDC
Flow Output Signal : ....from 0 to 5 VDC
Electrical Connector : .... Sub-D 15 pins Male

Options :

- Seals materials depend on gas (perfluoroelastomer Kalrez® is optional for some gases)
- Low differential pressure
- Card Edge adaptor
- Compatible with AFC261
- Other on request
- Note that there is a version of this product with digital electronics (sperataed datasheet)

1.1 CONVERSION DATA

If a mass flow meter or -controller, calibrated e.g. for N_2, 200 sccm, has to be used for working with another gas, say X, conversion data can be used to calculate the actual flow of gas X. The achieved accuracy is less than ±1% (standard calibration) but always better than 4%. The formula for calculating the flow of gas X is in this example.

$$\frac{\text{Actual flow of gas X}}{\text{Actual flow of } N_2} = \frac{C(X)}{C(N_2)}$$

Where the flow are in sccm or slm, and C(X) and $C(N_2)$ are the tabulated values of the conversion factors. In this example, when X is say CO_2 (C = 0,746) :

$$\frac{\text{Actual flow of } CO_2}{\text{Actual flow of } N_2} = \frac{0{,}746}{1{,}000}$$

So the actual flow of C02, if measured with a unit, that was originally calibrated for N_2 is obtained by multiplying the output by 0,746.

#	Name	Formula	Density	Sp. Heat[g/l]	C[cal/g/degC]
1*	**Acetone**	**C_3H_6O**	**2.59**	**0.310**	**0.340**
2	Acetylene	C_2H_2	1.169	0.40	0.58
3	Air	-	1.2929	0.2401	1.000
4	Allene	C_3H_4	1.81	0.358	0.42
5	Ammonia	NH_3	0.7710	0.519	0.68
6	Argon	Ar	1.7842	0.1246	1.453
7	Arsine	AsH_3	3.481	0.1178	0.666
8	Boron trichloride	BCl_3	5.26	0.130	0.40
9	Boron trifluoride	BF_3	3.1	0.158	0.56
10	Butane	C_4H_{10}	2.65	0.404	0.26
11	l-Butene	C_4H_8	2.54	0.368	0.29
12	Carbon dioxide	CO_2	1.977	0.201	0.74
13	Carbon monoxide	CO	1.2500	0.249	1.000
14	Carbon tetrachloride	CCl_4	6.86	0.129	0.309
15	Carbonyl fluoride	COF_2	2.96	0.170	0.544
16	Carbonyl sulphide	COS	2.70	0.169	0.64
17	Chlorine	Cl_2	3.209	0.116	0.83
18	Chlorine trifluoride	ClF_3	4.14	0.164	0.403
19	Chloroform	$CHCl_3$	5.33	0.32	0.388
20	Cyanogen	C_2N_2	2.34	0.264	0.44
21	Cyclopropane	C_3H_6	1.878	0.316	0.460
22	Deuterium	D_2	0.1800	1.728	0.999
23	Diborane	B_2H_6	1.24	0.495	0.44
24	Dichlorosilane	SiH_2Cl_2	4.54	0.141	0.43
25	Dichlorodimethylsilane	$Si(CH_3)_2Cl_2$	5.754	0.2029	0.234
26	Dimethylamine	$(CH_3)_2NH_3$	2.03	0.362	0.370
27	Dimethylether	$(CH_3)_2O$	2.08	0.3367	0.390
28	Ethane	C_2H_6	1.352	0.415	0.49
29	Ethyl chloride	C_2H_5Cl	2.90	0.234	0.40
30	Ethylene	C_2H_4	1.258	0.366	0.59
31	Ethylene oxide	C_2H_4O	1.95	0.259	0.54
32	Fluorine	F_2	1.094	0.1974	0.929
33	Fluoroform	CHF_3	3.125	0.173	0.506
34	Freon-11	CCl_3F	6.3	0.1415	0.34
35	Freon-12	CCl_2F_2	5.5	0.149	0.34
36	Freon-13	$CClF_3$	4.8	0.156	0.37
37	Freon-13Br	$CBrF_3$	6.8	0.1124	0.36
38	Freon-14	CF_4	3.96	0.167	0.41
39	Freon-22	$CHClF_2$	4.05	0.156	0.43
40	Freon-114	$C_2Cl_2F_4$	7.7	0.163	0.22
41	Genetron-21	$CHCl_2F$	4.64	0.144	0.41
42	Genetron-115	C_2ClF_5	7.1	0.1636	0.24
43	Germane	GeH_4	3.423	0.138	0.58
44	Helium	He	0.1788	1.242	1.454
45	3-Helium	3He	0.135	1.65	1.45
46	Hydrogen	H_2	0.0899	3.400	1.016
47	Hydrogen bromide	HBr	3.60	0.085	1.01
48	Hydrogen chloride	HCl	1.635	0.1937	0.981
49	Hydrogen fluoride	HF	0.90	0.348	0.99
50	Hydrogen iodide	HI	5.71	0.057	0.95
51	Hydrogen selenide	H_2Se	3.613	0.103	0.78
52	Hydrogen sulphide	H_2S	1.534	0.244	0.78
53	Isobutane	C_4H_{10}	2.63	0.395	0.26

#	Name	Formula	Density	Sp. Heat[g/l]	C[cal/g/degC]
54	Isobutylene	C_4H_4	2.51	0.339	0.321
55	Krypton	Kr	3.73	0.0596	1.45
56	Methane	CH_4	0.7166	0.528	0.722
57	Methanol	CH_3OH	1.430	0.3277	0.583
58	Methylamine	CH_3NH_2	1.392	0.400	0.491
59	Methyl bromide	CH_3Br	4.29	0.113	0.56
60	Methyl chloride	CH_3Cl	2.28	0.200	0.60
61	Methyl fluoride	CH_3F	1.53	0.267	0.67
62	Methyl mercaptan	CH_3SH	2.146	0.2506	0.508
63	Methyl trichlorosilane	$SiCH_3Cl_3$	6.670	0.164	0.250
64	Neon	Ne	0.900	0.2460	1.460
65	Nitric oxide	NO	1.3402	0.236	0.98
66	Nitrogen	N_2	1.2503	0.2484	1.000
67*	Nitrogen dioxide	NO_2	3.675	0.194	0.41
68*	Dinitrogen tetroxide	N_2O_4	3.675	0.200	0.37
69	Nitrogen trifluoride	NF_3	3.173	0.178	0.434
70	Nitrous oxide	N_2O	1.98	0.206	0.72
71	Oxygen	O_2	1.429	0.2183	0.996
72	Pentaborane	B_5H_9	2.9	0.565	0.17
73	n-Pentane	C_5H_{12}	3.4	0.38	0.21
74	Perfluoroethylene	C_2F_4	4.3	0.192	0.33
75	Phosgene	$COCl_2$	4.45	0.140	0.44
76	Phosphine	PH_3	1.523	0.2607	0.688
77	Propane	C_3H_8	1.98	0.392	0.35
78	Propylene	C_3H_6	1.89	0.357	0.405
79	Silane	SiH_4	1.438	0.3188	0.596
80	Silicon tetrachloride	$SiCl_4$	7.58	0.125	0.228
81	Silicon tetrafluoride	SiF_4	4.68	0.168	0.35
82	Sulphur dioxide	SO_2	2.91	0.149	0.67
83	Sulphur hexafluoride	SF_6	6.5	0.1590	0.27
84	Trichlorosilane	$SiHCl_3$	6.047	0.130	0.348
85	Trimethylamine	$(CH_3)_3N$	2.7	0.367	0.27
86	Tungsten hexafluoride	WF_6	13.2	0.0951	0.22
87	Uranium hexafluoride	UF_6	15.76	0.079	0.22
88	Vinyl bromide	C_2H_3Br	4.83	0.123	0.46
89	Vinyl chloride	C_2H_3Cl	2.82	0.202	0.48
90	Vinyl fluoride	C_2H_3F	2.060	0.241	0.551
91	Water vapour	H_2O	0.804	0.445	0.817
92	Xenon	Xe	5.88	0.039	1.41
93	Hexafluoroethane	C_2F_6	6.16	0.185	0.24
94*	Trimethyl borate	$B(OCH_3)_3$	4.64	0.13	0.5
95*	Trimethyl phosphite	$P(OCH_3)_3$	5.54	0.11	0.5
96*	Titanium tetrachloride	$TiCl_4$	8.465	0.122	0.30

Table 3.1 Conversion factors (continued on next page)

NOTE: When using gases marked with an asterisk (*), use "low pressure" AFC 50.00.

SECTION 2 - INSTALLATION

2.0 INTRODUCTION

This section is made of four parts and contains all the information necessary to install the AFC 50 mass flow controller or AFM 55 mass-flow meter.

- 2.1 - unpacking;
- 2.2 - mechanical installation;
- 2.3 - electrical installation;
- 2.4 - checks before start-up.

2.1 SITE STORAGE

MFC's shall be stored in their original package, in a dry and clean environment. It should not be exposed to temperature bellow 5°C (40°F) and over 50°C (120°F), and should be protected from external shocks.
If the MFC is to be stored after unpacking, it should be packed with plugs on gas inlet and outlet, in a protective aluminized and hermitically sealed bag. If the MFC is stored outside the clean room, we recommend to place it inside an outer bag sealed with an inert gas. This operations shall be performed in a class 100 cleanroom environment.

2.2 UNPACKING

The AFC 50 mass flow controller or AFM 55 mass-flow meter are manufactured under cleanroom conditions, and has been packed accordingly. Upon receipt, the cardboard packing should be checked for damage. If there is visible damage, please notify your local QUALIFLOW sales office. In order to minimize contamination of cleanrooms, the unit has been packed in two separately sealed plastic bags. The outside bag should be removed in the entrance to the clean room. The second bag should be removed when you install the unit.

2.3 HANDLING

The MFC shall be handled with care, unpacked and installed as detailed in this manual. A special care should be attached to prevent MFC contamination and fittings damage.

2.4 MECHANICAL INSTALLATION

2.4.0 GENERAL

Most applications will require a positive shutoff valve in line with the mass flow controller. Pressurized gas trapped between the two devices can cause surge effects, and consideration must be given to the sitting of the shutoff valve (upstream or downstream) in relation to the process sequencing. As far as the process parameters permit, it is recommended that you install an in-line filter upstream from the controller in order to prevent contamination.

The AFC 50 mass flow controller or AFM 55 mass-flow meter can be mounted in any position. The atmosphere should be clean and dry. The mounting should be free from shock or vibration. Mounting dimensions are shown in figure 2-1. Prior to installation, ensure that all the piping is thoroughly cleaned and dried. Do not remove the protective endcaps until you are ready to install the controller.

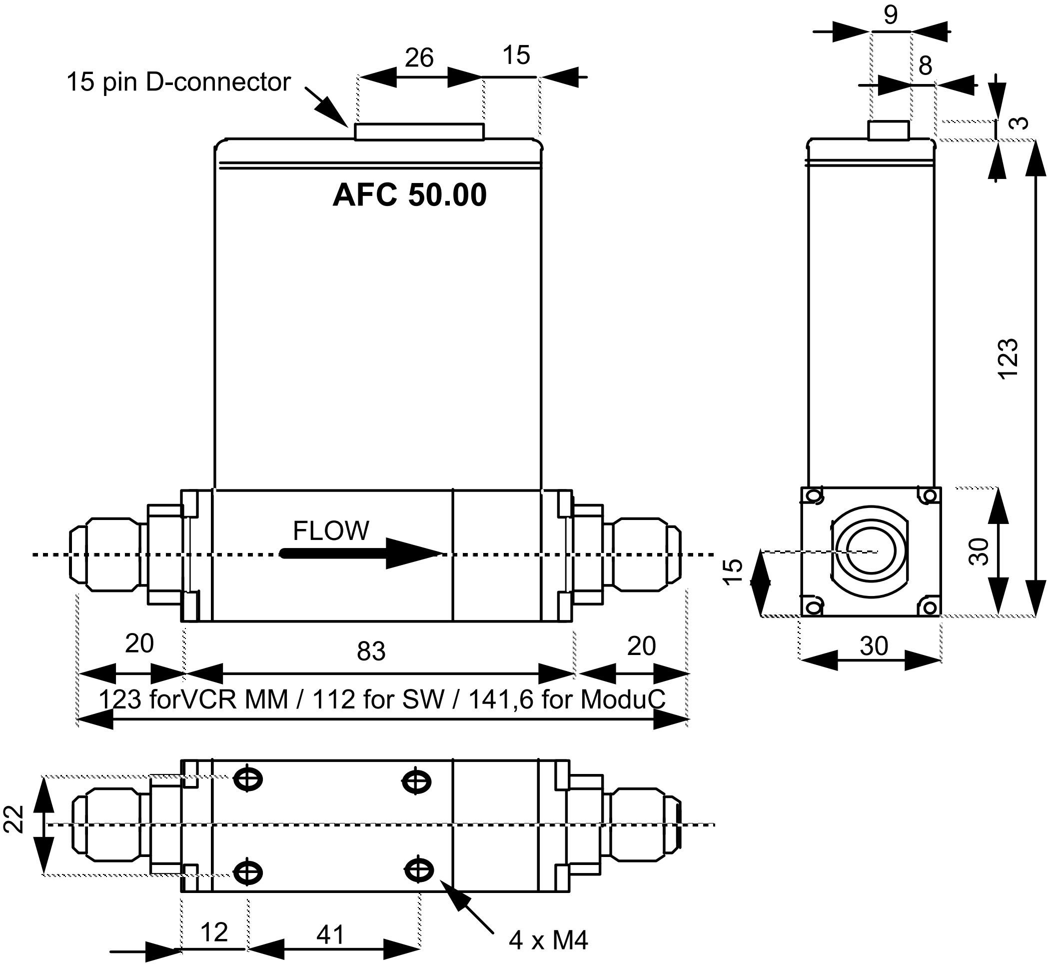


Figure 2-1 Dimensions of the AFC 50.00

2.4.1 INSTALLATION

WARNING: Toxic, corrosive or explosive gases must be handled with extreme care. After installing the mass flow controller, the system should be thoroughly checked to ensure it is leak free. Purge the mass flow controller with a dry inert gas for one hour before using corrosive gases.

Important: When installing the mass flow controller, ensure that the arrow on the back of the unit points in the same direction as the gas flow.

2.4.1.0. VCR COMPATIBLE COUPLINGS

The AFC 50 mass flow controller or AFM 55 mass-flow meter normally come with 1/4" male VCR compatible couplings on both sides. To install the AFC/AFM, follow the steps listed below. Refer to figure 2-2.

1. Check the gland to gland space, including the gaskets.
2. Remove the plastic gland protector caps.
3. a) When using loose VCR "original" style gaskets, insert the gasket into the female nut.
   b) For VCR retainer gaskets, snap the gasket onto the male coupling. See figure 2-2.
4. Tighten the nuts finger tight.
5. Scribe both nut and body in order to mark the position of the nut.
6. While holding the body with a wrench, tighten the nut:
   a) 1/8 turn past finger tight for 316 stainless steel and nickel gaskets.
   b) 1/4 turn past finger tight for copper, TFE and aluminium gaskets.

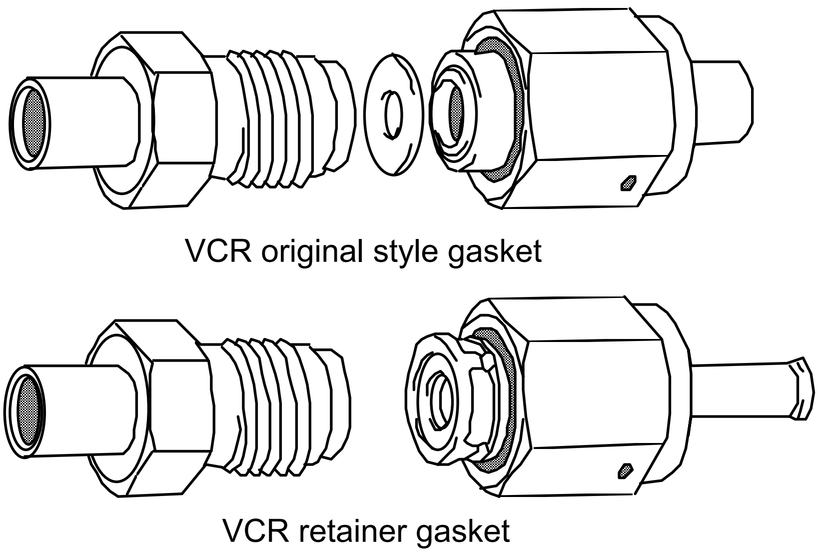


Figure 2-2 VCR compatible feetings

2.4.1.1 SWAGELOK COMPATIBLE COUPLINGS

On request the AFC 50 mass flow controller or AFM 55 mass-flow meter can be supplied with 1/4" male Swagelok compatible couplings. In this case polished stainless steel tubing must be used to ensure a leak tight system. The mounting instructions are as follows:

1. Insert the tubing to the shoulder inside the fitting.
2. Check that the ferrules are positioned as shown in figure 2-3.
3. Tighten the nuts finger tight.
4. Scribe both nut and body in order to mark the position of the nut.
5. Tighten the nuts 1 and 1/4 turn, while holding the body with a wrench.

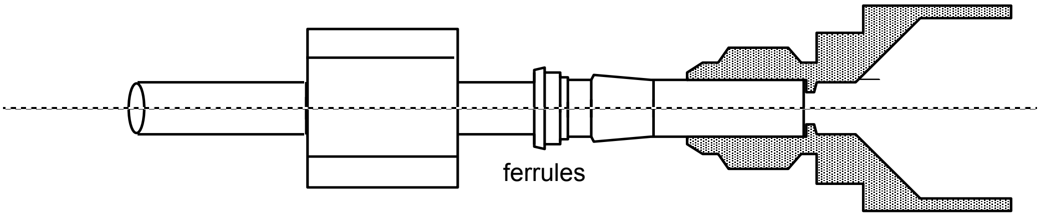


Figure 2-3 Orientation of Swagelok compatible couplings

2.5 ELECTRICAL INSTALLATION

2.5.0 GENERAL

Read carefully this section before connecting the AFC 50 mass flow controller or AFM 55 mass-flow meter, so that you understand the possible electrical configurations. This section includes the following sub-sections:

- connections
- softstart command
- pressure control
- ratio control
- read out using a digital voltmeter

2.5.1 CONNECTIONS

The standard AFC 50.00 has a 15 pole D-connector. The pin arrangement is shown in figure 2-4. For replacing cardedge connector MFC such as AFC 260, 261, 360 by AFC 50.00, special adaptors are available so that existing wiring can be used.

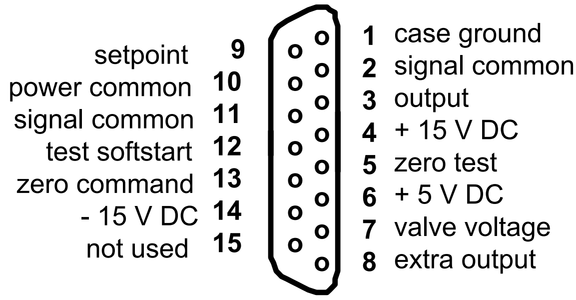


Figure 2-4 D-connector pin arrangement

Table 1 gives a more detailed explanation of the functions available at each of the pins:

Pin No.	Name	Functional description
Pin 1:	**case ground**	Ground for body and cap
Pin 2:	**signal common**	Reference "zero" level for input and output signals Connected to pin 11
Pin 3:	**output**	Sensor output signal Standard calibration +5 VDC =100% flow (ref. pin 2 or 11)
Pin 4:	**+15 VDC**	Positive power supply pole +15 VDC ± 5% Max. 200 mA (ref. pin 10)
Pin 5:	**zero test**	External "make" to pin 10 disables autozero, and allows verification of zero level and adjustment
Pin 6: or **output**	**+5 VDC reference**	Reference voltage for checking 100% setpoint flow creating intermediate setpoint levels (ref. pin 2 or pin 11)
Pin 7:	**valve voltage**	Voltage for checking the valve signal
Pin 8:	**extra output**	Normally connected to pin 3. Removing connection creates pressure control function as per section 2.3.4
Pin 9:	**setpoint input**	Externally induced voltage +5 VDC = max. flow (ref. pin 2 or pin 11)
Pin 10:	**power common**	Reference "zero" level for power source
Pin 11:	**signal common**	Connected to pin 2
Pin 12:	**test/softstart input**	External "make" to pin 10 creates softstart function External "make" to pin 14 creates purge (valve open) function. See section 2.3.3
Pin 13:	**zero command input**	External "make" to pin 10 results in automatic zero adjustment of output signal
Pin 14:	**-15 VDC**	Negative power supply pole -15 VDC (ref. pin 10)
Pin 15:		Not connected

Table 1 Description of D-connector pin functions

2.5.2 SOFTSTART COMMAND

If you have a non-zero setpoint and the flow is stopped by a shutoff valve, the mass flow controller will open fully to try and achieve the setpoint. When the flow is restored the mass flow controller will be fully open and there will be a substantial overshoot - see figure 2-6.

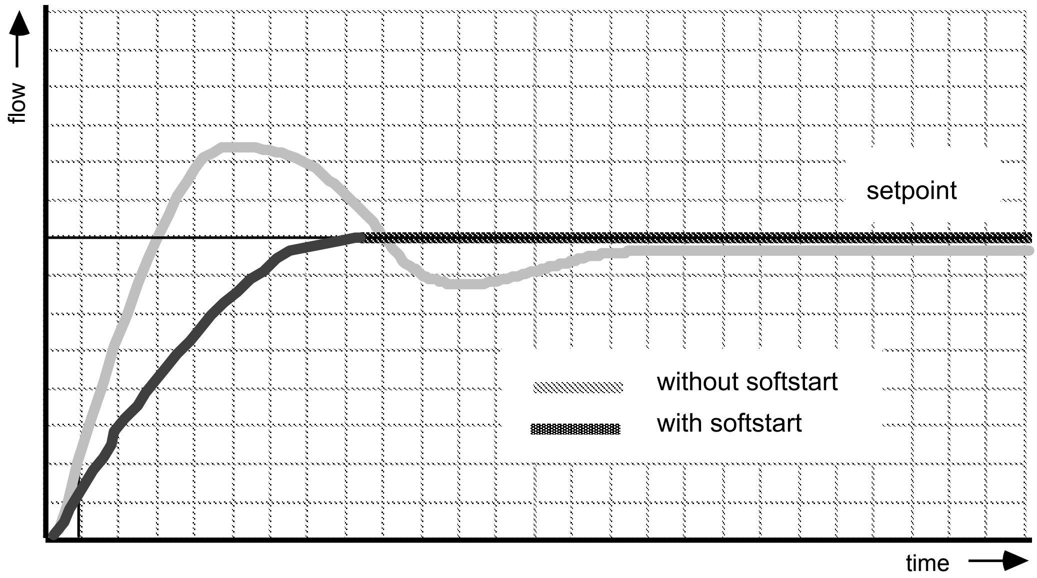


Figure 2-6 Effect of the soft start mode

This can be avoided by using the softstart feature. Externally connecting pins 10 and 12 will cause the mass flow controller to shut completely, regardless of the actual setpoint. The controller will close almost instantaneously. The connection can be made by the same switch that operates the shutoff valve. A typical arrangement is shown in figure 2-7. When the shutoff valve is reopened, pins 10 and 12 will be disconnected and the controller will **open** to control at the setpoint.

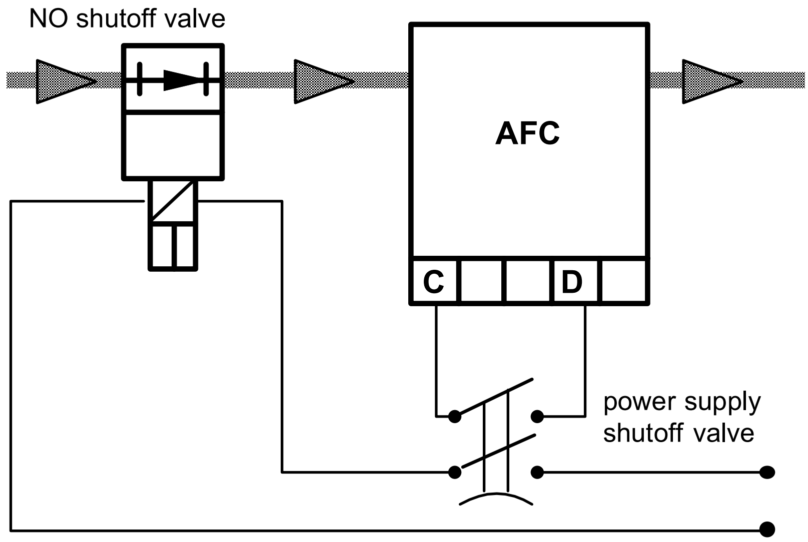


Figure 2-7 Softstart circuit

2.5.3 PURGE COMMAND

Externally connecting pin 12 to pin 14 forces the mass flow controller fully open, regardless of the setpoint value. This feature is generally used for purge procedures. An arrangement that can perform purge and softstart is shown in figure 2-8 below.

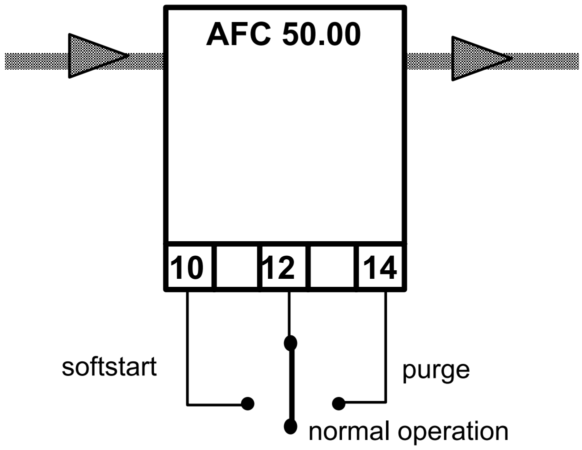


Figure 2-8 Purge command

2.5.4 PRESSURE CONTROL

The mass flow controller can be modified to work as a pressure controller. Pin 3 is normally connected to pin 10 by jumper J2. Desoldering this pad disconnects the sensor output signal from the control circuit. A pressure transducer output signal (0-5 VDC) can now be connected to pin 3, which makes the mass flow controller work as a pressure controller. The mass flow can still be monitored through pin 10.

2.5.5 RATIO CONTROL

For processes that require accurate blending of two or more different gases, ratio control can be obtained by a master-slave arrangement as shown in figure 2-9. The output signal of the master mass flow controller is used as an input (setpoint) signal by the slave mass flow controller.

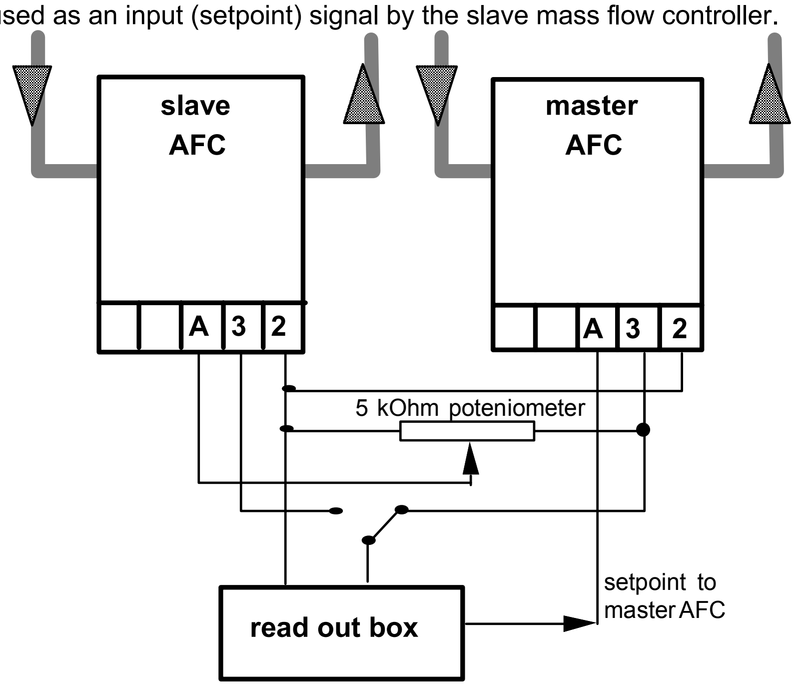


Figure 2-9 Ratio control

2.5.6 READ OUT USING A DIGITAL VOLTMETER

For testing, laboratory, or R&D applications, any DC voltmeter or recorder with an impedance of at least 5000 Ohms may be used to monitor the mass flow controller's performance.

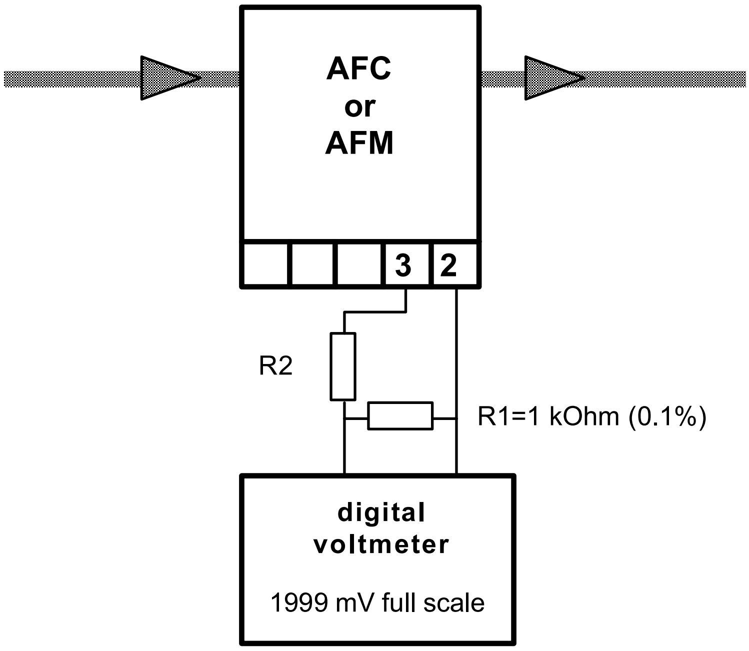


Figure 2-11 Voltage divider arrangement

Full scale read-out [mv]	1999	1500	1000	750	600	500	400	300	250
R2 [kOhm]	1.50	2.33	4.00	5.67	7.33	9.00	11.50	15.70	19.00

Table 2 Selection of R2.

2.6 CHECKS BEFORE START UP

Before operating the mass flow controller the following checks should be completed:

1. Check all tubing is leak proof.
2. Check the process sequence and proper function of all other gas components involved.
3. Check the voltage of command signals and power supply to the mass flow controller.
4. Check the appropriate gas type is being supplied at the rated pressure.
5. Allow the mass flow controller to warm up for 20 minutes, then check the zero level output.
6. Use dry inert gas for test runs.
7. Prior to using the mass flow controller for extremely corrosive gases, purge with a dry inert gas for one hour.

SECTION 3 - ADJUSTMENT PROCEDURE

3.0. GENERAL

The adjustment and calibration procedures described in this section are intended to restore the accuracy of the unit to its original level after cleaning or replacement of defective parts. Modification of the AFC 50.00 for other gas types or flow ranges will normally include modification of the bypass unit, replacement of the nozzle and eventually the sensor assembly.

3.1. INSTRUMENTATION

A prerequisite for calibration is a mass flow meter or any other flow meter with an accuracy that is at least equal to that required of the instrument under test. Ordinary rotameters are not adequate for calibration purposes. Gas temperature, and inlet and outlet pressures must reflect the actual process conditions as far as possible.

3.2. CALCULATING THE CONVERSION FACTOR

It may not always be possible to calibrate the mass flow controller with the type of gas it will actually be used for. Nitrogen, Hydrogen and Freon are commonly used for testing and calibration purposes. If the process gas is to be "X" and the calibration gas is "Y", the calibration flow rate can be found from the following formula :

$$\text{Flow of calibration gas Y} = \text{Flow of process gas X} * \frac{C(y)}{C(x)}$$

where C(x) and C(y) are conversion factors which can be found in the table in Section 1.

EXAMPLE: Suppose the mass flow controller has to be calibrated for a flow of 300 sccm of CO_2 and only N_2 is available at the test bench. According to the above formula, the equivalent flow of N_2 will be :

$$\text{Full scale flow of } N_2 = 300 * \frac{1.000}{0.746} = 402 \text{ sccm}$$

NOTE : Not using the actual process gas for calibration purposes will reduce the operational accuracy of the mass flow controller. The conversion procedure may result in a loss of accuracy of up to +/- 4%.

3.3. CALIBRATION PROCEDURE

1. Turn on the AFC and allow it to warm up for at least 20 minutes before starting the calibration procedure.
2. Verify the power supply voltage and the +5 VDC reference voltage of the mass flow controller to be calibrated.
3. If you are not using the intended process gas for calibration, recheck your calculation for the flow rate of the calibration gas.
4. Adjust the nozzle until the actuator voltage (measured in the wires) reaches 10 to 15 volt at inlet gas pressure of 1 to 2 bar and setpoint set to 100%.
5. Check for valve closing (0% setpoint). A 0.2% flow is an acceptable leak - anything more may entail replacing the valve.
6. Readjust nozzle if necessary.
7. Turn off the gas supply.
8. Disable the autozero system by externally connecting pin 5 to pin 10.
9. Adjust the zero readout of the mass flow controller by adjusting potentiometer P3.
10. Turn on the gas supply and increase the inlet gas pressure to the level expected in the actual process.

11. Induce the 100% setpoint by connectng +5 VDC to pin 9. The +5 VDC reference voltage may be used by externally connecting pin 6 to pin 9.
12. Adjust potentiometer P4 (gain) so that the actual flow through the reference flow meter agrees with the desired maximum flow.
13. Induce the 50% setpoint by connecting +2.5 VDC to pin 9.
14. Adjust potentiometer P2 so that 50% flow is measured by the reference flowmeter.
15. Recheck the zero and full scale calibrations. If necessary, repeat the above procedure starting from step 10.

3.4. DYNAMIC RESPONSE ADJUSTMENT

For special applications after modifying the unit for another gas type and/or flow range, it may be necessary to readjust the dynamic response/stability performance. This is done by modifying resistor R29 and capacitors C6 and C7. Contact QUALIFLOW for advice.

3.5. CHANGE OF GAS TYPE OR FLOW RANGE

If you wish to change the gas type or flow range, the following elements may need modifying:

- seals
- valve stem tip
- bypass ring
- bypass tubes
- screen bypass rings
- sensor assembly
- nozzle

Fluoro elastomer Viton® is the standard material used for seals and valve stem tips. For certain gases, you will need these parts made from perfluoroelastomer Kalrez® or polychloroprene Neoprene®

Bypass tubes Table shows the number of tubes required for flow rates from 10 to 5000 sccm. Nozzle size Table shows the nozzle sizes required for flowrates up to 25 slm. All the data in both tables are for N_2. Equivalent flow rates for other gases must be calculated using the formula in section 3.3.2.

	Number of tubes required		
	0.7mm	1.0mm	1.5mm
10	-	-	-
30	2	-	-
100	9	-	-
300	20	-	-
1000	-	18	-
3000	-	14	10
5000	-	-	23

Bypass tubes Table

NOTE 1: The sensor internal diameter is 0.4mm (0.7 mm is some special cases).

NOTE 2: For flows from 6 slm to 25 slm a screen bypass is used, see section §9
Contact QUALIFLOW for details.

Flow	Differential pressure				
	mbar < 50	mbar 50-300	bar 0.3 -1	bar 1-3	bar 3-10
< 50 sccm	2.5	0.8	0.5	0.3	0.3
50 - 250 sccm	2.5	0.8	0.5	0.3	0.3
250-1000 sccm	2.5	1.5	0.8	0.5	0.5
1 - 2.5 slm	-	1.5	1.50	0.8	0.5
2.5 - 10 slm	-	-	1.5	1.5	0.8
10 - 25 slm	-	-	-	1.5	0.8

Nozzle sizes (in mm) Table

3.6. CHANGING FROM NO TO NC, OR NC TO NO

The AFC 50.00 is available as normally open or normally closed.

•The normally *open* units have a *green line* on the cover

•The normally *closed* units have a *red line* on the cover

Due to system or process modifications you may wish to change the original NO or NC status of the unit. This is achieved by reversing the plunger and opening/closing solder pads X5, X6, X7, X8, X10 and X11. See table for details. After this modification the unit must be calibrated

Plunger orientation	Solder pads					
	X5	X6	X7	X8	X10	X11
Conical side towards inlet	open	closed	open	closed	closed	open
Conical side towards outlet	closed	open	closed	open	open	closed

SECTION 4 - MAINTENANCE

4.0. GENERAL

No routine maintenance is required to be performed on the meters or controllers, other than occasional cleaning and recalibration :
After 3 or 4 years when the unit is run with a ultra-clean and non corrosive gas.
After 1 or 2 years when the unit is run with a low purity gas and/or a corrosive gas.

Cleaning can be performed by removing the unit from the system, cleaning in- and outlet-fittings separately and pumping alternately reverse and forward for 5 minutes in each direction with a solvent system (one micron maximum absolute filtration).
Next, the unit must be blown with N_2 for 30 minutes minimum.
Reinstall cleaned fittings.
In extreme cases of contamination, it may be necessary to separately clean the sensor, the bypass and the valve.

4.1. DISASSEMBLY PROCEDURE

Refer to exploded views.

1. Remove cover screw 31 and carefully remove the cover.
2. Disconnect the sensor wiring from the PC-board by careful unsoldering.
3. Disconnect the actuator wiring from the PC-board by careful unsoldering.
4. Remove the PC-board from the sensor assembly by removing screws 25.
5. Remove sensor assembly 22 from the base block. Handle the sensor with care.
6. Remove the O-rings from the chambers in the base block.
7. Remove integral fitting plates 2 and 20 by removing screws 1 and 21. Remove the O-rings from the chambers in base block.
8. Cut the base block sticker on the line dividing the base block and the actuator using a sharp knife.
9. Remove nozzle 18 from the outlet-side fitting plate using an appropriate size screwdriver. Turn clockwise to remove.
10. Remove the O-ring from the nozzle.
11. Remove the actuator base by carefully pulling it out of the base block.
12. Remove the O-ring from the base block chamber.

NOTE: Further disassembly is only necessary in cases of *extreme contamination.*

13. Remove the multitube bypass by pulling the plastic ring in direction of thread.
14. Remove cap 8 from the actuator base using an appropriate size screwdriver.
15. Carefully unscrew valve stem tip 17 while holding locknut 10 at the opposite end of the plunger.
16. Check that spacer ring 9 can be freely turned inside the housing.
17. Remove the plunger including spacer ring and magnetic pole 11. Carefully pull the parts out by holding the locknut.
18. Remove O-rings 12 and 13.
19. Unscrew locknut 10 and remove spacer ring 9.
20. Remove magnetic pole 11 from the plunger.
21. Remove magnet coil 15 from the actuator base.
22. Remove O-ring 16.

4.2. SENSOR CLEANING AND REPLACEMENT

Check the resistance of sensor windings before cleaning. The resistance should be 250 +/- 10 Ohms for the 0.7 mm sensor and 190 +/- 10 Ohms for the 0.4 mm sensor. If the resistance is not within tolerance, replace the complete sensor assembly. If severely contaminated or clogged, the sensor tube can be cleaned by inserting a special plastic cleaning thread. The sensor tube should then be flushed with isopropyl alcohol using a hypodermic needle. Use compressed nitrogen for drying.

4.3. COIL

The coil must not be soaked in solvent since the coil wire and lead wires may be damaged. The inside of the coil can be cleaned using plastic rods of a suitable diameter wrapped with alcohol-soaked cleaning tissue. Blow dry with compressed nitrogen.

4.4. BYPASS

The bypass unit can be cleaned in one piece in the same way as the coil. Disassembling the bypass by removing the tubes does not make cleaning easier. If the bypass cannot be properly cleaned, replace the whole unit.

4.5. REASSEMBLY

We recommend that new O-rings are used in all instances when the unit is reassembled. Refer to exploded view. The use of O-ring lubricant is *not* recommended. The following procedure must be followed for reassembly :

1. Examine all parts for signs of damage and replace as necessary.
2. Fit O-ring onto lead wire side of magnetic coil.
3. Insert pick-up wire through hole in actuator base and attach coil lead wires using a small amount of tape. Pull lead wires through opening with care.
4. Insert the magnetic coil into the actuator base while gently pulling the pick-up wire.
5. Fit O-rings onto magnetic pole 11.
6. Pre-assemble the plunger, magnetic pole and spacer ring 9. Avoid any loads on the crown spring. Tighten, by holding the locknut in socket wrench and turning clockwise until finger tight.
7. Carefully insert plunger assembly into magnetic coil. Avoiding damaging the crown spring on the valve side.
8. Press against the outside edge of the spacer ring in order to overcome the friction of the O-rings on the magnetic pole.
9. Fasten the valve stem tip firmly finger tight.
10. Re-assemble the bypass unit.
11. Screw on actuator cap 8 and tighten until finger tight using an appropriate size screwdriver.
12. Move the bypass unit over the actuator base and press it against the shoulder.
13. Fit O-ring onto edge of actuator base.
14. Insert actuator base into base block.
15. Fit O-ring into groove of nozzle.
16. Push nozzle into fitting plate 20 and gently turn counter clockwise with appropriate size screwdriver until it locks against shoulder.
17. Fit O-rings onto edges of fitting plates.
18. Fit fitting plates on both ends with mounting screws, applying a torque of 2 Nm.
19. Insert O-rings for sensor tube connection into chambers in base block.
20. Mount the sensor assembly 22 onto the baseblock and tighten the screws to a torque of 2 Nm.
21. Connect sensor wiring blue-top / red-middle / orange-lower.
22. Connect the actuator wiring.
23. Leak test the assembled mass flow controller.
24. Start the calibration procedure as described.
25. Replace cover 30.
26. Before reinstallation in gas system, purge with dry nitrogen for 30 minutes.

SECTION 5 - TROUBLESHOOTING

5.0. INITIAL CHECK

The AFC 50.00 will generally be used as a component in complex gas handling systems. Therefore, it will often be difficult to diagnose failures correctly, since a certain malfunction may have a number of possible causes. For initial operation of new systems, verify that the malfunction is not caused by incorrect process sequencing or other system failures. It is recommended that you perform the following checks *before* removing a suspect mass flow controller for bench testing :

1. Verify the gas supply pressure and check that the flowpath to the mass flow controller has been opened.
2. Remove the cover and ensure that the power supply and command signals are correctly transmitted to the D-connector pins on the PC-board.
3. Verify that the output signal matches the external reading. See pin assignments.
4. Use the following table to help locate the fault.

5.1. SEVERAL SYMPTOMS

Problem 1: Output reading, without gas flow, is not zero

Possible cause	Action
Gas flow is actually present.	Check closure of series shutoff valve.
Autozero circuit is malfunctioning.	Install a new autozero PC-board.
Zero reading has drifted more than 1.5% (max autozero correction).	Reset autozero circuit by means of jumpering pin 10 to pin 5 and adjust potentiometer P3.

Problem 2: Zero reading cannot be adjusted

Possible cause	Action
Defective sensor.	Verify that sensor voltage between red and orange wires is equal to the voltage between red and blue wires. Both must be 4 to 6 volts. Contact QUALIFLOW for between red and blue wires. Both must be advice. If defective, the controller may need replacing.
Auto zero circuit is malfunctioning	Replace autozero PC-board

Problem 3: Valve will not close

Possible cause	Action
Setpoint is not zero	Check setpoint voltage on PC-board pin 9 to pin11
Purge mode activated	Check that pin 12 has no external connection to pin 14.
Incorrect flow reading	Check that pad X9 is soldered. Verify zerreading by closing the gas line. Action points 1 and 2.
Incorrect solder pad connection	Normally Open operation: pads X5, X7 and X11 soldered, pads X6, X8 and X10 unsoldered. Normally Closed operation: pads X6, X8 and X10 soldered, pads X5, X7 and X11 unsoldered.
Incorrect actuator voltage	Voltage across actuator wires must be: more than 20V Norm. Open, less than 5V Norm. Closed.
PC-board failure	If the previous actions do not work, replace controller and contact QUALIFLOW for advice.
Incorrect nozzle adjustment	Remove mass flow controller and readjus nozzle.
Plunger stuck	Remove controller and clean

Problem 4: Controller will not open to full scale flow

Possible cause	Action
Incorrect supply pressure	Check gas pressure at inlet side of mass flow controller
Incorrect setpoint on PC-board (pin 9)	Check setpoint voltage.
Softstart activated	Check that pin 12 has no external connection to pin 10
Incorrect flow reading	Check pad X9 is soldered.
Incorrect solder pad connections	Normally Open operation: pads X5, X7 and X11 soldered, pads X6, X8 and X10 unsoldered Normally Closed operation: pads X6, X8 and X10 soldered, pads X5, X7 and X11 unsoldered.
Incorrect actuator voltage	Voltage across actuator wires must be: more than 20V Norm. Closed, less than 5V Norm. Open
PC-board failure	If the 4th and 5th actions of this table do not work, replace the controller and contact QUALIFLOW for advice
Incorrect nozzle adjustment	Remove mass flow controller and readjust nozzle
Plunger stuck	Remove controller and clean

Problem 5: Unstable control

Possible cause	Action
Unstable pressure	Check inlet and outlet pressure stability.
Defective electronics	Replace mass flow controller and contact QUALIFLOW for advice

SECTION 6 – GENERAL MFC PRINCIPLES

6.0. MFC & MFM PRINCIPLES

Mass Flow Controllers (MFCs) are used wherever accurate measurement and control of a mass flow of gas is required independently of flow pressure change and temperature change in a given range.

Mass Flow Meters (MFMs) are used wherever accurate measurement of gas is required without control of the flow which is done by another device.

To help understand how an MFC works, it can be separated into 4 main components: a bypass, a sensor, an electronic board and a regulating valve :

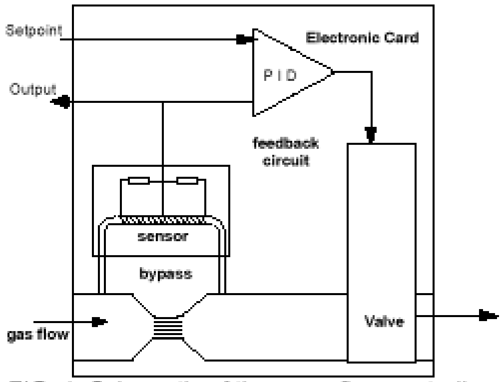


FIG. 1. Schematic of the mass flow controller.

The bypass, the sensor, and one part of the electronic board are the measurement side of the mass-flow controller and makes a Mass Flow Meter.

The regulating valve and the other part of the electronic board are the controlling side of the mass-flow controller and exist only on a Mass-Flow Controller.

So every Mass-Flow Controller includes a Mass-Flow Meter.

6.1. MEASUREMENT PRINCIPLES

The flow is divided between a heated sensing tube (the sensor), where the mass flow is actually measured, and a flow restriction or bypass, where the majority of flow passes.

The bypass is designed in a way that flow thru the sensor and thru the bypass is always proportional to the flow range for which the mass-flow is build.

The sensor is designed to deliver an output voltage almost proportional to the gas flow circulating thru it which is due to the bypass design proportional to the total flow circulating thru the mass-flow meter or controller.

The electronics board amplifies and linearizes the sensor signal so the output of the electronics board named “readout” gives a signal proportional to the total flow circulating thru the mass-flow meter or controller. Most of the time this signal is a 0-5 V voltage signal. 0 means “no flow” and 5 V means Full scale of the mass-flow. The full scale is the maximum flow for which the mass-flow is designed and calibrated to work with a good accuracy. It is always written on the stickers which are on the top of the cover and the side of the mass-flow stainless steel base. Also written on the sticker is the gas for which the mass-flow is calibrated to work with.

Why using a bypass ? Because the sensor element can only measure small flow (typically 5 sccm). So the bypass allow to measure greater amount of flow. On a 5 sccm full scale mass-flow, there is no bypass, all the gas flows thru the sensor. On a 100 sccm full scale mass-flow, the bypass is adjusted as when 100 sccm flow thru the mass-flow 5 sccm will flow thru the sensor and 95 sccm will flow thru the bypass.

6.2. SENSORS PRINCIPLES

Basically, the sensor uses the thermal properties of a gas to directly measure the mass flow rate. The sensor uses the basic principle that each gas molecule has a specific ability to pick up heat. This property, called the "specific heat" (Cp), directly relates to the mass and physical structure of the molecule and can be determined experimentally. The specific heat is well known for many gases and is generally insensitive to changes in temperature or pressure.

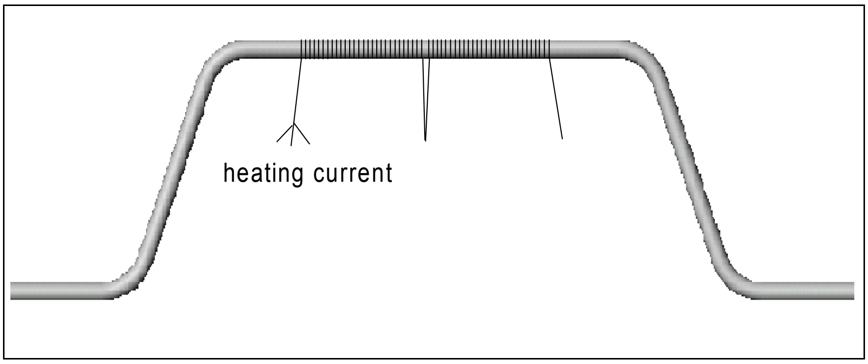
By adding heat to a gas and monitoring the change in temperature, the mass flow rate can be determined. To illustrate this concept, take the case of cool gas flowing through a heated tube. Mathematically, the heat loss can be described by the First Law of Thermodynamics,

$q = F.\ Cp\ \Delta T$

Where
q is the heat lost to the gas flow,
F is the mass flow,
Cp is the specific heat for a constant pressure,
ΔT is the net change in gas temperature as it traverses the tube.

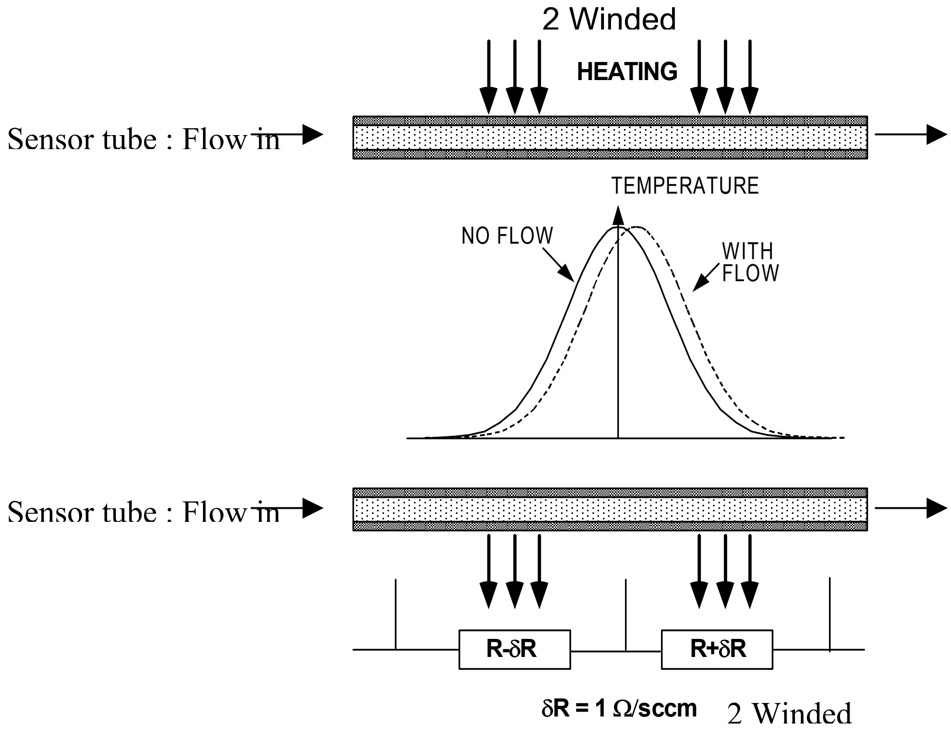
It is important to realize that both the specific heat and the flow rate determine the amplitude of the heat flux. As the mass and physical structure of molecules vary widely from gas to gas, so does the specific heat Cp. For the same molar flow rate, the heat flux can differ significantly for different gases. If this heat flux is monitored, the amplitude can be converted into an electrical signal. Given that the specific heat is known for the gas, then the mass flow rate can be determined directly from the electrical signal.

Now the MFC sensor includes capillary tube wound with two heated resistance and thermometers, measuring the change in temperature distribution created by the gas flowing inside this tube :



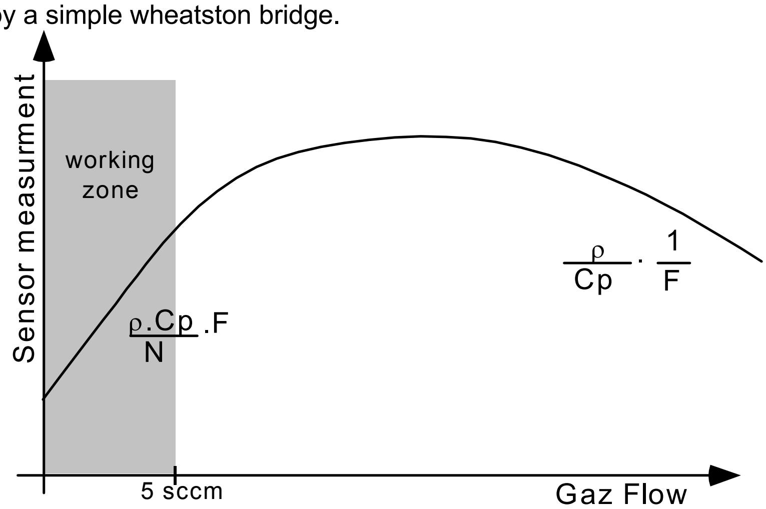
Sensor schematic

For zero flow, the upstream and downstream temperature will be equal. The windings are heated electrically to 80°C above the ambient temperature. When the gas is flowing, the upstream region cools down whereas the downstream region heats up causing a temperature gradient along, the length of the tube(see the sensor temperature profile figure).



Sensor temperature profile

The coils of the heating resistances are made with a thermal sensitive wire so that the temperature differences due to the flow are directly converted into resistances change. Those resistance change are convert in voltage by a simple wheatston bridge.



sensor response

For flow under 5 sccm the measurement is proportional to the flow with a coefficient which depends on:
ρ : Volumic mass of the gas
Cp : specific heat for a constant pressure,
N : “spin factor” Constant which depend of the molecular structure of the gas and compensates for the temperature dependence of Cp.

Value of N :
Monoatomic gas 1.04
Diatomic gas 1.00
Triatomic gas .94
Polyatomic gas .88

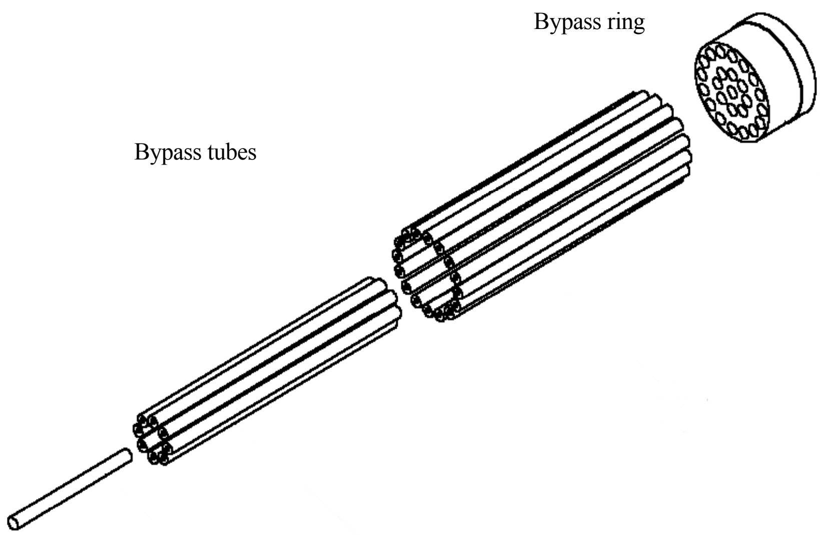
For flow higher then 5 sccm the sensor is first non linear then the measurement starts to decrease with flow because the gas flow is too fast and cool the 2 winded resistances instead of cooling the first one and heating the second one. This is the reason why bypass is necessary for higher full scale than 5 sccm.

Also the fact that the coefficients N and Cp are different from one gas to another explains why mass-flow can NOT be changed from one gas to another without using a special coefficient to converter the measurement or recalibrate the mass-flow.

Because of sensor saturation, if flow is ten time the full scale, output will be almost “no flow”! This will never happen on a mass-flow controller as the valve of the mass-flow will act as a restriction and will not allow the gas to flow ten times the full scale. But it can easily happened on a mass-flow meter, as, if there is no restriction on the gas line nothing in the mass-flow meter will limit the gas flow.

6.3. BYPASS PRINCIPLES

Acting as a restrictive element, the bypass is composed of a series of capillary tubes (or washers) held in a special bypass ring. The ring fits around the body and may hold up to 24 tubes. The number of tubes and their diameter depend on the customer’s specifications of gas type and flow range. For high flow rates the bypass tubes are replaced by a screen bypass.



Bypass tubes

The bypass principles are based on the laminar flow theory : When flow is laminar, the flow is proportional to the differential pressure between inlet and outlet of the tube :

$$F_m = \rho .. \frac{\pi .. R^4}{8.\eta .. l} . (P_{up} - P_{down})$$

ρ : Volumic mass of the gas

η : Viscosity of the gas

l : length of the tube

R : radius of the tube

So when a sensor tube (radius Rs, length ls) and a bypass tube are in parallel (radius Rb, length lb), the flow in the sensor tube is proportional to the flow in the bypass :

$$F_s = \frac{R_s^4 . l_s}{R_b^4 . l_b} . F_b$$

However this is true only if the flow is laminar so if the tube are small enough. This is way bypass are made by several thin tube instead of only one tube.

It is important to notice that a mass-flow meter or controller measure the flow thru the sensor which is not the total flow but only one part of the flow split by the bypass according to last equation. In this equation radius of the sensor tube and bypass tube is at power 4. Consequently any deposition in one of the tube changing the diameter will change the accuracy of the measurement. Also because of the need to have a laminar flow, bypass tube and sensor tube may have clogging. This why mass-flow meter and controller must be used with clean, filtered gases.

6.4. CONTROL PRINCIPLES

The electronic compares the amplified mass flow rate value (measured by the sensor) to the desired set point. This comparison generates an error signal that "feeds" the regulating valve.
The difference is used to drive the control valve. The control valve will proportionally open or close until the output is equal to the setpoint.

Note that valve can be normally open or normally close. This is the position that will have the valve when the mass-flow is not connected on power supply.

The valve can be actuated by a magnetic solenoid. Then it can be normally open or normally close and response time of the valve itself is almost instantaneous. In practise response time of the mass-flow controller is limited by the response time of the sensor. As sensor is based on thermal exchange it takes 1 to 5 s for the sensor to measure a gas change. Several techniques allows to increase this response time and allow to get on the best mass-flow response time bellow 5s.

SECTION 7 - WARRANTY AND SERVICES

7.0. PRODUCT WARRANTY

1. Qualiflow products are guaranteed against defects in materials and workmanship for a period of one year from the date of shipment, if used in accordance with specifications and not subject to physical damage, contamination, alteration or retrofit.

2. Buyers undertake to check and inspect the goods and to notify Qualiflow of shipment incidents by fax, phone or e-mail as soon as possible after receipting the goods.

3. During the warranty period, products must only be repaired by authorized Qualiflow service centers; otherwise, the Qualiflow product warranty will be invalidated.

4. Repairs will be performed free of charge during the one-year warranty period. If MFCs are out of warranty, Qualiflow will notify the owner of replacement or repair costs before proceeding. Factory service and repairs are guaranteed 90 days. The warranty excludes consumable materials and wear parts (in teflon, viton, etc.).

5. No MFC will be accepted for repair or warranty without a decontamination and purge certificate.

6. Each MFC is individually checked (visual inspection of fittings, helium leak test and flow calibration). Qualiflow shall not be responsible for any damage caused by gas leakage or the use of a dangerous gas. Users are responsible for following the safety rules applicable to each gas they use. Improper use of a Qualiflow MFC will void the warranty, and MFCs that have been damaged as a result of improper use will not be replaced by Qualiflow.

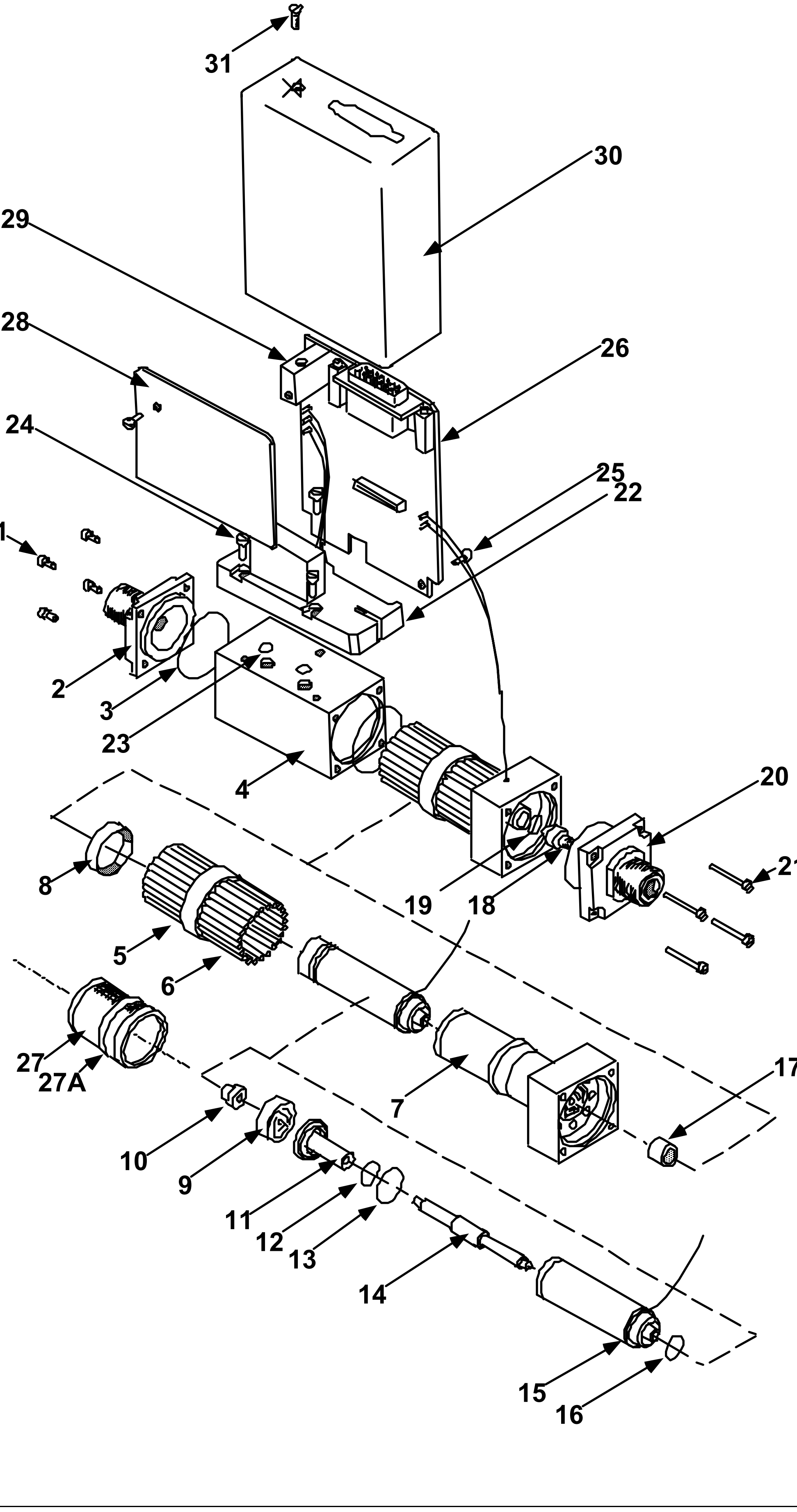
7. Specific warranty requirements are as follows :
    a. Gas must be clean and particle-free, which means a filter must be fitted in the gas line upstream of the MFC.
    b. Gas must comply with the following pressure specifications:
        i. Gas pressure must never exceed 10 bars.
        ii. Differential pressure must be more than 500 mbar for full-scale flow through the MFC valve.
        iii. Differential pressure must be less than 3 bars for the MFC valve to regulate without gas-flow oscillation.
        iv. Pressure at the mass-flow inlet must be regulated by an accurate pressure regulator to prevent gas-flow oscillation.
    c. Electrical connection requirements are as follows:
        i. The system must be wired carefully: non-observance of the pinout may irreversibly damage the electronic board inside the MFC, in which case the warranty will be invalidated.
        ii. A stable power supply is required, with ripple below 5mV.
    d. Gas connections: the VCR gland must be handled carefully. Qualiflow guarantees that all glands have been individually inspected and are scratch-free.
    e. Fitting procedure: the fitting procedure set out in the manual must be followed meticulously. Specifically, the purge procedure is very important if corrosive gases or toxic gases are used.
    f. The mass-flow must not be dismounted: the MFC warranty will be invalidated if the seal between the MFC block and cover is torn.

7.1. SERVICES

QUALIFLOW Products Engineers will help you to solve your problems regarding operation, calibration, connection, gas flows, gas mixture, etc…

We deliver technical support or maintenance within 24 hours.
Visit www.qualiflow.com and find your nearest repair and calibration center.

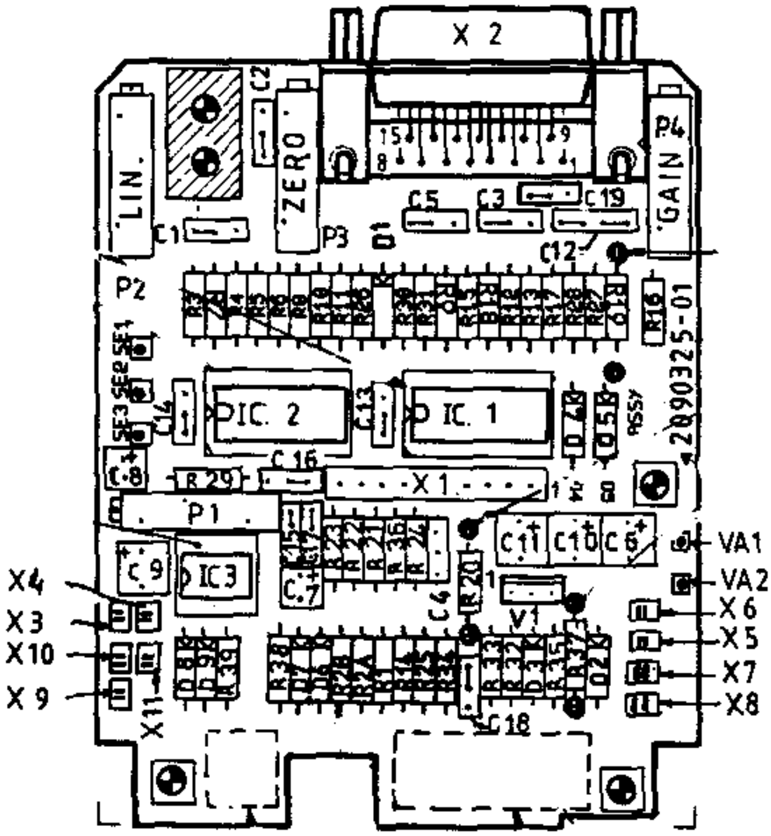
SECTION 8 - PARTS LISTS AND DESCRIPTION



Item	Qty	Description	Part Number
1	4	Screw	808071023
	4	Washer	808015559
2	1	Fitting plate inlet side	
		Male 1/4" VCR compatible	2018535-03
		Female 1/4" VCR compatible for Moduline®	2018535-01
		1/4" Swagelok compatible	2018535-02
3	3	O-ring	see item 32
4	1	Body	2001563-02
5	1	Bypass ring 24 holes	2001598-01
6	-	Bypass tube	
		ID 0.0 mm (shutoff pin)	808017489
		ID 0.4 mm	2001912-01
		ID 0.6 mm	2001912-02
		ID 0.8 mm	2001912-03
7	1	Actuator base	2001628-02
8	1	Actuator cap	2001652-01
9	1	Spacer ring	2001555-01
10	2	Locknut &	808071811
	1	Washer	4190201
11	1	Spool hub and crown spring	2001946-01
12	1	O-ring	see item 32
13	1	O-ring	see item 32
14	1	Actuator assembly	2001814-01
15	1	Magnetic coil assembly	2005584-01
16	1	O-ring	see item 32
17	1	Stem tip	
		with fluoro elastomer Viton®	2001882-02
		with perfluoroelastomer Kalrez®	2001882-04
		with polychloroprene Neoprene®	2001882-03
18	1	Nozzle	
		0.5 mm	2001696-02
		0.8 mm	2001696-03
		1.5 mm	2001696-04
		2.5 mm	2001696-05
19	1	O-ring	see item 32
20	1	Fitting plate outlet side	
		Male 1/4" VCR compatible	2002203-02
		Male 1/4" VCR compatible	
		for Moduline	2002203-02
		1/4" Swagelok compatible	2063131-01
21	4	Screw	808015532
	4	Washer	808015559
22	1	Sensor assembly	
		ID 0.4 mm	2002032-01
		ID 0.7 mm	2002032-02
23	2	O-ring	see item 32
24	3	Screw	4180324

	3	Washer	808015559
25	2	Screw	4180309
26	1	Main PC-board	2090325-01
27	1	Assy screen bypass	2002164-01
27A	1	Covering screen bypass	2002067-01
28	1	Autozero PC-board kit	2001644-01
29	1	PC-board spacer block	2002113-01
	1	Screw	4180314
30	1	Cover	2002084-01
31	1	Screw	4180313
32	1	Complete set of O-rings	
		with fluoro elastomer Viton®	2002148-011
		with perfluoroelastomer Kalrez®	2002148-033
		with polychloroprene Neoprene®	2002148-022

SECTION 9 – PC BOARD LAYOUT



SECTION 10 – PC BOARD SCHEMATICS