



AFC 260/AFC 261

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SECTION 1 - INTRODUCTION

1.1.SURVEY OF TYPES AND GAS RANGES

This user's manual covers the 260,261 models of QUALIFLOW mass flow meters and 360 & 361 mass flow controllers. Gas table and nomenclature are given in Table I.

Gas Range	Mass flow meters	Mass flow controllers
0 - 5000 sccm	AFM-360	AFC-260
5 - 20 slm	AFM-361	AFC-261

Table 1.1. Gas Ranges and nomenclature

Note : The figures related to the gases are with respect to nitrogen.
For other gases a conversion factor is given in relation to nitrogen (3.4.).

1.2. SPECIFICATIONS

Spec.	AFM-360-361	AFC-260	AFC-261
Input	+15VDC±5%, 25mA -15VDC ±5%, 25mA	±15VDC +5%, 25mA -15VDC ±5%, 180mA	±15VDC +5%, 25mA -15VDC ±5%, 180mA
Setpoint Signal		0.1 - 5 VDC	0.1 - 5 VDC
Output Signal	0 - 5 VDC	0 - 5 VDC	0 - 5 VDC
Response time (typ)		6s	6s
Repeatability	0,3% of Full Scale	0,3% of Full Scale	0,3% of Full Scale
Accuracy	± 1% of Full Scale	± 1% of Full Scale	± 1% of Full Scale
Gas T°. Range	5 - 40°C	5 - 40°C	5 - 40°C
T° coefficient	less than 0.1%/°C	less than 0.1%/°C	less than 0.1%/°C
Gas Pressure	10 bars max.	10 bars barr max. 0.5-3 at dlff 0.7-3 at diff for H ₂	10 bars max. 1 0-3 at dlff 1.2-3 at diff for H ₂ *
Pressure Coefficient	0.1%/atm(typ)	0.1%/atm (typ)	0.1%/atm (typ)
Leak Rate	<2.10 ⁻⁹ scc/sec.	<2.10 ⁻⁹ scc/sec.	<2.10 ⁻⁹ scc/sec.

Table 1.2. : Specifications values.

* For a differential pressure under 1.5 bar (22 psi) it is recommended to use a QUALIFLOW ® mass-flow controller AFC 50.00 to control 20 slm full scale flow.

Standard Gas table :

AFM-360 / AFC-260 (SCCM)	AFM-361 / AFC-261 (SLM)
0.2 - 10	0.2 - 10.0
0.4 - 20	0.4 - 20.0
0.6 - 30	
1 - 50	
2 - 100	
4 - 200	
6 - 300	
10 - 500	
20 - 1000	
40 - 2000	
60 - 3000	
100 - 5000	

Table 1.3 : Standard ranges values.

	Standard (VCR 1/4" MM)	Moduline (VCR 1/4" FM)	SWG (1/4")
AFC 260 10-500sccm	628021120.00	628021220.00	628021020.00
AFC 260 500-2000sccm	628021130.00	628021230.00	628021030.00
AFC 260 2-5slm	628021140.00	628021240.00	628021040.00
AFC 260 5-10slm N2,H2,O2,Ar	628021150.00	628021250.00	628021050.00
AFC 261 5-20slm	628051110.00	628051210.00	628051010.00
AFM 360 10-5000sccm	628151110.00	628151210.00	628151010.00
AFM 361 5-20slm	628161110.00	628051210.00	628161010.00

Table 1-4 : Part numbers of AFC 260, 261 and AFM 360,361

Note : AFC and AFM are delivered with Viton® seals except NH3 mass-flow which are delivered with neoprene seals. Please contact your local representative for other kind of seal material.

	260/360 MM	260/360 Mod.	260/360 SWG	261/361 MM	261/361 Mod	261/361 SWG
Long	123 mm	141.6 mm	112 mm	157	212.6	146.7
Wide	25mm	25mm	25mm	31mm	31mm	31mm
High	110 mm	110 mm	110 mm	115 mm	115 mm	115 mm
Weight	500 gr	500 gr	500 gr	950 gr	950 gr	950 gr

Table 1-5 : dimensions of AFC 260, 261 and AFM 360,361

SECTION 2 - INSTALLATION

2.1 INTRODUCTION

This section is made of four parts and contains all the information necessary to install the AFC 260 -261 mass flow controller or AFM 360 -361 mass-flow meter.

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

2.2 UNPACKING

The AFC 260 -261 mass flow controller or AFM 360 -361 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 MECHANICAL INSTALLATION

2.2.0 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 260 -261 mass flow controller or AFM 360 -361 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.

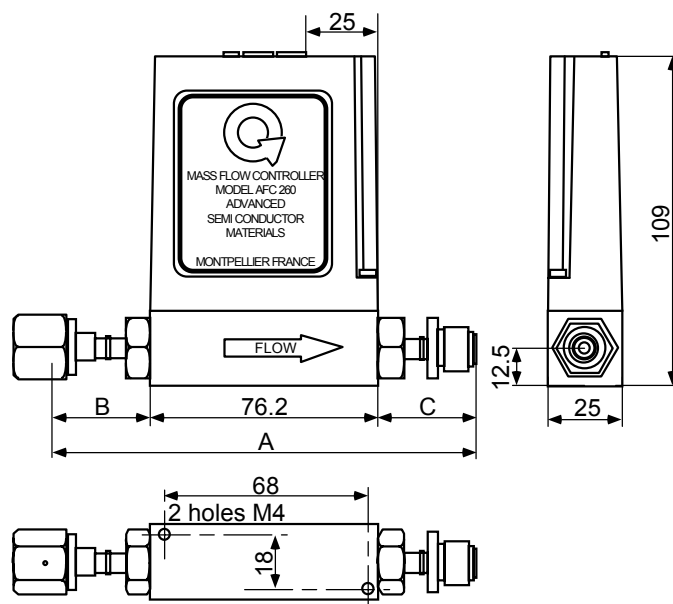


Figure 2-1 Dimensions of the AFC 260 - or AFM 360 mass-flow meter

Type	Inlet	Outlet	A	B	C
Modu C	Female VCR	Male VCR	141.6	32.95	32.45
Standard	Male VCR	Male VCR	123	23.8	23
Swagelok	Swagelok	Swagelok	112	18.2	17.6

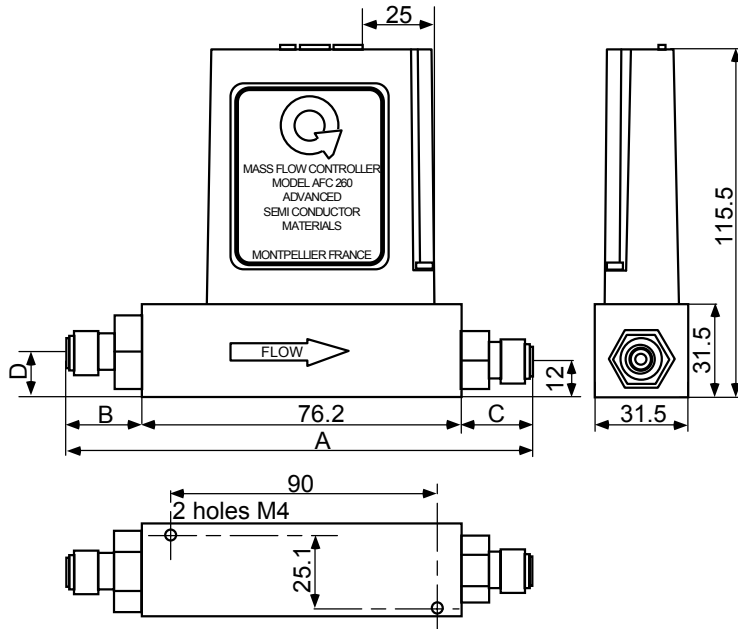


Figure 2-2 Dimensions of the AFC 261 - or AFM 361 mass-flow meter

Type	Inlet	Outlet	A	B	C	D
Modu C	Female VCR	Male VCR	212.6	80.9	23.7	12
Standard	Male VCR	Male VCR	157	25.3	23.7	14.5
Swagelok	Swagelok	Swagelok	146.7	20.5	18.2	14.5

2.2.1 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.

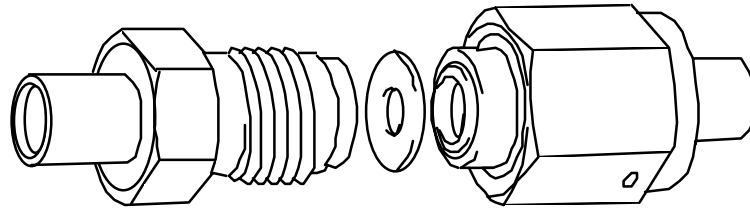
Important: When installing the mass flow controller, ensure that the arrow on the back of the unit points in the same direction as the gas flow.

2.2.1.1. VCR COMPATIBLE COUPLINGS

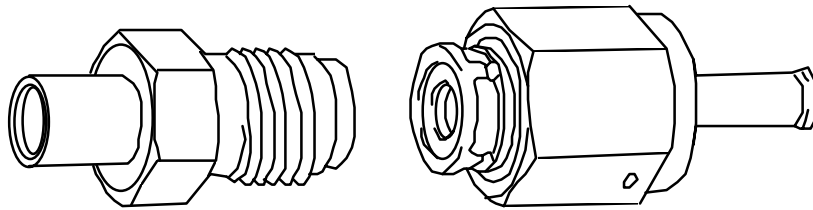
The AFC 260 -261 mass flow controller or AFM 360 -361 mass-flow meter normally come with 1/4" male VCR compatible couplings on both sides. To install the AFC/AFM, follow the steps listed below. Refer to figure 2-2.

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.



VCR original style gasket



VCR retainer gasket

Figure 2-2 VCR compatible couplings

2.2.1.2 SWAGELOK COMPATIBLE COUPLINGS

On request the AFC 260 -261 mass flow controller or AFM 360 -361 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.

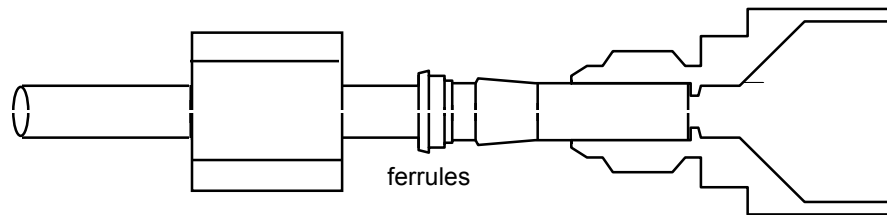


Figure 2-3 Orientation of Swagelok compatible couplings

2.4 ELECTRICAL INSTALLATION

2.3.0 GENERAL

It is important to read section 2.3 ELECTRICAL INSTALLATION before connecting the AFC 260 -261 mass flow controller or AFM 360 -361 mass-flow meter, so that you understand the electrical configurations that are possible. Within this section, there are the following sub-sections:

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

2.3.1 CONNECTIONS

The standard AFC 260 -261 mass flow controller or AFM 360 - 361 mass flow meter has a cardedge connector. The pin arrangement is shown in figure 2-4.

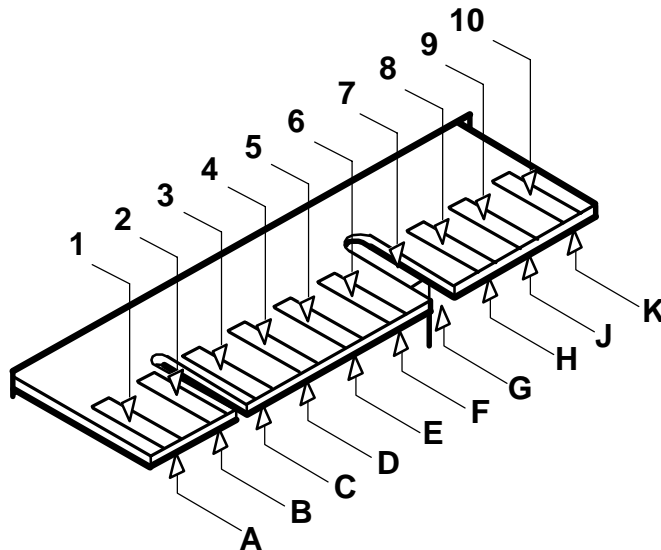


Figure 2-4 cardedge connector pin arrangement

Table 1 gives a more detailed explanation about the functions available on every pins :

Cardedge connector

1 Case Ground	A Control Input 0.1 - 5 VDC
2 Common	B Common valve ****
3 Output O - 5 VDC	C Common
4 +15 VDC	D Valve test point; Soft start connection **
6 Zener Test Point	F -15 VDC
7	J Sensor Up-stream ***
8	K Sensor Common ***
9	L Sensor Downstream ***
10	Extra Output *

Notes: * 1. For vacuum pressure control applications. See 2.3.3.
 ** 2. Soft start connection. See 2.3.2.
 *** 3. Not available in earlier PC boards.
 **** 4. Valve common is jumpered to C. Remove this jumper and use separate common is advise everytime it is possible.
 5. Any DC voltmeter or recorder can be used to visualize the output signal. Input impedance should be at least 5000 ohms.
 6. The control Input signal should be from any voltage source with maximum impedance 2500 ohms.

Table 1 Description of D-connector pin functions

2.3.2 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.

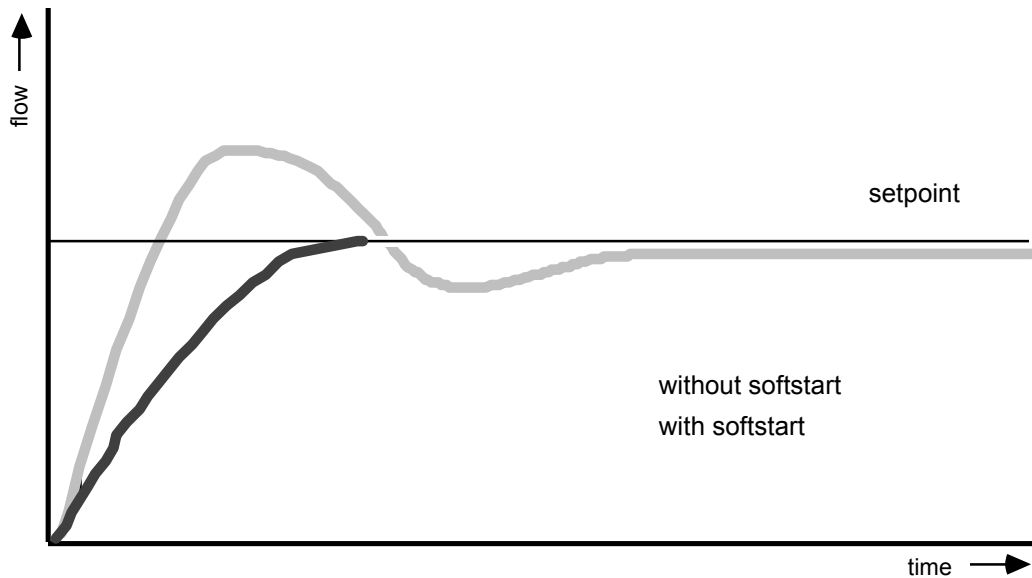


Figure 2-6 Effect of the soft start mode

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.

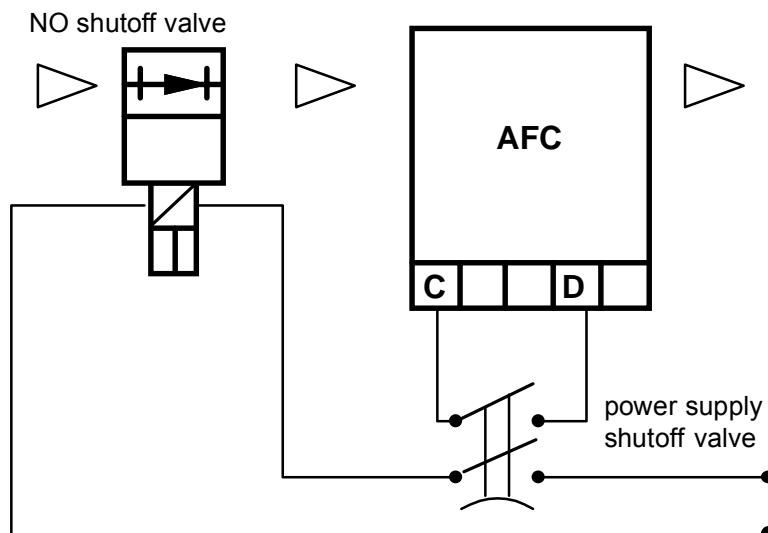


Figure 2-7 Softstart circuit

2.3.3 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 (see PC-board layout in section 4.2). 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.

2.3.7 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.

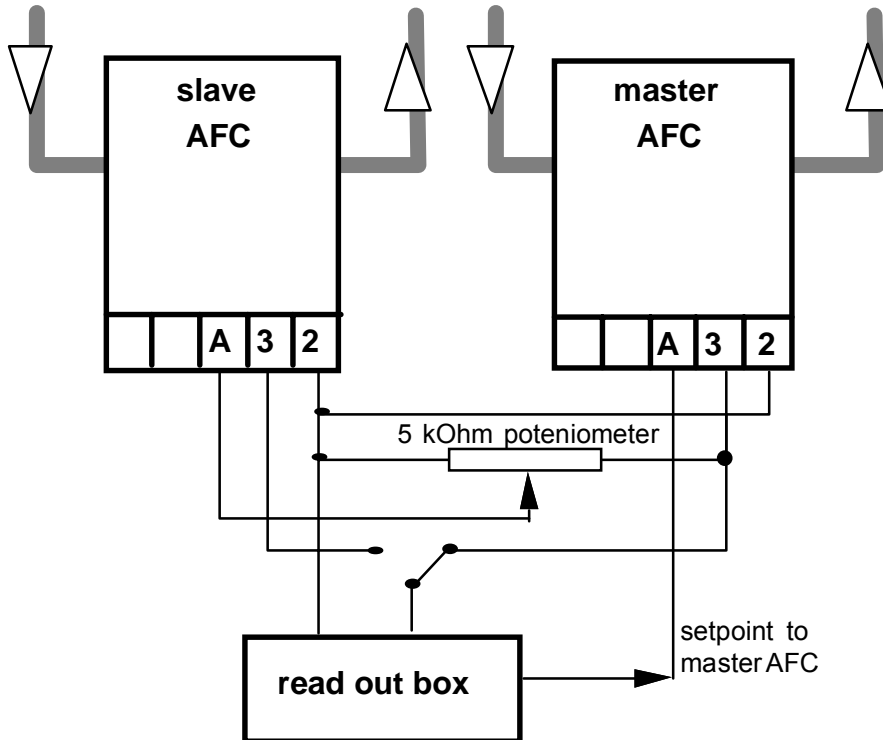


Figure 2-9 Ratio control

2.3.4 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.

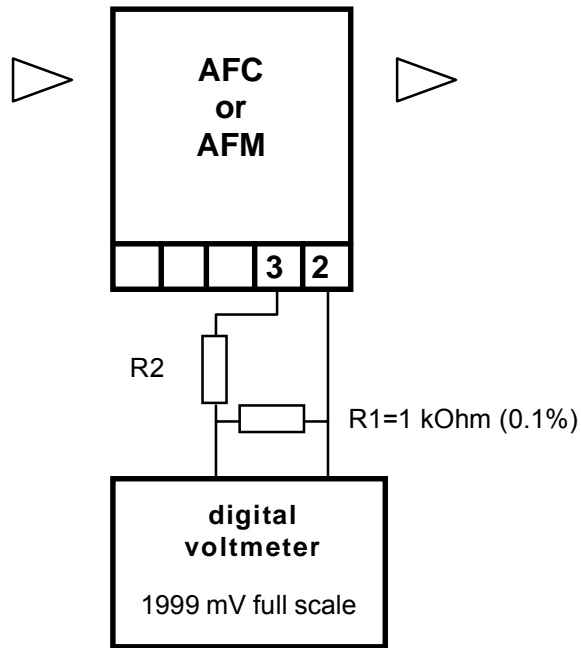


Figure 2-11 Voltage divider arrangement

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.

2.5 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 - OPERATION

3.1 SENSOR AND BYPASS

The massflow sensor is a laminar-flow device, which forms together with the bypass the flowpath. The splitting up of the flow is additive and independent of gas pressure and temperature. The flow rate through the sensor capillary tube is measured by resistance thermometers, wound on the outside of the tube.

These thermal sensitive resistors are part of a bridge circuit. With no flow through the tube, the bridge is balanced and the differential amplifier, that follows the bridge, gives zero volt output. With flow, the internal heat exchange is altered and consequently the temperature profile along the tube, which causes a bridge output signal.

A linearity circuit corrects the possible inherent non linearity of the sensor. The output signal is amplified to give 5.00 VDC at the required flowrate. By means of bypass-substitution the flow through the sensor is made almost the same for all the flow ranges.

3.2 CONTROL VALVE

AFC-260 and AFC-261 flow controllers are equipped with a completely interchangeable control valve. The valve housing contains the shut-off plunger and the actuator whereas the orifice is situated in the base-block. In case of contamination or clogging, the valve can be taken out, giving access to the seat and the shut-off plunger. The critical places can be cleaned, even polished and the valve can be reinstalled. (See cleaning instructions 5.4.).

3.3 ELECTRONICS

In the schematic (see last page), the sensor elements are shown between u, c and d. R1 and R2 complete the bridge together with potentiometer R3 (ZERO), for balancing of the bridge. OpAmp C amplifies the differential voltage. Potentiometer R9 (GAIN), together with R8, R10 and R5 determine the D.C. gain. R11 with C4 give the differentiating action; a sudden change in the bridge voltage causes an extra gain (AC gain). The time constant of this transient is determined by R11. At the factory this resistor is selected during transient tests for every individual meter or controller.

Z1 and R14, R12 and R13 determine the current through the sensor. As not every sensor/bypass pair is completely linear, linearizing circuit (Op. Amp. B, R15 until R20) varies the sensor current as a function of the output voltage. The influence of R19 (LINEARITY) is maximal at half of full scale output and almost zero at zero and full scale output.

Output voltage and setpoint voltage are compared by Op Amp A. If flow is too low, T2 closes further to decrease the current through the control valve and vice versa.

R25 forms a current limiter, as all valves close at different voltages. R25 is to be selected in shut-off tests.

C6 and R24 reduce the gain of C during a flow and/or setpoint transient, providing a slowly changing valve control voltage, which in turn gives a gradual change in flow rate.

D2 and D3 protect the electronics from damage in case + and -15 V power is reversed.

Op Amps .A, B and C are parts of a quad i.c., 14 pins DIL. The commercial available i.c. enhances field service and reduces down-time, as replacement hardly effects accuracy.

3.4 CONVERSION DATA

If a mass flow meter or -controller, calibrated e.g. for N₂, 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 $\pm 1\%$ (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(N₂) are the tabulated values of the conversion factors. In this example, when X is say CO₂ (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 CO₂, if measured with a unit, that was originally calibrated for N₂ is obtained by multiplying the output by 0,746.

#	Name	Formula	Density	Sp. Heat[g/l]	C[cal/g/degC]
1*	Acetone	C ₃ H ₆ O	2.59	0.310	0.340
2	Acetylene	C ₂ H ₂	1.169	0.40	0.58
3	Air	-	1.2929	0.2401	1.000
4	Allene	C ₃ H 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 ₄ H ₁₀	2.65	0.404	0.26
11	I-Butene	C ₄ H 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 ₂ N ₂	2.34	0.264	0.44
21	Cyclopropane	C ₃ H ₆	1.878	0.316	0.460
22	Deuterium	D ₂	0.1800	1.728	0.999
23	Diborane	B ₂ H ₆	1.24	0.495	0.44
24	Dichlorosilane	SiH ₂ Cl ₂	4.54	0.141	0.43
25	Dichlorodimethylsilane	Si(CH ₃) ₂ Cl ₂	5.754	0.2029	0.234
26	Dimethylamine	(CH ₃) ₂ NH ₃	2.03	0.362	0.370
27	Dimethylether	(CH ₃) ₂ O	2.08	0.3367	0.390
28	Ethane	C ₂ H ₆	1.352	0.415	0.49
29	Ethyl chloride	C ₂ H ₅ Cl	2.90	0.234	0.40
30	Ethylene	C ₂ H ₄	1.258	0.366	0.59
31	Ethylene oxide	C ₂ H ₄ O	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 ₃ F	6.3	0.1415	0.34
35	Freon-12	CCl ₂ F 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 ₂ Cl ₂ F ₄	7.7	0.163	0.22
41	Genetron-21	CHCl ₂ F	4.64	0.144	0.41
42	Genetron-115	C ₂ ClF 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 ₂ Se	3.613	0.103	0.78
52	Hydrogen sulphide	H ₂ S	1.534	0.244	0.78
53	Isobutane	C ₄ H ₁₀	2.63	0.395	0.26

#	Name	Formula	Density	Sp. Heat[g/l]	C[cal/g/degC]
54	Isobutylene	C ₄ H ₈	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 ₃ OH	1.430	0.3277	0.583
58	Methylamine	CH ₃ NH ₂	1.392	0.400	0.491
59	Methyl bromide	CH ₃ Br	4.29	0.113	0.56
60	Methyl chloride	CH ₃ Cl	2.28	0.200	0.60
61	Methyl fluoride	CH ₃ F	1.53	0.267	0.67
62	Methyl mercaptan	CH ₃ SH	2.146	0.2506	0.508
63	Methyl trichlorosilane	SiCH ₃ Cl 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 ₂ O ₄	3.675	0.200	0.37
69	Nitrogen trifluoride	NF ₃	3.173	0.178	0.434
70	Nitrous oxide	N ₂ O	1.98	0.206	0.72
71	Oxygen	O ₂	1.429	0.2183	0.996
72	Pentaborane	B ₅ H ₉	2.9	0.565	0.17
73	n-Pentane	C ₅ H ₁₂	3.4	0.38	0.21
74	Perfluoroethylene	C ₂ F 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 ₃ H ₈	1.98	0.392	0.35
78	Propylene	C ₃ H 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) ₃ N	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 ₂ H ₃ Br	4.83	0.123	0.46
89	Vinyl chloride	C ₂ H ₃ Cl	2.82	0.202	0.48
90	Vinyl fluoride	C ₂ H ₃ F	2.060	0.241	0.551
91	Water vapour	H ₂ O	0.804	0.445	0.817
92	Xenon	Xe	5.88	0.039	1.41
93	Hexafluoroethane	C ₂ F 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 4 - ADJUSTMENT PROCEDURE

4.1. REQUIRED FACILITIES

To perform any adjustment, cleaning or replacement on massflow equipment, appropriate tools and facilities must be present, as these are high accuracy transducers.

The facilities are:

1. An accurate reference massflow measuring system or a flow meter. (note the pressure and temperature corrections). Normal rotameters are not accurate enough. The only suffice when relative rough measurements or flow monitoring are necessary.
2. A clean room, clean tools.
3. A voltmeter (at least 1000 Ω/V).
4. Supply of gas, preferably N₂ for safe working.

4.2. POTENTIOMETERS ADJUSTMENT

To gain access to the p.c. board, carefully remove the cover from the body. Every flowmeter and -controller is calibrated at the factory for a particular gas and flow range, as indicated on the top sticker, within $\pm 1\%$. If any adjustment is necessary, a reference measuring system with at least the same accuracy should be used. (c.f. 4.1.1.).

1. To remove containment's, the unit must be flushed and dried with nitrogen.
2. Apply power to the unit and monitor the output signal. Obey a warm-up time of about 10 minutes.
3. With no flow (caps on in- and outlet fittings) adjust the ZERO potentiometer R3 to give zero output.
4. Apply gas to the inlet fitting and put the reference flowmeter in series.
5. Disconnect the valve lead wires. The valve will fully open. Now the flowcontroller works essentially the same as a flowmeter.
6. Adjust the flow to exactly the full scale value. Adjust the GAIN potentiometer R9 to give 5.00 VDC output.
7. Recheck ZERO (step 3).
8. At half of the full scale flow, the meter should give 2.50 VDC output. If not, adjust the LINEARITY potentiometer R29. After this, ZERO and GAIN should be checked and readjusted if necessary (ZERO and GAIN should normally be independent of LINEARITY). Continue these steps until all points are within desired calibration.
9. Flowcontrollers can also be calibrated while working as flowcontrollers. First, calibrate ZERO as per step 3. Then, with 5.00 VDC setpoint, adjust GAIN, until the actual flow is equal to the required flow rate. Next, with 2.50 VDC setting, adjust LINEARITY. (Note that output stays at the setpoint value now, while flow varies).

4.3. VALVE ADJUSTMENT

1. Plumb the inlet side of the controller to a regulated supply of the correct gas. Connect the reference flowmeter in series or monitor the flow as measured by the controller.
2. Bring the Inlet pressure to 0.3 -- 0.4 bar (AFC-260) or 0.6 -- 0.8 bar (AFC-261) and disconnect the valve lead wire. While gently turning the adjustment nut on top of the valve, bring the flow to 100% of the required value. Reconnect the lead wires.

3. Check that the valve will shut off to less than 2% of F.S. flow at all 0.3 and 3 bar.
4. If the valve does not close adequately, check the valve heater voltage; this may be increased to a maximum of approximately 10 VDC (AFC-260 or 15 VDC (AFC-261) by reducing the current limiting Resistor R25. If valve still will not close, the seat may be contaminated. For further repair, see 5.4.

4.4. CHANGE OF CALIBRATION

1. If it is desired to calibrate the unit for a gas other than the original calibration, there may not be sufficient adjustment in the GAIN potentiometer to obtain 5.0 VDC at full flow. In such case, center the GAIN potentiometer and replace R10 the unit, following the instructions 4.2.
2. If it is necessary to change the range of a flowmeter or -controller beyond the electronics adjustment capabilities, one has to replace the bypass assembly to produce the nominal sensor output at full scale flow. In addition, the valve may have to be replaced.
The bypass is a preadjusted assembly which can be removed and reinstalled with the use of a screwdriver.
Also bypass washers may be added or removed, in such a way that the number of grooves that is added or removed is proportional to the shift in flow range. There are three types of washers, with one, with ten and with forty grooves after such replacements, recalibration as per instructions 4.2. is absolutely necessary.

4.5. DYNAMIC RESPONSE ADJUSTMENT

After replacement of a valve, recalibration of a unit to a different range of gas, it may be necessary to readjust the feedback control circuit in order to optimise the dynamic response and stability performance of a controller.

This entails reselecting R11 and R24 during transient tests. This is best accomplished by setting the inlet pressure to 20psi (or the known operating pressure), while switching the setpoint from 50% to 100% of full scale and vice versa and noting the response. The flowmeter section, valve and maximum valve voltage must have been previously set.

1. After calibrating the flowmeter section and selecting R25, install C6 (22 Ω F, 25 VDC) and R24 (20k) and R11 (1k) with resistance substitution boxes.
2. Alternately give 100% and 50% setpoint and observe the output and response. Best performance is when about 5% overshoot is observed. Reducing R11 reduces the time constant and overshoot but increases output ripple.
3. Once R11 has been selected and installed increase R24 to the highest possible value. Increasing R24 increases the dynamic gain of the controller, thereby improving the dynamic response to changes in upstream pressure and/or setpoint.
Too high a value will result in output oscillation and instability.
Typical values are for Hydrogen and Helium:
R11 about 400 to 700 Ω , R24 30 k Ω to 100 k Ω
For nitrogen and other gases :
R11 about 400 to 700 Ω , R24 60 k Ω to 360 k Ω .

SECTION 5 - MAINTENANCE

5.1.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 N₂ 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.

5.2.DISASSEMBLY AND ASSEMBLY PROCEDURES

Refer to exploded views.

1. Unscrew in- and outlet-fittings
2. Remove the sensor-screws, after having the lead wires unsoldered from the p.c. board. Handle the sensor with care.
3. Remove the screws which hold the valve print plate to the base block after unsoldering the valve leads wires.
4. Carefully remove the valve body from the base block. Remove the two o-rings.
5. Unscrew the bypass. Do not damage the thread or the bypass washers.
6. The valve can be further take apart, by unscrewing the adjustment not completely in pulling the tube-holder with actuator tube and heater element carefully out of the valve housing.

Note: If o-rings are dirty, cut or cracked, they have to be exchanged with appropriate new ones.

The sequence of assembling is following above instructions in the reverse direction.

Caution : The sensor capillary sometimes extends beyond the seals o-rings. When positioned on the base without verifying that capillary ends fit in the holes in the base, the capillary can be bend or damaged. Therefore, center the sensor by means of the mounting screws, hold it up and then fasten the screws.

Reassembling of the valve assembly into the base block should always be done with the adjustment not fully opened. (Fully turned anticlockwise).

Afterwards, follow-up valve adjustment procedure 4.3.

5.3. SENSOR CLEANING AND REPLACEMENT

If it is determined that the sensor is contaminated, flush with a solvent in hypodermicneedle, while running a small wire (0.15 mm diameter, available on request).

Do not immerse the entire sensor assembly in a solvent; the solvent will keep under the cover and destroy or at least change the sensor characteristics. Slow dry with nitrogen.

If the sensor resistance has changed or even open circuit is measured, the assembly should be replaced. The measured resistance between red and green (R1) and between red and yellow (R2) must be between 160 and 190 Ω and $\Delta R = R2-R1$ must be less than ± 1 Ω. Check also that there is no short-circuit between the tube and the red wire.

Examine the sensor seals, and replace when damaged.

5.4. CONTROL VALVE CLEANING AND REPLACEMENT

After having taken the valve out of the base, the status of the shut-off ball and the seat in the base block can be examined. The shut-off ball can be cleaned with alcohol, freon or even a HF solution (5% HF, 95% deionised water).

Do not completely immerse the assembled valve housing in a solvent, as the heater element can be destroyed. To get access to the inside, proceed as indicated in 5.2.6.

The conical seat in the ball can be treated with solvent and a felt tip. If appropriate polishing equipment is available, the seat and shut-off ball can be polished.

After polishing, the parts must be cleaned.

If the critical parts are unfortunately corroded or attacked too much, replace.

Afterwards, follow assembling instruction 5.2. and adjustment instruction 4.3.

SECTION 6 - TROUBLESHOOTING

6.1.INITIAL CHECK

1. Check set-up and procedure against connection instructions 2.1. and 2.2. Permanent damage to the unit may result if purging procedures are not followed, or if line power is accidentally applied to the signal leads.
2. Test line cord for compliance with pinassignment, and continuity from all wires to correct pins. Use hipot tester to check for any pin-to-pin shorts; during this test, flex the cable coming out of the connector to find intermittent shorts.
3. Check insulation resistance from pins to base- All except pin 1 should exceed 50 MΩ at 50 VDC.
Pin 1 to base should measure less than 1 Ω.
4. Proceed as indicated in 4.2., points 1,2 and 4.

6.2.SEVERAL SYMPTOMS

Symptom	Possible Cause	Remedy
No output	Faulty meter No actual Flow Sensor clogged Valve closed Electronics failure Faulty power supply	Read output at pins 3 and 2 directly with alternate meter. Check pressure, valve positions line or filter blockage. Follow 5.3. Follow 5.4 See below Check input / output voltages (±15VDC, +5VDC).
Maximum signal (between 150% and 200% of full scale) a) Indication correct: flow is high b) Indication erroneous Signal offset at zero flow Valve will not close	Valve defective Open resistance on sensor element Electronics failure Electronics not adjusted Contamination Open valve heater Electronic failure Mechanical damage from overpressure or other cause Operation on wrong gas(often the case when tested with H ₂ , He or Ar).	Check valve voltage as measured across valve lead wires. Valve should close when voltage rises to 6-10 VDC (AFC-260), 11-15 VDC (AFC-261). Lower voltage indicates lack of closing command or electronic failure; repair electronics. 14 - 15 VDC indicates open circuit on valve heater (AFC-260). Measure DC resistance on AFC-261; Replace Valve. Replace sensor See below Follow 4.2. Follow 5.1. or 5.4. Check d.c. resistance : + 100 ohms (AFC-260) + 125 ohms (AFC-261) See below Adjust valve (4.3.) or replace valve (4.4.) Test on proper gas

Valve will not open	Contamination Electrically commanded closed or potentiometer shorted. Clogged inlet fitting screen, appearing as closed valve.	Follow 5.1. or 5.4. Check command signal (pins A and B) and pot. Check for electronics failure
Valve controls at higher flow rates, but not at minimum	Contamination Erosion or corrosion, improper adjustment or inadequate drive	Clean filter screen. Follow 5.1. or 5.4. Follow 5.4. Adjust 4.3. Reduce R25
Valve oscillate or hunts	Jumpy pressure regulator Improper system dynamics due to excessive inlet pressure. Improper dynamics in electronics.	Replace Reduce upstream pressure regulator setting See 4.5.
General failure or miscalibration	Power supply voltage not nominal	Check +15 VDC, -15 VDC and +5.00 VDC
Flow indication saturated (0.7 or +12 VDC) regardless of flow	Bridge or sensor failure Component Failure	Check sensor resistance Voltage Yellow to common (8 to 10 VDC) Pin 6 to common should read -6.2 ± 2 VDC.
Valve drive open or saturated (0 or 6-10 VDC AFC-260) (0 or 11-15 VDC AFC-261)	TS2 open or short, IC LM-324 failed.	Check R3, R9, other- components and solder joints. Check TS2, LM-324 and other components.
All circuit functional but out of calibration	Contamination, or as a result of cleaning or repairing.	Adjust.(see 4.)
Unit controls but output voltage does not agree with potentiometer setting	+ 5.00 VDC not nominal Large input voltage offset in Op Amp A. C6 leaks	Check supply. Adjust if necessary. Check and replace if necessary. Replace.

Table 6.1. symptoms, causes and solutions

Model	Valve closing voltage	R25 (1 W, 5%)
AFC 260	Up to 6 VDC	100 Ω
	6 to 7 VDC	75 Ω
	7 to 8 VDC	62 Ω
	8 to 9 VDC	39 Ω
	9 to 10 VDC	30 Ω
AFC 261	10 to 12 VDC	30 to 60 Ω
	13 to 14 VDC	20 to 10 Ω
	15 VDC	jumper

Table 6.2. Values of the valve resistance R25

Note : Do not exceed 10 VDC on AFC-260 valve. R25 must be 30 Ω or greater to prevent severe damage (distortion or burn-out). Overpowering the valve unnecessarily may reduce its life and reliability.

CAUTION : When the gas supply has been shut off or when purging a hydrogen controller with another gas such as Nitrogen, do not command less than 10% of Full scale as severe damage to the control valve may result.

SECTION 7 – GENERAL MFC PRINCIPLES

7.1.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 :

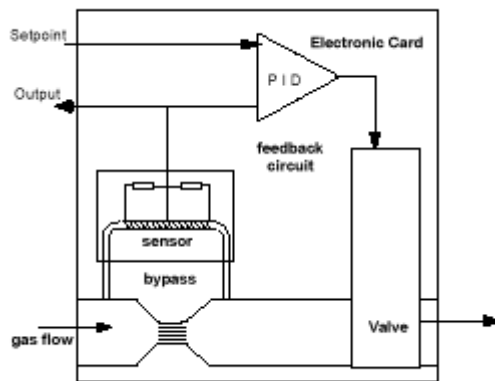


FIG. 1. Schematic of the mass flow controller.

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.

7.2.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.

7.3.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" (C_p), 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,

$$q = F \cdot C_p \Delta T$$

Where

q is the heat lost to the gas flow,

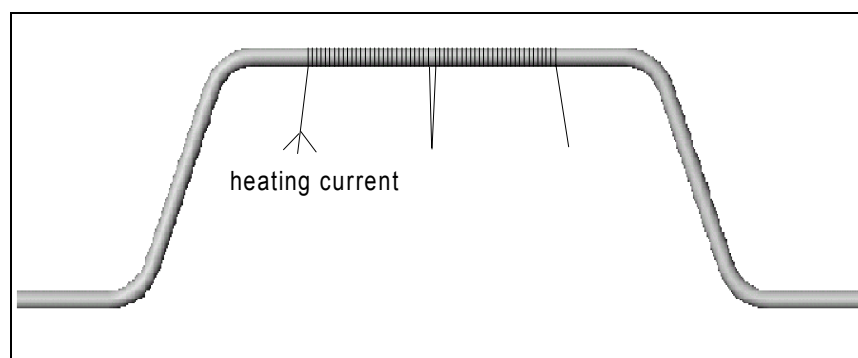
F is the mass flow,

C_p is the specific heat for a constant pressure,

ΔT is the net change in gas temperature as it traverses the tube.

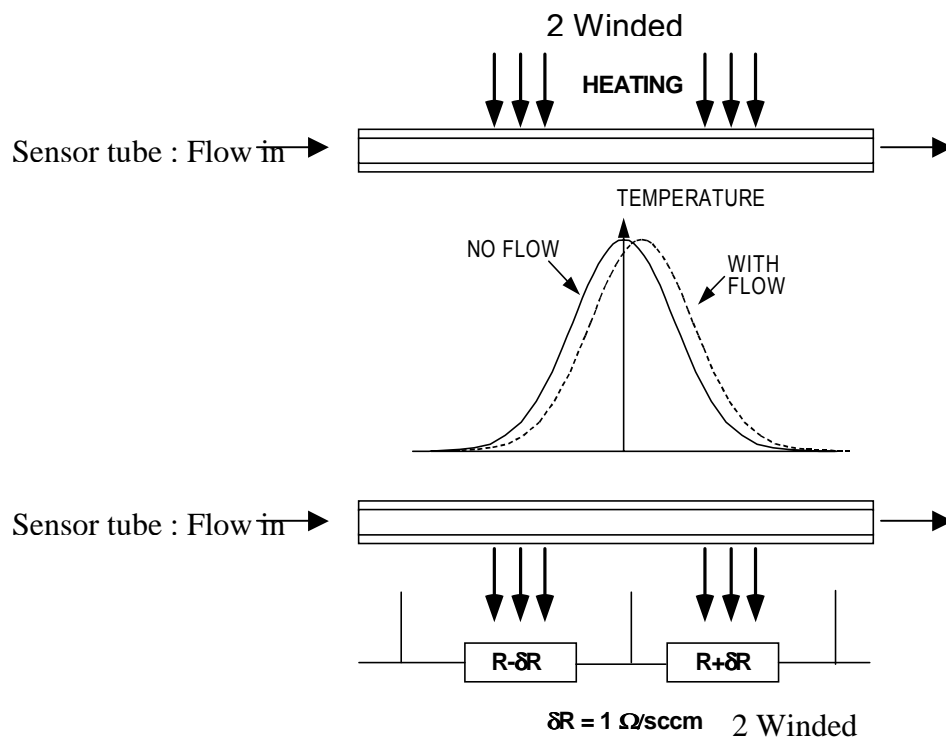
It is important to realize that both the specific heat and the flow rate determine the amplitude of the heat flux. As the mass and physical structure of molecules vary widely from gas to gas, so does the specific heat C_p . For the same molar flow rate, the heat flux can differ significantly for different 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 :



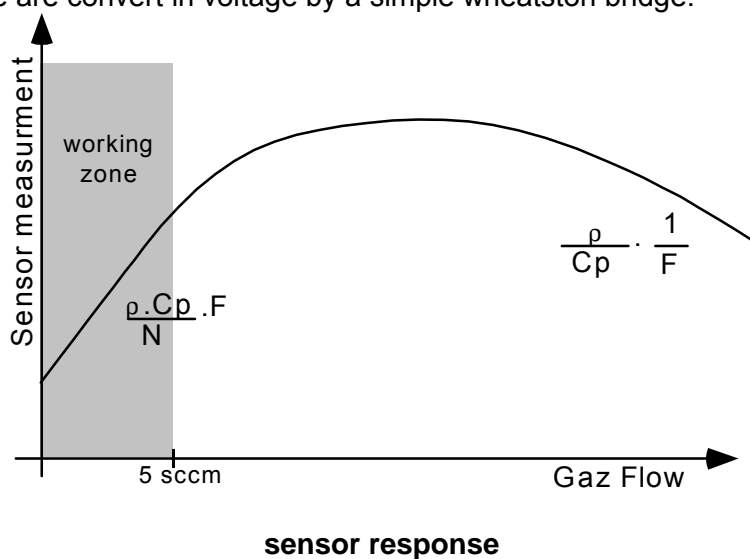
Sensor schematic

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

C_p : 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 C_p .

Value of N :

Monoatomic gas 1.04

Diatomic gas 1.00

Triatomic gas .94

Polyatomic gas .88

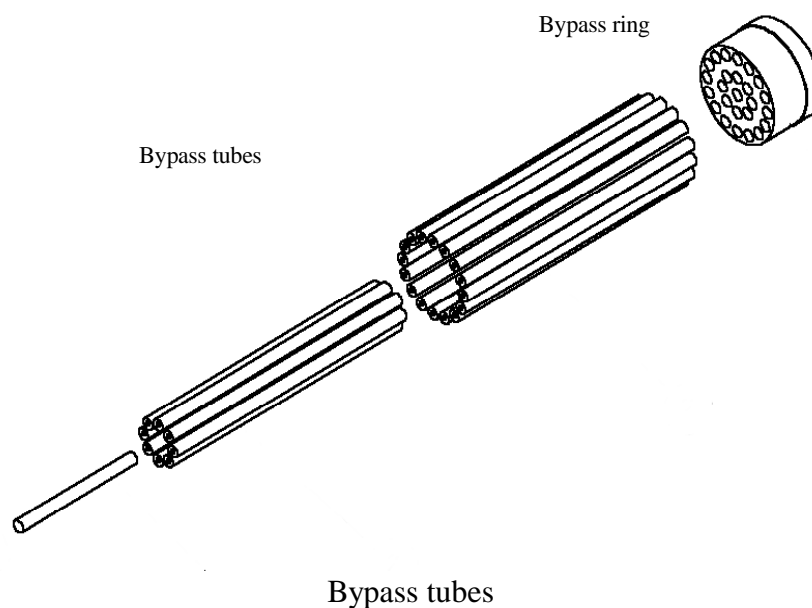
For flow higher then 5 sccm the sensor is first non linear then the measurement starts to decrease with flow because the gas flow is too fast and cool the 2 winded resistances instead of cooling the first one and heating the second one. This is the reason why bypass is necessary for higher full scale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

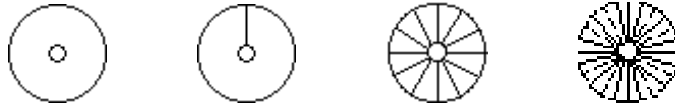
Also the fact that the coefficients N and C_p are different from one gas to another explains why mass-flow can NOT be changed from one gas to another without using a special coefficient to converter the measurement or recalibrate the mass-flow.

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.

7.4.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 washers (equivalent to several thin 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 :

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

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 R_s , length l_s) and a bypass tube are in parallel (radius R_b , length l_b), the flow in the sensor tube is proportional to the flow in the bypass :

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

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.

7.5. 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.

The valve can be also made by a heating wire which heat a small tube then dilation will move a ball at the end of the tube. This kind of valve can be only normally open and is quite slow.

Mass-flow controller using such valve will have response time around 5 to 6 s for flow below 5 slm and up to 10 s for flow up to 5 slm !! However this technology is simple and reliable and can be recommend for many low cost application when response time is not critical.

SECTION 8 - WARRANTY AND SERVICES

8.1.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 dismantled: the MFC warranty will be invalidated if the seal between the MFC block and cover is torn.

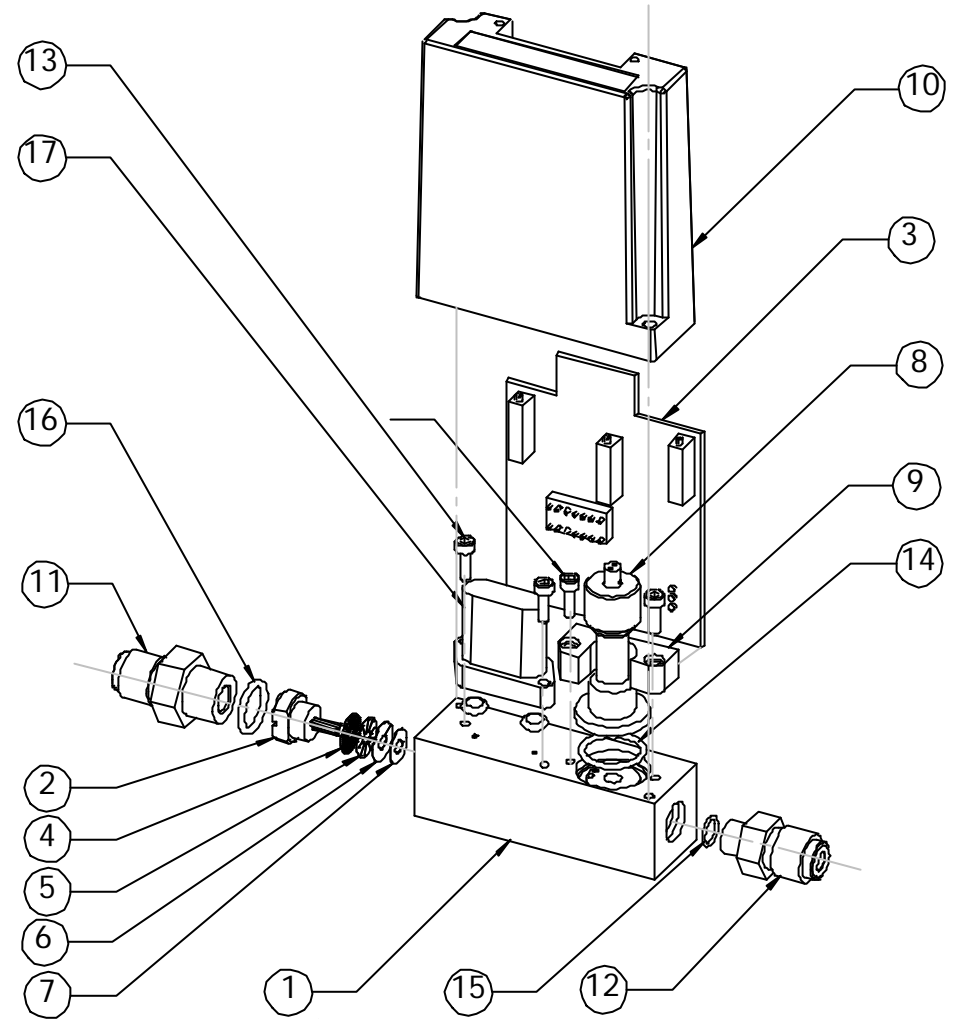
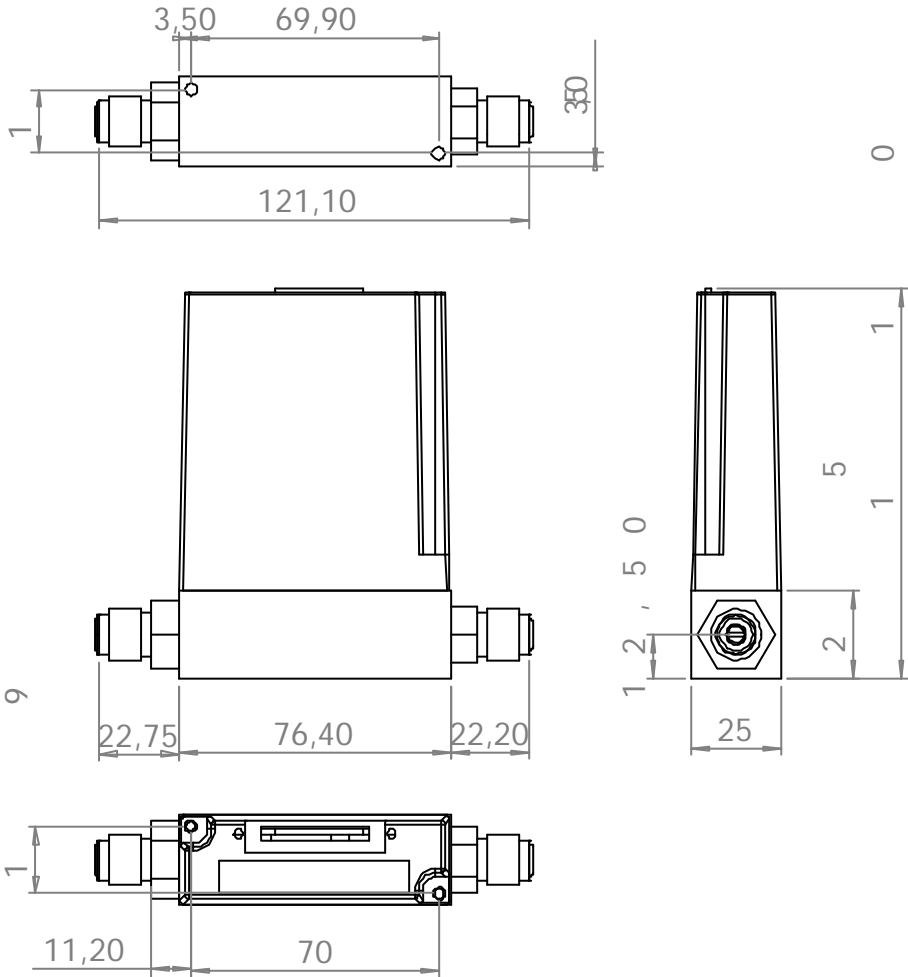
8.2.SERVICES

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.

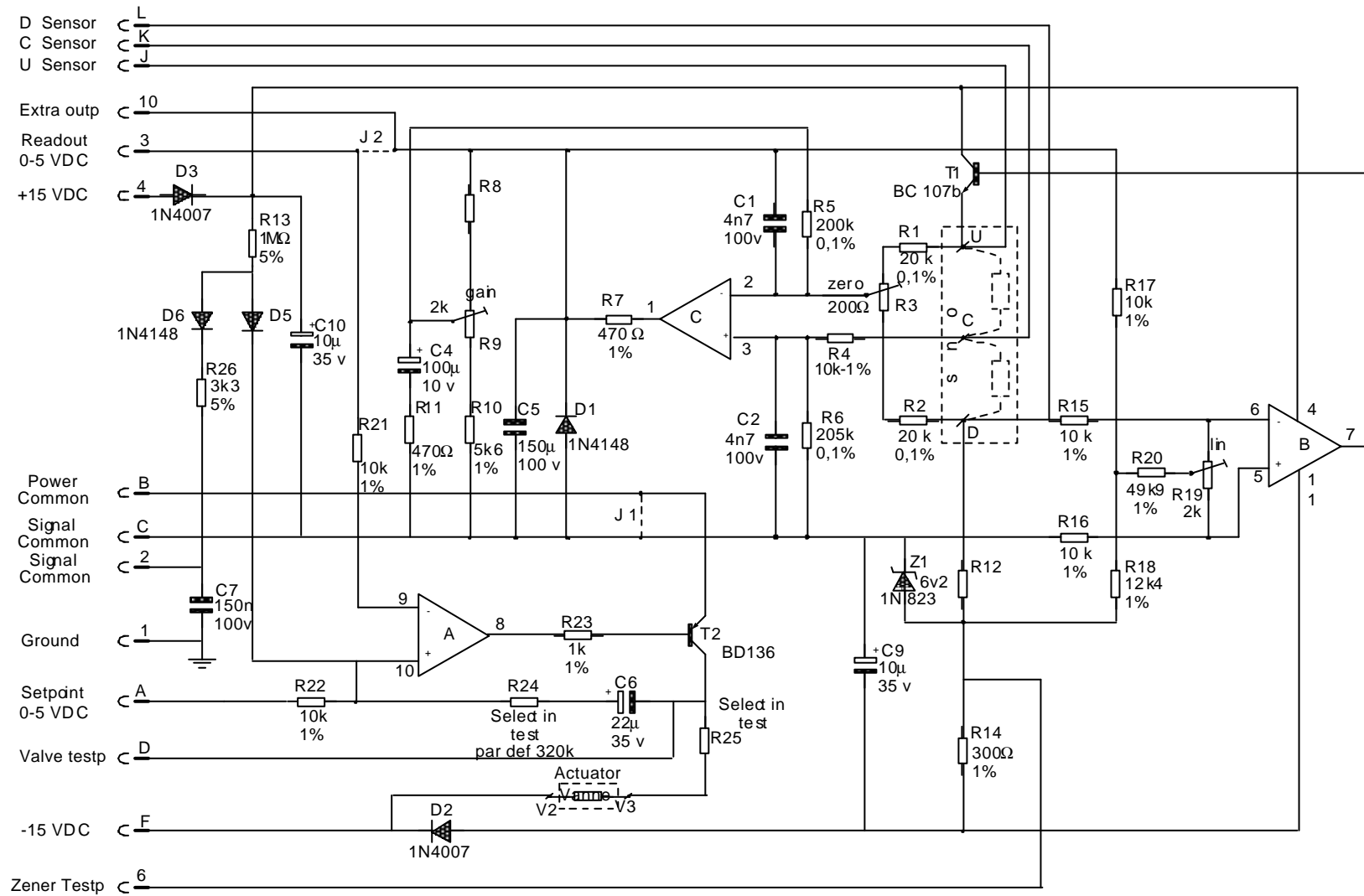
SECTION 9 - PARTS LISTS AND DESCRIPTION



ITEM	QUANTITY	PN	DESCRIPTION
1	1	Q2017989-01	BODY
2	1	Q2017997-01	BYPASS
3	1	Q535830010.00	BOARD
4	1	Q580110211.11	BYPASSING 40
5	1	Q580110220.11	BYPASS WASHER
6	1	Q580110230.11	BYPASS WASHER 1-GROVE
7	1	Q580110240.11	BYPASS WASHER 10-GROVE
8	1	Q580210040.00	VALVE ASSY 4.7mm
9	1	Q580211183.11	PLATE VALVE PRINT
10	1	Q580213020.11	AFC CAP
11	1	Q600274100	INLET FITTING
12	1	Q600274200	OUTLET FITTING
13	4	Q808071012	SCREW CHC M3*10
14	1	Q808092030	O-RING 15.6*1.78
15	1	Q808092031	O-RING 8.92*1.83
16	1	Q808092032	O-RING 11.90*1.98
17	1	Q997200000	SENSOR ASSY (VITON)

REV	DESCRIPTION	DATE	DES.
Tolerance: Ra:			
Finish:			
Finition:			
Des: FL	Date: 25/8/98	DESIGNATION: AFC 260	
Chk:	Date:		
Vérif.:	Date:		
Aprvd:	Date:		
Approuvé:	Date:		
SCALE: Echelle:	Format SIZE: A3	260OVFM010L007H	REV 1
Material: Matière:	FOLIO 1/1		
All dimensions are in mm			

NOT BE USED FOR ENGINEERING DESIGN OR MANUFACTURE IN WHOLE OR IN PART
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ELECTRONIC SCHEMATIC

AFC 260

Jan. 1996

R12 must be 412 Ω, but may be 390 Ω or adjusted values in older versions.