

OPERATING MANUAL

DFC MASS FLOW CONTROLLER

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AALBORG®

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⚠ CAUTION:

This product is not intended to be used in life support applications!

⚠ CAUTION:

Some of the IC devices used in the instrument are static-sensitive and may be damaged by improper handling. When adjusting or servicing the device, use of a grounded wrist strap is recommended to prevent inadvertent damage to the integral solid-state circuitry.

⚠ CAUTION:

K-Factors at best are only an approximation.
K-Factors should not be used in applications that require accuracy better than +/- 5 to 10%.

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1. UNPACKING THE DFC MASS FLOW CONTROLLER

1.1 Inspect Package for External Damage

Your DFC Mass Flow Controller was carefully packed in a sturdy cardboard carton, with anti-static cushioning materials to withstand shipping shock. Upon receipt, inspect the package for possible external damage. In case of external damage to the package contact the shipping company immediately.

1.2 Unpack the Mass Flow Controller

Open the carton carefully from the top and inspect for any sign of concealed shipping damage. In addition to contacting the shipping carrier please forward a copy of any damage report to your distributor or Aalborg® directly.

When unpacking the instrument please make sure that you have all the items indicated on the Packing List. Please report any shortages promptly.

1.3 Returning Merchandise for Repair

Please contact the customer service representative of your distributor or Aalborg® if you purchased your Mass Flow Controller directly, and request a **Return Authorization Number (RAN)**. **Equipment returned without an RAN will not be accepted.** Aalborg® reserves the right to charge a fee to the customer for equipment returned under warranty claims if the instruments are tested to be free from warranted defects.

Shipping charges are borne by the customer. Meters returned "collect" will not be accepted!

It is mandatory that any equipment returned for servicing be purged and neutralized of any dangerous contents including but not limited to toxic, bacterially infectious, corrosive or radioactive substances. No work shall be performed on a returned product unless the customer submits a fully executed, signed SAFETY CERTIFICATE. Please request form from the Service Manager.

2. INSTALLATION

2.1 Primary Gas Connections

Please note that the DFC Mass Flow Controller will not operate with liquids. Only clean gases are allowed to be introduced into the instrument. If gases are contaminated they must be filtered to prevent the introduction of impediments into the sensor.



Caution: It is the users responsibility to determine if the instrument is appropriate for their OXYGEN application, and for specifying O2 cleaning service if required. Aalborg is not liable for any damage or personal injury, whatsoever, resulting from the use of this instrument for oxygen.

Attitude sensitivity of the Mass Flow Controller is $\pm 15^\circ$. This means that the gas flow path of the Flow Controller must be horizontal within those stated limits. Should there be need for a different orientation of the meter, re-calibration may be necessary. It is also preferable to install the DFC transducer in a stable environment, free of frequent and sudden temperature changes, high moisture, and drafts.

Prior to connecting gas lines inspect all parts of the piping system including ferules and fittings for dust or other contaminants.

Be sure to observe the direction of gas flow as indicated by the arrow on the front of the meter when connecting the gas system to be monitored.

Insert tubing into the compression fittings until the ends of the properly sized tubings home flush against the shoulders of the fittings. Compression fittings are to be tightened according to the manufacturer's instructions to one and one quarter turns. Avoid over tightening which will seriously damage the Restrictor Flow Elements (RFE's)!

DFC transducers are supplied with standard 1/4 inch (DFC 26 and 36) or 3/8 inch (DFC 46), or optional 1/8 inch inlet and outlet compression fittings which should not be removed unless the meter is being cleaned or calibrated for a new flow range.

Using a Helium Leak Detector or other equivalent method perform a thorough leak test of the entire system. (All DFC's are checked prior to shipment for leakage within stated limits. See specifications in this manual.)

2.2 Electrical Connections

DFC transducers require a +15VDC and -15VDC power supply to operate. Additionally, a readout panel meter, digital multimeter, or other equivalent device is required to observe the flow signal in analog mode. A variable analog 0-5VDC reference input is required for DFC models to operate in analog mode. The Aalborg® SDPROC accessory Command Modules offer a convenient and compact means to fulfill these needs.

2.3 Communication Parameters and Connections

| | | | |
|-------------------|-----------|------------------|-----|
| Baud rate: | 9600 baud | Stop bit: | 1 |
| Data bits: | 8 | Parity: | NON |

RS-232 option: Crossover connection has to be established:

Pin 11 (TX) of the "D" connector has to be connected to RX (pin 2 on the DB9 connector).

Pin 24 (RX) of the "D" connector has to be connected to TX (pin 3 on the DB9 connector).

Pin 20 (Common) of the "D" connector has to be connected to GND (pin 5 on the DB9 connector).

RS-485 option:

The RS485 converter/adaptor has to be configured for: multidrop, 2 wire, half duplex mode. The transmitter circuit has to be enabled by TD or RTS (depending on which is available on the converter/adaptor). Settings for the receiver circuit usually should follow the selection made for the transmitter circuit in order to eliminate Echo.

Pin 11 (-) of the "D" connector has to be connected to T- or R- on the RS-485 converter/adaptor.

Pin 24 (+) of the "D" connector has to be connected to T+ or R+ on the RS-485 converter/adaptor.

Pin 20 (Common) of the "D" connector has to be connected to GND on the RS-485 converter/adaptor.

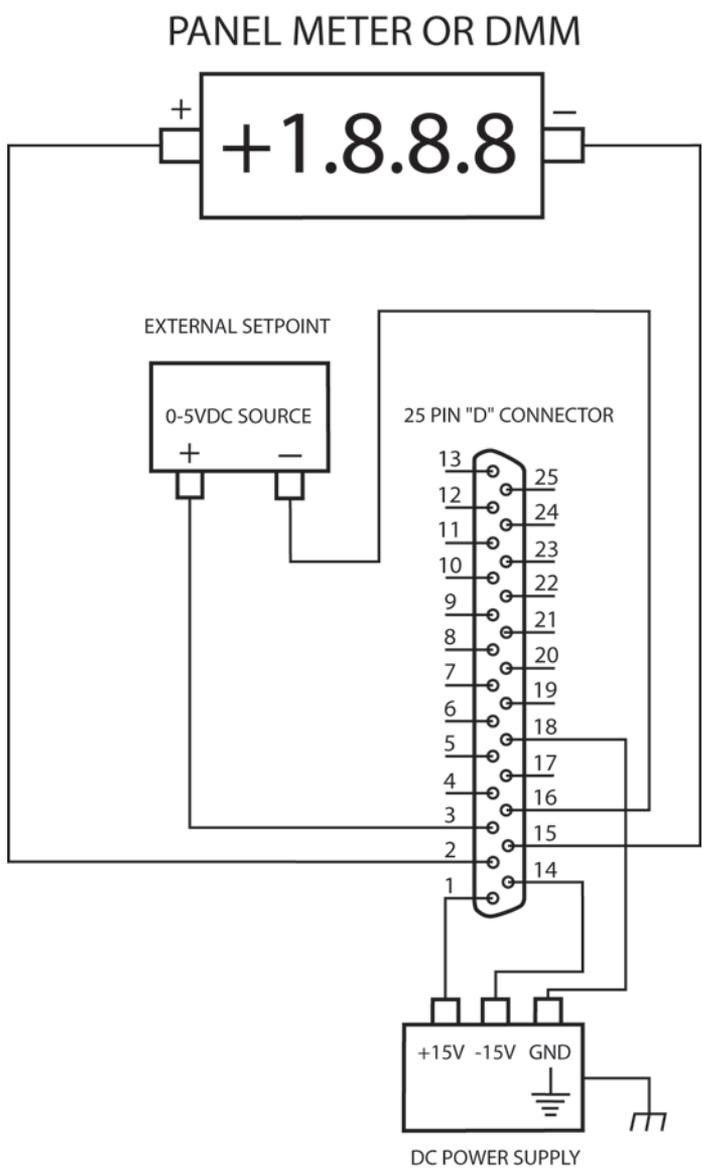


FIGURE b-1, WIRING DIAGRAM FOR DFC TRANSDUCERS.

PIN FUNCTION

| | |
|----|--|
| 1 | +15 VDC Power Supply |
| 2 | 0-5 VDC Flow Signal (4-20mA Option) |
| 3 | 0-5 VDC Set Point Input (4-20mA Option) |
| 4 | Force Valve Open Control |
| 5 | Force Valve Closed Control |
| 6 | (Reserved) |
| 7 | (Reserved) |
| 8 | Relay No. 1 - Common Contact |
| 9 | Relay No. 1 - Normally Open Contact |
| 10 | Relay No. 2 - Normally Closed Contact |
| 11 | RS485 (-) (Optional RS232 TX) |
| 12 | (No Connection) |
| 13 | Common, Signal Ground |
| 14 | -15 VDC Power Supply |
| 15 | Common, Signal Ground For Pin 2 |
| 16 | Common, Signal Ground For Pin 3 |
| 17 | (Optional) RS232 Common |
| 18 | Common, Power Supply |
| 19 | Common |
| 20 | Common |
| 21 | Relay No. 1 - Normally Closed Contact |
| 22 | Relay No. 2 - Common Contact |
| 23 | Relay No. 2 - Normally Open Contact |
| 24 | RS485 (+) (Optional RS232 RX) |
| 25 | Return for Pin 2 (Optional 4-20 mA Only) |

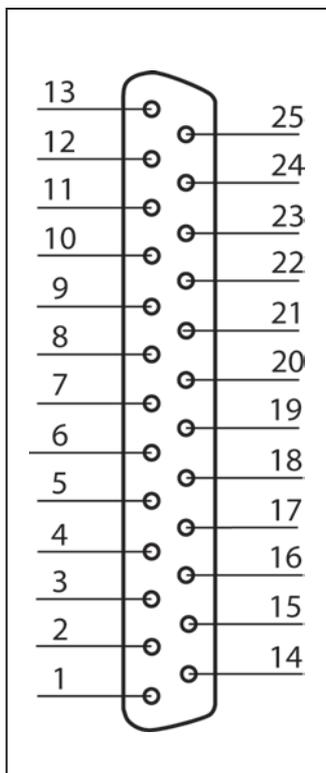


FIGURE b-2, DFC 25 PIN "D" CONNECTOR CONFIGURATION



Important notes:

In general, "D" Connector numbering patterns are standardized. There are, however, some connectors with nonconforming patterns and the numbering sequence on your mating connector may or may not coincide with the numbering sequence shown in our pin configuration table above. It is imperative that you match the appropriate wires in accordance with the correct sequence regardless of the particular numbers displayed on your mating connector.

Make sure power is OFF when connecting or disconnecting any cables in the system.

The (+) and (-) power inputs are each protected by a 500mA M (medium time-lag) resettable fuse. If a shorting condition or polarity reversal occurs, the fuse will cut power to the flow transducer circuit. Disconnect the power to the unit, remove the faulty condition, and reconnect the power. The fuse will reset once the faulty condition has been removed.

Cable length may not exceed 9.5 feet (3 meters).

Use of the DFC flow transducer in a manner other than that specified in this manual or in writing from Aalborg®, may impair the protection provided by the equipment.

3. PRINCIPLE OF OPERATION

The stream of gas entering the Mass Flow transducer is split by shunting a small portion of the flow through a capillary stainless steel sensor tube. The remainder of the gas flows through the primary flow conduit. The geometry of the primary conduit and the sensor tube are designed to ensure laminar flow in each branch. According to principles of fluid dynamics the flow rates of a gas in the two laminar flow conduits are proportional to one another. Therefore, the flow rates measured in the sensor tube are directly proportional to the total flow through the transducer.

In order to sense the flow in the sensor tube, heat flux is introduced at two sections of the sensor tube by means of precision wound heater sensor coils. Heat is transferred through the thin wall of the sensor tube to the gas flowing inside. As gas flow takes place heat is carried by the gas stream from the upstream coil to the downstream coil windings. The resultant temperature dependent resistance differential is detected by the electronic control circuit. The measured gradient at the sensor windings is linearly proportional to the instantaneous rate of flow taking place.

An output signal is generated that is a function of the amount of heat carried by the gases to indicate mass molecular based flow rates.

Additionally, DFC model Mass Flow Controllers incorporate a microprocessor and non-volatile memory that stores all calibration factors and directly controls a proportionating solenoid valve. The digital closed loop control system of the DFC continuously compares the mass flow output with the selected flow rate. Deviations from the set point are corrected by compensating valve adjustments, thus maintaining the desired flow parameters with a high degree of accuracy.

Free PC Software with Gas Blending and Programmable Flow functions.

4. SPECIFICATIONS

FLOW MEDIUM: Please note that DFC Mass Flow Controllers are designed to work with clean gases only. Never try to meter or control flow rates of liquids with any DFC.

CALIBRATIONS: Performed at standard conditions [14.7 psia (1.01 bars) and 70° F (21.1 °C)] unless otherwise requested or stated.

ENVIRONMENTAL (PER IEC 664): Installation Level II; Pollution Degree II.

4.1 DFC 26/36/46 Mass Flow Controllers

ACCURACY: $\pm 1\%$ of full scale, including linearity for gas temperatures ranging from 59 °F to 77 °F (15 °C to 25 °C) and pressures of 10 to 60 psia (0.7 to 4.1 bars).

REPEATABILITY: $\pm 0.15\%$ of full scale.

TEMPERATURE COEFFICIENT: 0.1% of full scale/ °C.

PRESSURE COEFFICIENT: 0.01% of full scale/psi (0.07 bar).

RESPONSE TIME: 1.0 to 2.0 second to within $\pm 2\%$ of set point over 20% to 100% of full scale.

GAS PRESSURE: 1000 psig (68.9 bars) maximum; optimum pressure is 20 psig (1.4 bars); 25 psig (1.7 bars gauge) for DFC46.

DIFFERENTIAL PRESSURES REQUIRED: 5 to 50 psig (0.35 to 3.34 bars) differential pressures. Optimum differential pressure is 25 psid (1.7 bars). See Table IV for pressure drops associated with various models and flow rates.

MAXIMUM PRESSURE DIFFERENTIAL: 50 psid for DFC26/DFC36, 40 psid for DFC46.

GAS AND AMBIENT TEMPERATURE: 32 °F to 122 °F (0 °C to 50 °C). 14 °F to 122 °F (-10 °C to 50 °C) - Dry gases only.

RELATIVE GAS HUMIDITY: Up to 70%.

MAXIMUM INTERNAL LEAK: 0.5% FS.

LEAK INTEGRITY: 1×10^{-9} sccs He maximum to the outside environment.

ATTITUDE SENSITIVITY: 1% shift for a 90 degree rotation from horizontal to vertical; standard calibration is in horizontal position.

OUTPUT SIGNALS: Linear 0-5 VDC (2000 Ω minimum load impedance); 4-20 mA optional (50-500 Ω loop resistance); 20 mV peak to peak max noise.

Contact your distributor or Aalborg® for optional RS232 or IEEE488 interfaces.

COMMAND SIGNAL: 0-5 VDC (200K Ω input impedance); 4-20 mA optional.

TRANSDUCER INPUT POWER: DFC - +15 $\pm 5\%$ VDC, 450 mA max, 6.75 watts max; -15 $\pm 5\%$ VDC, 450 mA max; 6.75 watts max;

Power inputs are each protected by a 500mA M (medium time-lag) resettable fuse, and an inverse shunt rectifier diode for polarity protection.

WETTED MATERIALS: 316 stainless steel, 416 stainless steel, FKM O-rings;

BUNA-N®, EPR or FFKM O-rings are optional.

Aalborg® makes no expressed or implied guarantees of corrosion resistance of mass flow meters as pertains to different flow media reacting with components of meters. It is the customers' sole responsibility to select the model suitable for a particular gas based on the fluid contacting (wetted) materials offered in the different models.

INLET AND OUTLET CONNECTIONS: 1/4" (DFC 26/DFC36) or 3/8" (DFC46) compression fittings standard. 1/8" (DFC26) or 3/8" (DFC26/DFC36) compression fittings or 1/4" (DFC26/DFC36) VCR® fittings are optional.

TRANSDUCER INTERFACE CABLE: Flat cable with 25-pin "D" connectors on the ends is standard. Optional shielded cable is available with male/female 25-pin "D" connector ends. [Cable length may not exceed 9.5 feet (3 meters)].

FREE PC SOFTWARE WITH GAS BLENDING AND PROGRAMMABLE FLOW FUNCTIONS.

4.2 CE Compliance

Any model DFC bearing a CE marking on it, is in compliance with the below stated test standards currently accepted.

EMC Compliance with 89/336/EEC as amended;
Emission Standard: EN 55011:1991, Group 1, Class A
Immunity Standard: EN 55082-1:1992

FLOW RANGES

TABLE I DFC 26 LOW FLOW MASS FLOW CONTROLLERS*

| CODE | scc/min [N ₂] | CODE | std liters/min [N ₂] |
|------|---------------------------|------|----------------------------------|
| 01 | 0 to 10 | 07 | 0 to 1 |
| 02 | 0 to 20 | 08 | 0 to 2 |
| 03 | 0 to 50 | 09 | 0 to 5 |
| 04 | 0 to 100 | 10 | 0 to 10 |
| 05 | 0 to 200 | | |
| 06 | 0 to 500 | | |

TABLE II DFC 36 MEDIUM FLOW MASS FLOW CONTROLLERS*

| CODE | standard liters/min [N ₂] |
|------|---------------------------------------|
| 11 | 0 to 15 |
| 30 | 20 |
| 31 | 30 |
| 32 | 40 |
| 33 | 50 |

TABLE III DFC 46 HIGH FLOW MASS FLOW CONTROLLERS*

| CODE | standard liters/min [N ₂] |
|------|---------------------------------------|
| 40 | 60 |
| 41 | 80 |
| 42 | 100 |

* Flow rates are stated for Nitrogen at STP conditions [i.e. 70 °F (21.1 °C) at 1 atm]. For other gases use the K factor as a multiplier from APPENDIX 2.

TABLE IV PRESSURE DROPS

| MODEL | FLOW RATE [std liters/min] | MAXIMUM PRESSURE DROP | | |
|---------------|-------------------------------|-----------------------|--------|--------|
| | | [mm H ₂ O] | [psid] | [mbar] |
| DFC 26 | up to 10 | 720 | 1.06 | 75 |
| DFC 36 | 15 | 2630 | 3.87 | 266 |
| | 20 | 1360 | 2.00 | 138 |
| | 30 | 2380 | 3.50 | 241 |
| | 40 | 3740 | 5.50 | 379 |
| | 50 | 5440 | 8.00 | 551 |
| DFC 46 | 60 | 7480 | 11.00 | 758 |
| | 100 | 12850 | 18.89 | 1302 |

TABLE V APPROXIMATE WEIGHTS

| MODEL | WEIGHT | SHIPPING WEIGHT |
|-----------------------|--------------------|--------------------|
| DFC 26 transmitter | 2.20 lbs (1.00 kg) | 3.70 lbs (1.68 kg) |
| DFC 36/46 transmitter | 2.84 lbs (1.29 kg) | 4.34 lbs (1.97 kg) |

5. OPERATING INSTRUCTIONS

5.1 Preparation and Warm Up

It is assumed that the Mass Flow Controller or Controller has been correctly installed and thoroughly leak tested as described in section (2). Make sure the flow source is OFF. Power up the transducer using your own power supply (or switch the POWER switch to the ON position at the front panel of your SDPROC Command Module). Allow the Mass Flow Meter or Controller to warm-up for a minimum of 15 minutes.

During initial powering of the DFC transducer, the flow output signal will be indicating a higher than usual output. This is indication that the DFC transducer has not yet attained it's minimum operating temperature. This condition will automatically cancel within a few minutes and the transducer should eventually zero.



Caution: If the valve is left in the AUTO (control) or OPEN mode for an extended period of time, it may become warm or even hot to the touch. Use care in avoiding direct contact with the valve during operation.

5.2 Flow Signal Output Readings

The flow signal output can be viewed on the panel meter, digital multimeter, or other display device used as shown in figure b-1.

When using the accessory SDPROC Command Module the flow rate will appear on the display at the front panel. The observed reading is a 0 to 100% indication (direct engineering units are optional). [If using a multichannel readout, be sure that the CHANNEL selector switch is set to the correct channel.]

Analog output flow signals of 0 to 5 VDC or optional 4 to 20 mA are attained at the appropriate pins the 25-pin "D" connector (see Figure b-2) on the side of the DFC transducer. The output flow signal is also available at the DATA connector on the rear panel of the SDPROC Command Module.

Meter signal output is linearly proportional to the mass molecular flow rate of the gas being metered. The full scale range and gas for which your meter has been calibrated are shown on the flow transducer's front label.

For information on the RS485 or optional RS232 interfaces please contact your distributor or Aalborg®.

5.3 Swamping Condition

If a flow of more than 10% above the maximum flow rate of the Mass Flow Controller is taking place, a condition known as "swamping" may occur. Readings of a "swamped" meter cannot be assumed to be either accurate or linear. Flow must be restored to below 110% of maximum meter range. Once flow rates are lowered to within calibrated range, the swamping condition will end. Operation of the meter above 110% of maximum calibrated flow may increase recovery time.

5.4 Set Point Reference Signal

DFC flow controllers have a built-in solenoid valve and allow the user to set the flow to any desired flow rate within the range of the particular model installed. This valve is normally closed when no power is applied.

The set point input in analog mode responds to an analog 0 to 5 VDC reference voltage or 4-20mA reference current. This voltage is a linear representation of 0 to 100% of the full scale mass flow rate. Response time to set point changes are 1 second to within 2% of the final flow over 25 to 100% of full scale.

A variable 0 to 5VDC analog signal may be applied directly to the SET POINT and COMMON connections of the DFC transducer (see Figure b-1).

If a potentiometer is used to adjust the set point reference signal its value should be between 5K to 100K ohm and it should be capable of at least 10-turns or more for adjustment.

5.5 Valve OFF Control

It may, at times, be desirable to set the flow and maintain that setting while being able to turn the flow control valve off and on again. This can be accomplished via pin 5 on the 25-pin "D" connector. When 0 VDC (LOW) signal is applied (connection via a relay, switch or NPN open collector transistor is permissible), the solenoid valve is not powered and therefore will remain normally closed. Conversely, when the pin is disconnected from 0 VDC ("floating") the solenoid valve will remain active.

The simplest means for utilizing the VALVE OFF control feature, is to connect a toggle switch between the COMMON and FORCE VALVE CLOSED pins of the DFC transducer. Toggling the switch on and off will allow for activating and deactivating the solenoid valve.

5.6 Valve Open /Purge

At times, it may be necessary to purge the flow system with a neutralizing gas such as pure dry nitrogen. The DFC transducer is capable of a full open condition for the solenoid valve, regardless of set point conditions. Connecting the FORCE VALVE OPEN pin (pin 4 on 25-pin "D" connector) to ground will fully open the valve. This connection can be made with a relay, switch or NPN open collector transistor. Conversely, when the pin is disconnected from 0 VDC ("floating") the solenoid valve will remain active. (Note: in digital mode hardware I/O overrides software command).

The simplest means for utilizing the VALVE OPEN control feature, is to connect a toggle switch between the COMMON and FORCE VALVE OPEN pins of the DFC transducer. Toggling the switch on will cause the valve to open fully and purge the system. Toggling the switch off will allow the solenoid valve to resume normal activity.



Caution: If the valve is left in the AUTO (control) or OPEN mode for an extended period of time, it may become warm or even hot to the touch. Use care in avoiding direct contact with the valve during operation.

5.7 Analog Interface Configuration

The DFC can be configured for the desired range and scaling by selection of analog board (see APPENDIX 1 on page 21) jumpers as follows:

- 0 to 5 V output:** Jumper pins 2 and 3 of JP6.
Jumper pins 2 and 3 of JP3.
Jumper pins 2 and 3 of JP5.
Jumper pins 1 and 2 of JP12.
- 0 to 5 V input:** Jumper pins 2 and 3 of JP2.
Jumper pins 2 and 3 of JP4.
Jumper pins 1 and 2 of JP11.
- 0 to 10 V output:** As for 0 to 5V, but jumper pins 2 and 3 of JP12.
- 4 to 20 mA output:** Jumper pins 1 and 2 of JP6.
Jumper pins 1 and 2 of JP3.
Jumper pins 1 and 2 of JP5.
Jumper pins 1 and 2 of JP12.
- 4 to 20 mA input:** Jumper pins 1 and 2 of JP2.
Jumper pins 1 and 2 of JP4.
Jumper pins 1 and 2 of JP11.

By default the DFC is configured for analog input output ranges set to 0-5V (unless ordered with special configuration).

6. MAINTENANCE

6.1 Introduction

It is important that the Mass Flow Controller is used with clean, filtered gases only. Liquids may not be metered. Since the RTD sensor consists, in part, of a small capillary stainless steel tube, it is prone to occlusion due to impediments or gas crystallization. Other flow passages are also easily obstructed. Therefore, great care must be exercised to avoid the introduction of any potential flow impediment. To protect the instrument a 50 micron (DFC26) or 60 micron (DFC36/46) filter is built into the inlet of the flow transducer. The filter screen and the flow paths may require occasional cleaning as described below. There is no other recommended maintenance required. It is good practice, however, to keep the meter away from vibration, hot or corrosive environments and excessive RF or magnetic interference.

If periodic calibrations are required they should be performed by qualified personnel and calibrating instruments, as described in section (7). It is recommended that units are returned to Aalborg® for repair service and calibration.



CAUTION: TO PROTECT SERVICING PERSONNEL IT IS MANDATORY THAT ANY INSTRUMENT BEING SERVICED IS COMPLETELY PURGED AND NEUTRALIZED OF TOXIC, BACTERIOLOGICALLY INFECTED, CORROSIVE OR RADIOACTIVE CONTENTS.

6.2 Flow Path Cleaning

Before attempting any disassembly of the unit for cleaning, try inspecting the flow paths by looking into the inlet and outlet ends of the meter for any debris that may be clogging the flow through the meter. Remove debris as necessary. If the flow path is not unclogged, then proceed with steps below.

Do not attempt to disassemble the sensor. If blockage of the sensor tube is not alleviated by flushing through with cleaning fluids, please return meter to Aalborg® for servicing.

6.2.1 Restrictor Flow Element (RFE)

The Restrictor Flow Element (RFE) is a precision flow divider inside the transducer, which splits the inlet gas flow by a preset amount to the sensor and main flow paths. The particular RFE used in a given Mass Flow Controller depends on the gas and flow range of the instrument.

6.2.2 DFC 26 models

Unscrew the inlet compression fitting of meter. Note that the Restrictor Flow Element (RFE) is connected to the inlet fitting.

Carefully disassemble the RFE from the inlet connection. The 50 micron filter screen will now become visible. Push the screen out through the inlet fitting. Clean or replace each of the removed parts as necessary. If alcohol is used for cleaning, allow time for drying.

Inspect the flow path inside the transducer for any visible signs of contaminants. If necessary, flush the flow path through with alcohol. Thoroughly dry the flow paths by flowing clean dry gas through.

Carefully re-install the RFE and inlet fitting, avoiding any twisting and deforming the RFE. Be sure that no dust has collected on the O-ring seal.



Note: Overtightening will deform and render the RFE defective.

It is advisable that at least one calibration point be checked after re installing the inlet fitting - see section (7).

6.2.3 DFC 36/46 models

Unscrew the four socket head cap screws (two 10-24 and two 6-32) at the inlet side of the meter. This will release the short square block containing the inlet compression fitting.

The 60 micron filter screen will now become visible. Remove the screen. DO NOT remove the RFE inside the flow transducer! Clean or replace each of the removed parts as necessary. If alcohol is used for cleaning, allow time for drying.

Inspect the flow path inside the transducer for any visible signs of contaminants. If necessary, flush the flow path through with alcohol. Thoroughly dry the flow paths by flowing clean dry gas through.

Re-install the inlet parts and filter screen. Be sure that no dust has collected on the O-ring seal.

It is advisable that at least one calibration point be checked after re installing the inlet fitting - see section (7).

6.2.4 Valve Maintenance (DFC)

The solenoid valve consists of 316 and 416 stainless steel, and FKM (or optional EPR or FFKM) O-rings and seals. No regular maintenance is required except for periodic cleaning.

Various corrosive gases may demand more frequent replacement of FKM O-rings and seals inside the valve. Be sure to use an elastomer material, appropriate for your specific gas application. Contact your distributor or Aalborg® for optional sealing materials available.

Set the DFC into PURGE mode, and attempt to flush through with a clean, filtered, and neutral gas such as nitrogen. [Another option for fully opening the valve is to remove the plastic cap on top of the valve, and turn the set screw counter-clockwise until it stops. Set valve for the closed position. Apply an inlet pressure of 5 psig and atmospheric pressure at the outlet. If a small flow occurs, turn the set screw on top of the solenoid valve clockwise until the flow through the DFC just stops.



Note: Removal of the factory installed calibration seals and/or any adjustments made to the meter, as described in this section, will void any calibration warranty applicable.

7. CALIBRATION PROCEDURES

7.1 Flow Calibration

Aalborg® Instruments' Flow Calibration Laboratory offers professional calibration support for Mass Flow Meters and Controllers, using precision calibrators under strictly controlled conditions. NIST traceable calibrations are available. Calibrations can also be performed at customers' site using available standards.

Factory calibrations are performed using NIST traceable precision volumetric calibrators incorporating liquid sealed frictionless actuators.

Generally, calibrations are performed using dry nitrogen gas. The calibration can then be corrected to the appropriate gas desired based on relative correction [K] factors shown in the gas factor table see Appendix 2. A reference gas, other than nitrogen, may be used to closer approximate the flow characteristics of certain gases. This practice is recommended when a reference gas is found with thermodynamic properties similar to the actual gas under consideration. The appropriate

relative correction factor should be recalculated see section (9).

It is standard practice to calibrate Mass Flow Meters/Controllers with dry nitrogen gas at 70 °F (21.1EC), 20 psig (1.4 bars) [25 psig (1.7 bars) for DFC46] inlet pressure and 0 psig (0 bar) outlet pressure. It is best to calibrate the DFC transducers to actual operating conditions. Specific gas calibrations of non-toxic and non-corrosive gases are available at specific conditions. Please contact your distributor or Aalborg® for a price quotation.

It is recommended that a flow calibrator of at least four times better collective accuracy than that of the Mass Flow Controller to be calibrated be used. Equipment required for calibration includes a flow calibration standard and a certified high sensitivity multimeter (which together have a collective accuracy of $\pm 0.25\%$ or better), an insulated (plastic) screwdriver, a flow regulator (example: metering needle valve) installed upstream from the Mass Flow Controller and a pressure regulated source of dry filtered nitrogen gas (or other suitable reference gas).

The gas and ambient temperature, as well as inlet and outlet pressure conditions should be set up in accordance with actual operating conditions.

7.2 Calibration of DFC Mass Flow Controllers

All adjustments to the DFC calibration and control loop tuning are accomplished using the RS485 (or optional RS232) interface in conjunction with setup and calibration software available from Aalborg®. The sensor zero is automatically adjusted internally whenever the control valve is fully closed (set point less than 2% of full scale) and the unit is warmed up.

DFC Mass Flow Meters may be field recalibrated/checked using the setup and calibration program for the same range they were originally factory calibrated for. Flow range changes may require a different Restrictor Flow Element (RFE). Additionally, a different Solenoid Valve Orifice for the DFC Mass Flow Controller (see Table VI) may also be required. Consult your distributor or Aalborg® for more information.

TABLE VI DFC SOLENOID VALVE ORIFICE SELECTION TABLE

| ORIFICE PART NUMBER | FLOW RATE [N ₂] |
|---------------------|-----------------------------|
| OR.020 | 10 to 1000 sccm |
| OR.040 | 1 to 5 slpm |
| OR.055 | 5 to 10 slpm |
| OR.063 | 10 to 15 slpm |
| OR.094 | 20 to 50 slpm |
| OR.125 | 50 to 100 slpm |

8. TROUBLESHOOTING

8.1 Common Conditions

Your Mass Flow Controller was thoroughly checked at numerous quality control points during and after manufacturing and assembly operations. It was calibrated in accordance to your desired flow and pressure conditions for a given gas or a mixture of gases.

It was carefully packed to prevent damage during shipment. Should you feel that the instrument is not functioning properly please check for the following common conditions first:

Are all cables connected correctly?

Are there any leaks in the installation?

Is the power supply correctly selected according to requirements? When several meters are used a power supply with appropriate current rating should be selected.

Were the connector pinouts matched properly? When interchanging with other manufacturers' equipment, cables and connectors must be carefully wired for correct pin configurations.

Is the pressure differential across the instrument sufficient?

For best results it is recommended that instruments are returned to the factory for servicing. See section 1.3 for return procedures.

8.2 Technical Assistance

Aalborg® Instruments will provide technical assistance over the phone to qualified repair personnel. Please call our Technical Assistance at (845) 770-3000. Please have your Serial Number and Model Number ready when you call.

8.3 Troubleshooting Guide

| Indication | Likely Reason | Remedy |
|---|--|--|
| lack of reading or output | power supply off | check connection of power supply |
| | fuse blown (DFC) | disconnect DFC transducer from power supply; remove the shorting condition or check polarities; fuse resets automatically |
| | fuse blown (SDPROC) | disconnect power cord from AC supply; remove and inspect fuses at AC power input connector of SDPROC; replace as necessary |
| | | REMOVE CAUSE OF SHORT CIRCUIT! |
| | filter screen obstructed at inlet | flush clean or disassemble to remove impediments or replace |
| | occluded sensor tube | flush clean or disassemble to remove impediments or return to factory for replacement |
| | pc board defect | return to factory for replacement |
| | valve adjustment wrong | re-adjust valve (section 6.2.4) |
| output reads at (+) or (-) saturation only | fuse blown (DFC) | disconnect DFC transducer from power supply; remove the shorting condition or check polarities; fuse resets automatically |
| | | REMOVE CAUSE OF SHORT CIRCUIT! |
| flow reading does not coincide with the set point (DFC models only) | inadequate gas pressure | apply appropriate gas pressure |
| | filter screen obstructed at inlet | flush clean or disassemble to remove impediments or replace |
| | ground loop | signal and power supply commons are different |
| no response to set point (DFC models only) | inadequate gas pressure | apply appropriate gas pressure |
| | cable or connector malfunction | check cables and all connections or replace |
| | set point is too low (<2% of full scale) | re-adjust set point |
| | valve adjustment wrong | re-adjust valve (section 6.2.4) |
| unstable or no zero reading | gas leak | locate and correct |
| | pc board defective | return to factory for replacement |

| Indication | Likely Reason | Remedy |
|---|--|--|
| full scale output at "no flow" condition or with valve closed | defective sensor gas Leak | return to factory for replacement locate and repair |
| calibration off | gas metered is not the same as what meter was calibrated for composition of gas changed gas leak pc board defective RFE dirty occluded sensor tube filter screen obstructed at inlet transducer is not mounted properly | use matched calibration see K factor tables in APPENDIX 2 locate and correct return to factory for replacement flush clean or disassemble to remove impediments flush clean or disassemble to remove impediments or return to factory for replacement flush clean or disassemble to remove impediments or replace check for any tilt or change in the mounting of the transducer; generally, units are calibrated for horizontal installation (relative to the sensor tube) |
| DFC valve does not work in open position | incorrect valve adjustment pc board defect cable or connectors malfunction differential pressure too high insufficient inlet pressure | re-adjust valve (section 6.2.4) return to factory for replacement check cable and connectors or replace decrease pressure to correct level adjust appropriately |
| DFC valve does not work in close position | incorrect valve adjustment pc board defect cable or connectors malfunction orifice obstructed | re-adjust valve (section 6.2.4) return to factory for replacement check cable and connectors or replace disassemble to remove impediments or return to factory |

9. CALIBRATION CONVERSIONS FROM REFERENCE GASES

The calibration conversion incorporates the K factor. The K factor is derived from gas density and coefficient of specific heat. For diatomic gases:

$$K_{\text{gas}} = \frac{1}{d \times C_p}$$

where d = gas density (gram/liter)

C_p = coefficient of specific heat (cal/gram)

Note in the above relationship that d and C_p are usually chosen at standard conditions of one atmosphere and 25° C.

If the flow range of a Mass Flow Controller or Controller remains unchanged, a relative K factor is used to relate the calibration of the actual gas to the reference gas.

$$K = \frac{Q_a}{Q_r} = \frac{K_a}{K_r}$$

where Q_a = mass flow rate of an actual gas (sccm)

Q_r = mass flow rate of a reference gas (sccm)

K_a = K factor of an actual gas

K_r = K factor of a reference gas

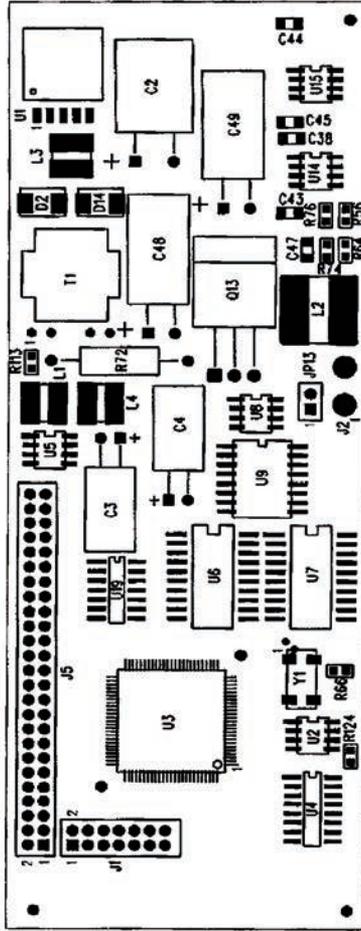
For example, if we want to know the flow rate of oxygen and wish to calibrate with nitrogen at 1000 SCCM, the flow rate of oxygen is:

$$Q_{O_2} = Q_a = Q_r \times K = 1000 \times 0.9926 = 992.6 \text{ sccm}$$

where K = relative K factor to reference gas (oxygen to nitrogen)

APPENDIX 1

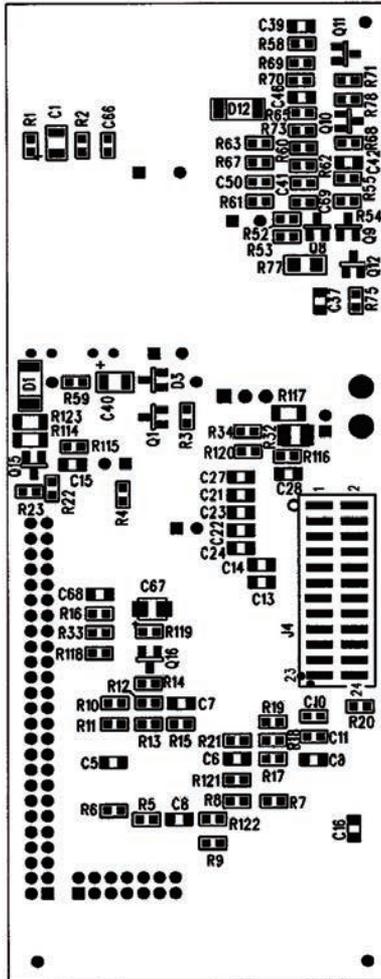
COMPONENTS DIAGRAMS



DFC Digital PC Board
(Primary Side)

APPENDIX 1

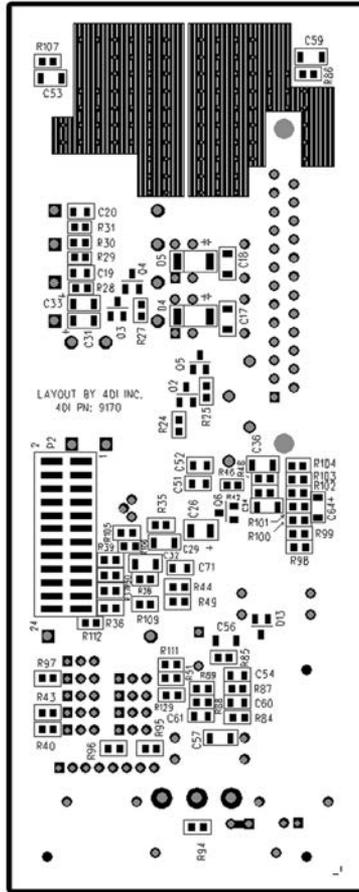
(CONTINUED)



DFC Digital PC Board
(Secondary Side)

APPENDIX 1

(CONTINUED)



DFC Analog PC Board
(Secondary Side)

APPENDIX 2
GAS FACTOR TABLES ("K" FACTORS)

CAUTION: K-Factors at best are only an approximation. K factors should not be used in applications that require accuracy better than +/- 5 to 10%.

| ACTUAL GAS | K FACTOR Relative to N ₂ | Cp [Cal/g] | Density [g/l] |
|---|--|---------------|------------------|
| Acetylene C ₂ H ₂ | .5829 | .4036 | 1.162 |
| Air | 1.0000 | .240 | 1.293 |
| Allene (Propadiene) C ₃ H ₄ | .4346 | .352 | 1.787 |
| Ammonia NH ₃ | .7310 | .492 | .760 |
| Argon Ar | 1.4573 | .1244 | 1.782 |
| Argon AR-1 (>10 L/min) | 1.205 | .1244 | 1.782 |
| Arsine AsH ₃ | .6735 | .1167 | 3.478 |
| Boron Trichloride BCl ₃ | .4089 | .1279 | 5.227 |
| Boron Trifluoride BF ₃ | .5082 | .1778 | 3.025 |
| Bromine Br ₂ | .8083 | .0539 | 7.130 |
| Boron Tribromide Br ₃ | .38 | .0647 | 11.18 |
| Bromine PentaTrifluoride BrF ₅ | .26 | .1369 | 7.803 |
| Bromine Trifluoride BrF ₃ | .3855 | .1161 | 6.108 |
| Bromotrifluoromethane (Freon-13 B1) CBrF ₃ | .3697 | .1113 | 6.644 |
| 1,3-Butadiene C ₄ H ₆ | .3224 | .3514 | 2.413 |
| Butane C ₄ H ₁₀ | .2631 | .4007 | 2.593 |
| 1-Butene C ₄ H ₈ | .2994 | .3648 | 2.503 |
| 2-Butene C ₄ H ₈ CIS | .324 | .336 | 2.503 |
| 2-Butene C ₄ H ₈ TRANS | .291 | .374 | 2.503 |
| Carbon Dioxide CO ₂ | .7382 | .2016 | 1.964 |
| Carbon Dioxide CO ₂ -1 (>10 L/min) | .658 | .2016 | 1.964 |
| Carbon Disulfide CS ₂ | .6026 | .1428 | 3.397 |
| Carbon Monoxide CO | 1.00 | .2488 | 1.250 |
| Carbon Tetrachloride CCl ₄ | .31 | .1655 | 6.860 |
| Carbon Tetrafluoride (Freon-14)CF ₄ | .42 | .1654 | 3.926 |
| Carbonyl Fluoride COF ₂ | .5428 | .1710 | 2.945 |
| Carbonyl Sulfide COS | .6606 | .1651 | 2.680 |
| Chlorine Cl ₂ | .86 | .114 | 3.163 |
| Chlorine Trifluoride ClF ₃ | .4016 | .1650 | 4.125 |
| Chlorodifluoromethane (Freon-22)CHClF ₂ | .4589 | .1544 | 3.858 |
| Chloroform CHCl ₃ | .3912 | .1309 | 5.326 |
| Chloropentafluoroethane(Freon-115)C ₂ ClF ₅ | .2418 | .164 | 6.892 |
| Chlorotrifluoromethane (Freon-13) CClF ₃ | .3834 | .153 | 4.660 |
| CyanogenC ₂ N ₂ | .61 | .2613 | 2.322 |
| CyanogenChloride ClCN | .6130 | .1739 | 2.742 |
| Cyclopropane C ₃ H ₆ | .4584 | .3177 | 1.877 |

| ACTUAL GAS | K FACTOR Relative to N ₂ | Cp [Cal/g] | Density [g/l] |
|---|--|---------------|------------------|
| Deuterium D ₂ | 1.00 | 1.722 | 1.799 |
| Diborane B ₂ H ₆ | .4357 | .508 | 1.235 |
| Dibromodifluoromethane CBr ₂ F ₂ | .1947 | .15 | 9.362 |
| Dichlorodifluoromethane (Freon-12) CCl ₂ F ₂ | .3538 | .1432 | 5.395 |
| Dichlorofluoromethane (Freon-21) CHCl ₂ F | .4252 | .140 | 4.592 |
| Dichloromethylsilane (CH ₃) ₂ SiCl ₂ | .2522 | .1882 | 5.758 |
| Dichlorosilane SiH ₂ Cl ₂ | .4044 | .150 | 4.506 |
| Dichlorotetrafluoroethane (Freon-114) C ₂ Cl ₂ F ₄ | .2235 | .1604 | 7.626 |
| 1,1-Difluoroethylene (Freon-1132A) C ₂ H ₂ F ₂ | .4271 | .224 | 2.857 |
| Dimethylamine (CH ₃) ₂ NH | .3714 | .366 | 2.011 |
| Dimethyl Ether (CH ₃) ₂ O | .3896 | .3414 | 2.055 |
| 2,2-Dimethylpropane C ₃ H ₁₂ | .2170 | .3914 | 3.219 |
| Ethane C ₂ H ₆ | .50 | .420 | 1.342 |
| Ethanol C ₂ H ₆ O | .3918 | .3395 | 2.055 |
| Ethyl Acetylene C ₄ H ₆ | .3225 | .3513 | 2.413 |
| Ethyl Chloride C ₂ H ₅ Cl | .3891 | .244 | 2.879 |
| Ethylene C ₂ H ₄ | .60 | .365 | 1.251 |
| Ethylene Oxide C ₂ H ₄ O | .5191 | .268 | 1.965 |
| Fluorine F ₂ | .9784 | .1873 | 1.695 |
| Fluoroform (Freon-23) CHF ₃ | .4967 | .176 | 3.127 |
| Freon-11 CCl ₃ F | .3287 | .1357 | 6.129 |
| Freon-12 CCl ₂ F ₂ | .3538 | .1432 | 5.395 |
| Freon-13 CClF ₃ | .3834 | .153 | 4.660 |
| Freon-13B1 CBrF ₃ | .3697 | .1113 | 6.644 |
| Freon-14 CF ₄ | .4210 | .1654 | 3.926 |
| Freon-21 CHCl ₂ F | .4252 | .140 | 4.592 |
| Freon-22 CHClF ₂ | .4589 | .1544 | 3.858 |
| Freon-113 CCl ₂ FCClF ₂ | .2031 | .161 | 8.360 |
| Freon-114 C ₂ Cl ₂ F ₄ | .2240 | .160 | 7.626 |
| Freon-115 C ₂ ClF ₅ | .2418 | .164 | 6.892 |
| Freon-C318 C ₄ F ₈ | .1760 | .185 | 8.397 |
| Germane GeH ₄ | .5696 | .1404 | 3.418 |
| Germanium Tetrachloride GeCl ₄ | .2668 | .1071 | 9.565 |
| Helium He | 1.454 | 1.241 | .1786 |
| Helium He-1 (>50 L/min) | 2.43 | 1.241 | .1786 |
| Helium He-2 (>10-50 L/min) | 2.05 | 1.241 | .1786 |
| Hexafluoroethane C ₂ F ₆ (Freon-116) | .2421 | .1834 | 6.157 |
| Hexane C ₆ H ₁₄ | .1792 | .3968 | 3.845 |
| Hydrogen H ₂ -1 | 1.0106 | 3.419 | .0899 |
| Hydrogen H ₂ -2 (>10-100 L) | 1.35 | 3.419 | .0899 |
| Hydrogen H ₂ -3 (>100 L) | 1.9 | 3.419 | .0899 |

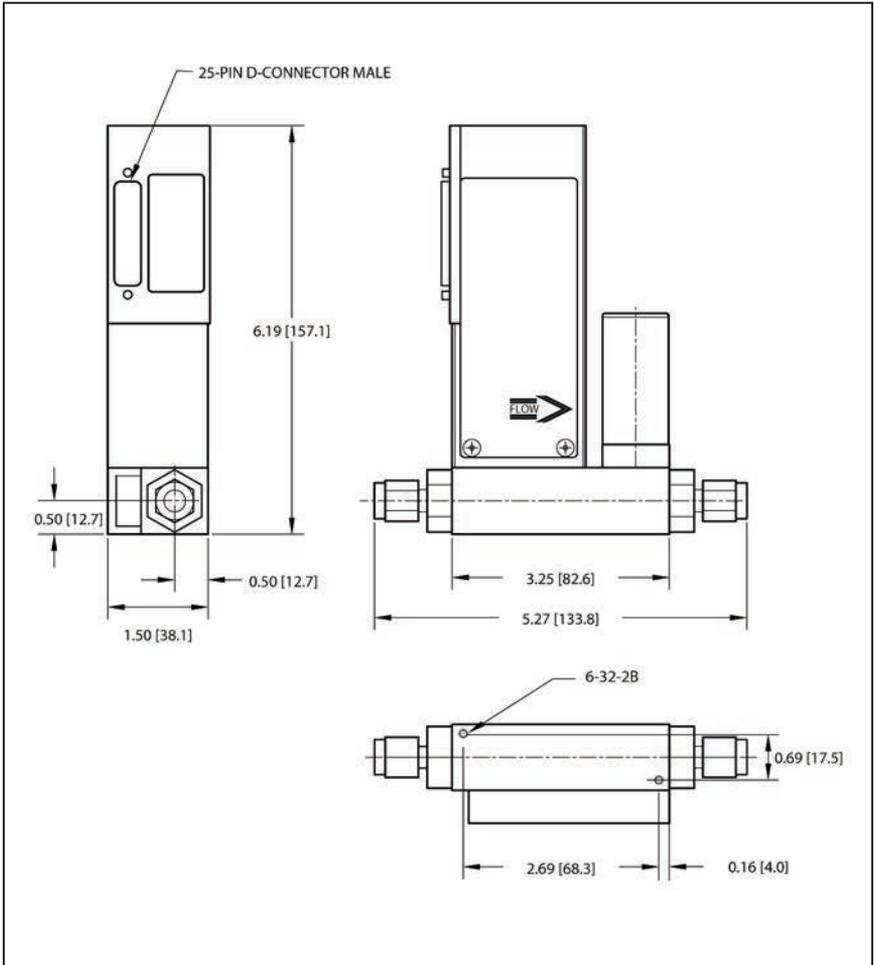
| ACTUAL GAS | K FACTOR Relative to N ₂ | Cp [Cal/g] | Density [g/l] |
|--|--|---------------|------------------|
| Hydrogen Bromide HBr | 1.000 | .0861 | 3.610 |
| Hydrogen Chloride HCl | 1.000 | .1912 | 1.627 |
| Hydrogen Cyanide HCN | .764 | .3171 | 1.206 |
| Hydrogen Fluoride HF | .9998 | .3479 | .893 |
| Hydrogen Iodide HI | .9987 | .0545 | 5.707 |
| Hydrogen Selenide H ₂ Se | .7893 | .1025 | 3.613 |
| Hydrogen Sulfide H ₂ S | .80 | .2397 | 1.520 |
| Iodine Pentafluoride IF ₅ | .2492 | .1108 | 9.90 |
| Isobutane CH(CH ₃) ₃ | .27 | .3872 | 3.593 |
| Isobutylene C ₄ H ₆ | .2951 | .3701 | 2.503 |
| Krypton Kr | 1.453 | .0593 | 3.739 |
| Methane CH ₄ | .7175 | .5328 | .715 |
| Methane CH ₄ -1 (>=10 L/min) | .75 | .5328 | .715 |
| Methanol CH ₃ | .5843 | .3274 | 1.429 |
| Methyl Acetylene C ₃ H ₄ | .4313 | .3547 | 1.787 |
| Methyl Bromide CH ₃ Br | .5835 | .1106 | 4.236 |
| Methyl Chloride CH ₃ Cl | .6299 | .1926 | 2.253 |
| Methyl Fluoride CH ₃ F | .68 | .3221 | 1.518 |
| Methyl Mercaptan CH ₃ SH | .5180 | .2459 | 2.146 |
| Methyl Trichlorosilane (CH ₃)SiCl ₃ | .2499 | .164 | 6.669 |
| Molybdenum Hexafluoride MoF ₆ | .2126 | .1373 | 9.366 |
| Monoethylamine C ₂ H ₅ NH ₂ | .3512 | .387 | 2.011 |
| Monomethylamine CH ₃ NH ₂ | .51 | .4343 | 1.386 |
| Neon NE | 1.46 | .246 | .900 |
| Nitric Oxide NO | .990 | .2328 | 1.339 |
| Nitrogen N ₂ | 1.000 | .2485 | 1.25 |
| Nitrogen Dioxide NO ₂ | .737 | .1933 | 2.052 |
| Nitrogen Trifluoride NF ₃ | .4802 | .1797 | 3.168 |
| Nitrosyl Chloride NOCl | .6134 | .1632 | 2.920 |
| Nitrous Oxide N ₂ O | .7128 | .2088 | 1.964 |
| Octafluorocyclobutane (Freon-C318) C ₄ F ₈ | .176 | .185 | 8.397 |
| Oxygen O ₂ | .9926 | .2193 | 1.427 |
| Oxygen Difluoride OF ₂ | .6337 | .1917 | 2.406 |
| Ozone | .446 | .195 | 2.144 |
| Pentaborane B ₅ H ₉ | .2554 | .38 | 2.816 |
| Pentane C ₅ H ₁₂ | .2134 | .398 | 3.219 |
| Perchloryl Fluoride ClO ₃ F | .3950 | .1514 | 4.571 |
| Perfluoropropane C ₃ F ₈ | .174 | .197 | 8.388 |
| Phosgene COCl ₂ | .4438 | .1394 | 4.418 |
| Phosphine PH ₃ | .759 | .2374 | 1.517 |

| ACTUAL GAS | K FACTOR Relative to N ₂ | Cp [Cal/g] | Density [g/l] |
|--|--|---------------|------------------|
| Phosphorous Oxychloride POCl ₃ | .36 | .1324 | 6.843 |
| Phosphorous Pentafluoride PH ₅ | .3021 | .1610 | 5.620 |
| Phosphorous Trichloride PCl ₃ | .30 | .1250 | 6.127 |
| Propane C ₃ H ₈ | .35 | .399 | 1.967 |
| Propylene C ₃ H ₆ | .40 | .366 | 1.877 |
| Silane SiH ₄ | .5982 | .3189 | 1.433 |
| Silicon Tetrachloride SiCl ₄ | .284 | .1270 | 7.580 |
| Silicon Tetrafluoride SiF ₄ | .3482 | .1691 | 4.643 |
| Sulfur Dioxide SO ₂ | .69 | .1488 | 2.858 |
| Sulfur Hexafluoride SF ₆ | .2635 | .1592 | 6.516 |
| Sulfuryl Fluoride SO ₂ F ₂ | .3883 | .1543 | 4.562 |
| Tetrafluoroethane (Forane 134A) CF ₃ CH ₂ F | .5096 | .127 | 4.224 |
| Tetrafluorohydrazine N ₂ F ₄ | .3237 | .182 | 4.64 |
| Trichlorofluoromethane (Freon-11) CCl ₃ F | .3287 | .1357 | 6.129 |
| Trichlorosilane SiHCl ₃ | .3278 | .1380 | 6.043 |
| 1,1,2-Trichloro-1,2,2 Trifluoroethane (Freon-113) CCl ₂ FCF ₂ | .2031 | .161 | 8.36 |
| Triisobutyl Aluminum (C ₄ H ₉)AL | .0608 | .508 | 8.848 |
| Titanium Tetrachloride TiCl ₄ | .2691 | .120 | 8.465 |
| Trichloro Ethylene C ₂ HCl ₃ | .32 | .163 | 5.95 |
| Trimethylamine (CH ₃) ₃ N | .2792 | .3710 | 2.639 |
| Tungsten Hexafluoride WF ₆ | .2541 | .0810 | 13.28 |
| Vinyl Bromide CH ₂ CHBr | .4616 | .1241 | 4.772 |
| Vinyl Chloride CH ₂ CHCl | .48 | .12054 | 2.788 |
| Xenon Xe | 1.44 | .0378 | 5.858 |

APPENDIX 3

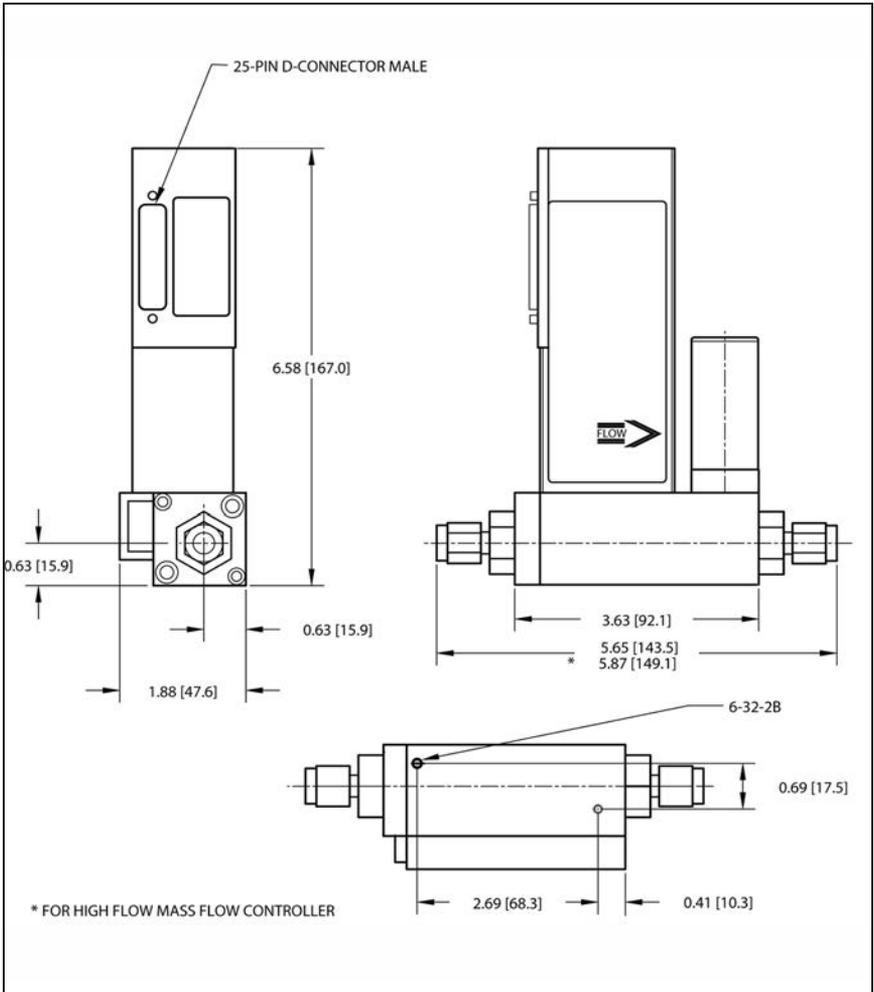
DIMENSIONAL DRAWINGS

DFC 26 Mass Flow Controller



NOTES: Aalborg® reserves the right to change designs and dimensions at its sole discretion at any time without notice. For certified dimensions please contact Aalborg®.

DFC 36/46 Mass Flow Controller



NOTES: Aalborg® reserves the right to change designs and dimensions at its sole discretion at any time without notice. For certified dimensions please contact Aalborg®.

APPENDIX 4

SENDING COMMANDS TO THE DFC

RS485

The standard DFC comes with an RS485 interface. The protocol described below allows for the unit using either a custom software program or a “dumb terminal”. All values are sent as printable ASCII characters. The start character is always ! and the command string is terminated with a carriage return (line feeds are automatically stripped out by the DFC:

!<Addr>, <Cmd>,Arg1,Arg2,Arg3,Arg4<CR>

WHERE:

| | |
|--------------|---|
| ! | Start character |
| Addr | RS485 device address in the ASCII representation of hexadecimal (00 through FF are valid). ** |
| Cmd | The one or two character command from the table above. |
| Arg1 to Arg4 | The command arguments from the table above. Multiple arguments are comma delimited. |
| CR | Carriage return character. |
| ** | Default address for all units is 11. |

Several examples of commands follow.

All assume that the DFC has been configured for address 15 (0F hex) on the RS485 bus:

- To put the unit in digital mode: !0F,M,D<CR>
The DFC will reply: !0FMD<CR>
- To set the flow of 50% of FS: !0F,S,50.0<CR>
The DFC will reply: !0FS50.0<CR>
- To get a flow reading: !0F,F<CR>
The DFC will reply: !0F50.0<CR>
(Assuming the flow is at 50% FS)
- Set the high alarm limit to 5% above Set point: !0F,A,H,5.0<CR>
The DFC will reply: !0FA5.0<CR>

AALBORG DFC SOFTWARE INTERFACE COMMANDS

NOTE: AN "*" INDICATES POWER UP DEFAULT SETTINGS.

| COMMAND NAME | DESCRIPTION | NO. | COMMAND SYNTAX | | | | | RESPONSE |
|--------------|---|-----|----------------|--|------------|------------|------------|--|
| | | | COMMAND | ARGUMENT 1 | ARGUMENT 2 | ARGUMENT 3 | ARGUMENT 4 | |
| Mode | Selects Analog or Digital mode for set point and feed back signals | 1 | M | A (sets analog mode)* D (sets digital mode) S (Returns Status) | | | | MA MD MA or MD |
| Set Point | Sends the desired flow setting to the unit in digital mode | 2 | S | <Value> (Desired flow in current engineering units) | | | | S <Value> |
| Flow | Requests the current sensor reading | 3 | F | | | | | <Value> (Actual flow in current engineering units) |
| Valve | Sets or reads the operating mode of the control valve. (Note:Hardware I/O overrides software command.) | 4 | V | A (Automatic Mode)* O (Force Open) C (Force Closed) S (Return Status) | | | | VA VO VC VA, VO or VC |
| Gas Select | Selects one of the ten primary gas calibration tables to use. Tables are entered via the MEM commands at time of calibration. | 5 | G | 0 (gas 0)* to 9 (gas 9) | | | | G1 through G10 |

| COMMAND SYNTAX | | | | | | | | |
|----------------|--|-----|---------|--|--|------------|------------|---|
| COMMAND NAME | DESCRIPTION | NO. | COMMAND | ARGUMENT 1 | ARGUMENT 2 | ARGUMENT 3 | ARGUMENT 4 | RESPONSE |
| Auto Zero | Sets/reads the status of the auto zero feature (Note: The Z,N command can take several minutes to complete. Unit will not respond to other commands when this is in progress) | 6 | Z | E (enable, do when SP<2% FS)* D (disable, never do it) N (do it now) W (Write Zero to SDPROC) S (status) | | | | ZE ZD ZN ZW(when done) ZE, ZD or ZIN, <value> while Z,N is in progress. |
| Flow Alarms | Set/reads the status of the gas flow alarms. | 7 | A | H (high deviation) L (low deviation) D (disable)* S (status) | <Value> <Value> | | | AH<Value> AL<Value> AD N (no alarm) H (high alarm) L (low alarm) |
| Relay Action | Assigns action of the two SPDT relays. The coil is energized when the condition specified by "Argument 2" becomes true. | 8 | R | 1 (relay 1) 2 (relay 2) | N (no action, relay disabled)* T (totalizer >limit) H (high flow alarm) L (low flow alarm) R (Range between high & low flow alarm) | | | RN RT RH RL RR |

| COMMAND SYNTAX | | | | | | | | |
|----------------|---|-----|---------|--|---|--|------------|---|
| COMMAND NAME | DESCRIPTION | NO. | COMMAND | ARGUMENT 1 | ARGUMENT 2 | ARGUMENT 3 | ARGUMENT 4 | RESPONSE |
| Totalizer | Controls action of the flow totalizer. | 9 | T | Z (set to zero) S (start the totalizer) P (stop the totalizer) | S (status) N (now) F (at flow) N (now) T (at total) | <value> (gas flow) | | RN, RT, RH, RL, RR TZ TSN TS <value> TPN TPT (N/C) <valve> |
| K Factors | Applies a gas correction factor to the currently selected primary gas calibration table. (NOTE: Does not work with %FS. engineering unit. Changes take affect after next set point command). | 10 | K | D (disable)* D (disable, sets K=1)* I (internal K factor table) E (user specified factor) | | <index> (index to K factor) <value> (decimal correction factor) | | <value> (total gas volume) TD KD KI <index><name> <value> KE <Value> |
| Units | Set the units of measure for the digital flow set point, flow signal and totalizer. Note: The units of the totalizer output are not per unit time. | 11 | U | % (%full scale)* SLPM (standard liters per min.) SLPH (standard liters per hr.) | | | | U% USLPM USLPH |

| COMMAND SYNTAX | | | | | | | | |
|-------------------|---|-----|---------|---|--------------------------------------|---|------------|---------------------------------|
| COMMAND NAME | DESCRIPTION | NO. | COMMAND | ARGUMENT 1 | ARGUMENT 2 | ARGUMENT 3 | ARGUMENT 4 | RESPONSE |
| | | | | MLPH (standard milliliters per min.) | | | | UMLPM |
| | | | | MLPH (standard milliliters per hour) | | | | UMLPH |
| | | | | SCFH (standard cubic feet per hour) | | | | USCFH |
| | | | | SCFM (standard cubic feet per min.) | | | | USCFM |
| | | | | LBPH (pounds per hour) | | | | ULBPH |
| | | | | LBPM (pounds per min.) | | | | ULBPM |
| | | | | UD (user defined) | <value>(conversion factor from SLPM) | Time Base: S = Seconds M = Minutes H = Hours | | UUD<value> |
| Maintenance Timer | Hours since last time unit was calibrated. | 12 | C | R (read timer) C (set timer to zero) | | | | <value> CC |
| Full Scale | Returns the full scale rated flow in SLPM. (Note: This term is not multiplied by the current K factor) | 13 | E | | | | | <value> |
| Read Mem. | Reads the value in the specified memory location. | 14 | MR | 0000 to 999 (Table Index) | | | | <value> |
| Write Mem. | Writes the specified value to the specified memory location. Use CAREFULLY can cause unit to malfunction. | 15 | MW | 0000 to 999 (Table Index) | <value> | | | MWXXX<value> XXX=Table Index |

| COMMAND SYNTAX | | | | | | | | |
|--|--------------------|-----|------------|--|------------|------------|------------|---|
| COMMAND NAME | DESCRIPTION | NO. | COMMAND | ARGUMENT 1 | ARGUMENT 2 | ARGUMENT 3 | ARGUMENT 4 | RESPONSE |
| Auto Tune (Available for units with maximum flow up to 80L/min) | Performs Auto Tune | 16 | AT | <Value> (Desired flow in current engineering units, use 80-90% F.S. for best results) | | | | AT<Value> (when auto tune starts) |
| | | | S (Status) | | | | | ATSI<Kp, Ki, Kd> (in progress) ATSD<Kp, Ki, Kd> (done) |

APPENDIX 5

CALIBRATION TABLE: GAS INDEPENDENT VARIABLES

| INDEX | NAME | DATA TYPE | NOTES |
|-------|----------------|-----------|---------------------------------------|
| 0 | BlankSDPROC | char[10] | Do not modify. For internal use only. |
| 1 | SerialNumber | char[20] | |
| 2 | ModelNumber | char[20] | |
| 3 | SoftwareVer | char[10] | |
| 4 | TimeSinceCalHr | float | Time since last calibration in hours. |
| 5 | Options | uint | Misc. Options. |
| 6 | AOutOffset_mA | int | |
| 7 | AddressRS485 | char[3] | Two character address for RS485 only. |
| 8 | AlnScaleV | float | |
| 9 | AlnOffsetV | float | |
| 10 | AlnScale_mA | float | |
| 11 | AlnOffset_mA | float | |
| 12 | AoutScaleV | float | |
| 13 | AoutScale_mA | float | |
| 14 | SensorZero | uint | |
| 15 | Klag[0] | float | |
| 16 | Klag[1] | float | |
| 17 | Klag[2] | float | |
| 18 | Klag[3] | float | |
| 19 | Klag[4] | float | |
| 20 | Klag[5] | float | |
| 21 | Reserved | float | |
| 22 | Reserved | float | |
| 23 | Reserved | float | |
| 24 | Reserved | float | |
| 25 | Reserved | float | |
| 26 | Reserved | float | |
| 27 | Kgain[0] | float | |
| 28 | Kgain[1] | float | |

| INDEX | NAME | DATA TYPE | NOTES |
|-------|--------------------------|-----------|--|
| 29 | Kgain[2] | float | |
| 30 | Kgain[3] | float | |
| 31 | Kgain[4] | float | |
| 32 | Kgain[5] | float | |
| 33 | Reserved | float | |
| 34 | Reserved | float | |
| 35 | Reserved | float | |
| 36 | Reserved | float | |
| 37 | Reserved | float | |
| 38 | Reserved | float | |
| 39 | ValveTbI[0][open] | float | Index 0: Valve actuation. Must be 0.0.- Do Not Alter |
| 40 | ValveTbI[0][valve value] | uint | Index 0: Valve: D/A value - Do Not Alter |
| 41 | ValveTbI[1][flow] | float | Index 1: Actual valve opening in % FS. Do Not Alter |
| 42 | ValveTbI[1][valve value] | uint | Index 1: Valve D/A counts corresponding to flow. Do Not Alter |
| 43 | ValveTbI[2][flow] | float | Do Not Alter |
| 44 | ValveTbI[2][valve value] | uint | Do Not Alter |
| 45 | ValveTbI[3][flow] | float | Do Not Alter |
| 46 | ValveTbI[3][valve value] | uint | Do Not Alter |
| 47 | ValveTbI[4][flow] | float | Do Not Alter |
| 48 | ValveTbI[4][valve value] | uint | Do Not Alter |
| 49 | ValveTbI[5][flow] | float | Do Not Alter |
| 50 | ValveTbI[5][valve value] | uint | Do Not Alter |
| 51 | ValveTbI[6][flow] | float | Do Not Alter |
| 52 | ValveTbI[6][valve value] | uint | Do Not Alter |
| 53 | ValveTbI[7][flow] | float | Do Not Alter |
| 54 | ValveTbI[7][valve value] | uint | Do Not Alter |
| 55 | ValveTbI[8][flow] | float | Do Not Alter |
| 56 | ValveTbI[8][valve value] | uint | Do Not Alter |
| 57 | ValveTbI[9][flow] | float | Index 9: Valve fully open. Must be 1.0- Do Not Alter |
| 58 | ValveTbI[9][valve value] | uint | Index 9: D/A count for a fully open valve. Must be 4095.- Do Not Alter |
| 59 | AutoTune Time Constant | uint | Do Not Alter |

CALIBRATION TABLE: GAS DEPENDENT VARIABLES

| INDEX | NAME | DATA TYPE | NOTES |
|-------|----------------------------|-----------|-----------------------------------|
| 100 | GasIdentifier | char[27] | |
| 101 | FullScaleRange | float | |
| 102 | StdTemp | float | |
| 103 | StdPressure | float | |
| 104 | StdDensity | float | |
| 105 | CalibrationGas | char[27] | |
| 106 | CalibratedBy | char[20] | |
| 107 | CalibratedAt | char[20] | |
| 108 | DateCalibrated | char[10] | |
| 109 | DateCalibrationDue | char[10] | |
| 110 | PID_Kp | float | |
| 111 | PID_Ki | float | |
| 112 | PID_Kd | float | |
| 113 | SensorTbl[0][Sensor Value] | uint | Index 0: Must be 120 (zero value) |
| 114 | SensorTbl[0][Flow] | float | Index 0: Must be 0.0 (zero PFS) |
| 115 | SensorTbl[1][Sensor Value] | uint | A/D value from sensor. |
| 116 | SensorTbl[1][Flow] | float | Actual Flow in PFS. |
| 117 | SensorTbl[2][Sensor Value] | uint | |
| 118 | SensorTbl[2][Flow] | float | |
| 119 | SensorTbl[3][Sensor Value] | uint | |
| 120 | SensorTbl[3][Flow] | float | |
| 121 | SensorTbl[4][Sensor Value] | uint | |
| 122 | SensorTbl[4][Flow] | float | |
| 123 | SensorTbl[5][Sensor Value] | uint | |
| 124 | SensorTbl[5][Flow] | float | |
| 125 | SensorTbl[6][Sensor Value] | uint | |
| 126 | SensorTbl[6][Flow] | float | |
| 127 | SensorTbl[7][Sensor Value] | unit | |
| 128 | SensorTbl[7][Flow] | float | |

| INDEX | NAME | DATA TYPE | NOTES |
|-------|-----------------------------|-----------|----------------------------|
| 129 | SensorTbl[8][Sensor Value] | uint | |
| 130 | SensorTbl[8][Flow] | float | |
| 131 | SensorTbl[9][Sensor Value] | uint | |
| 132 | SensorTbl[9][Flow] | float | |
| 133 | SensorTbl[10][Sensor Value] | uint | |
| 134 | SensorTbl[10][Flow] | float | Flow in PFS. Should be 1.0 |
| 135 | | | |
| 136 | | | |
| 137 | | | |

Note: Values will be available for selected gas only.

APPENDIX 6

WARRANTY

Limited
Warranty

Policy
Coverage

Aalborg® warrants its products to be free from defects in materials and workmanship for a period of not to exceed (12) months from the date of purchase.

Customer Responsibilities

It is the sole responsibility of the customer to ensure the proper selection of equipment that is compatible with the flow medium and operating conditions in use. Products must be operated by qualified personnel knowledgeable in the equipment's intended application, limitations, and proper usage. Use of the equipment in a manner inconsistent with operational guidelines, including exposure to incompatible gases, liquids, or conditions, voids all warranty coverage.

Limitations and Exclusions

This warranty does not cover:

Product that was used outside of its stated specifications.

Products that, upon examination by Seller, or Seller's authorized service provider, are found to have been mishandled, misused, abused, or damaged by Buyer or any third party. A product repaired or modified by performed by a party other than Aalborg® or its authorized representatives. Improperly stored, installed, operated, or maintained in a manner inconsistent with Seller's instructions. Defects attributed to normal wear and tear or failure to comply with Seller's safety warnings. Indirect, incidental, consequential, special, punitive, or consequential damages, including lost profits. Shipping or transportation charges to Aalborg® or its authorized service facility.

Return Authorizations

Goods shall not be returned without Seller's prior authorization.

It is recommended that our service representatives be contacted to rectify product issues remotely, if possible. When not possible, request a Return Authorization Number (RAN) and a SERVICE SAFETY ASSURANCE CERTIFICATE form to be completed and attached for factory evaluation.

If a defect covered by this warranty is discovered, the product will be repaired or replaced at Aalborg's sole discretion, free of charge for parts and labor. Such repair, replacement, or credit shall be Buyer's sole remedy for defective Goods and Services.

For defective Goods not covered by this warranty, repair or replacement shall not be performed until and unless Buyer issues an Order to Seller authorizing such repair or replacement at Seller's then-current repair or replacement price. In addition, Seller may charge Buyer for any testing or inspection costs. In no event shall Seller retain or store returned Goods for more than three (3) months.

Disclaimer

THESE WARRANTIES, INCLUDING THE REMEDIES SET FORTH HEREIN, ARE EXCLUSIVE AND ARE IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED. NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE IS INTENDED OR GIVEN.

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Email: info@aalborg.com
Website: www.aalborg.com*

Form nr.: AAL-WP1

NOTE: Follow Return Procedures In Section 1.3.

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ASIAN Service Facility

Authorized Repair and Service Facility for Aalborg Thermal Mass Flow Systems

AALBORG-Beijing Comity

Measure & Control Co.

**Floor 1 Tower B Jindayuan Office Building
Xisanqi, Hai Dian District, Beijing, China**

Phone: 86-10-6295-0464, 86-10-6295-0465

Fax: 86-10-6295-0466

Website: <http://www.comity-tec.com>

European Service Facility

Authorized Repair and Service Facility for Aalborg Thermal Mass Flow Systems

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Single Tube

Aluminum / Brass / Stainless ● Interchangeable Glass Flow Tubes ● Optional Valves

Multiple Tube

Two to Six Channels ● Aluminum or Stainless

PTFE Single and Multiple Tube

Chemically Inert ● 1 to 4 Channels ● Interchangeable Glass Flow tubes

PTFE - PFA

Chemically Inert ● Low to Medium Flow of Corrosive Liquids with PFA Flow Tube Kits

Aluminum / Stainless / PTFE ● Including Five Glass Flow Tubes and a Set of Floats
Gas Proportioners

Aluminum / Stainless ● Used for Blending Two or Three Gases

Medium Range

Glass Safety Shield ● Dual Air and Water Scale

Optical Sensor Switch

Non-Invasive Means for Detection of a High or Low Flow

High Flow Industrial Stainless Steel Flow Meters

Heavy Duty Stainless Steel ● Direct Reading Air and Water Scales

VALVES

Barstock

Brass or Stainless ● Standard or High Precision

PTFE

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Stainless ● For Controlling Gas or Liquid Flow

● Pulse width Modulated

SMV ● Stepping Motor Valve

peristaltic PUMPS

Fixed RPM Pumps

Pump Heads

Tubing Pumps

Variable Speeds

Dispensing Pumps

Flexible Tubings

ELECTRONIC METERS & CONTROLLERS

Low Cost Mass Flow Meters

Aluminum or Stainless ● With or Without LCD Readout

Low Cost Mass Flow Controllers

Aluminum or Stainless ● With or Without LCD Readout

Mass Flow Controllers

Stainless ● One to Four Channel Systems

Digital Mass Flow Controllers

Auto Zero ● Totalizer ● Alarms ● Built in RS485

Multi Parameter Digital Mass Flow Meters

Displays Flow Pressure and Temperature

Paddle Wheel Meters

For Liquids ● Optional Temperature Measurements

Smart Rate / Totalizer / Signal Conditioner

LCD Keypad ● RS232 / 485 ● Pulse Output ● Alarms