ANALYT MESSTECHNIK




OPERATING MANUAL

# Aalborg DFC Digital Mass Flow Controller

Installation, wiring, operation, digital communication, calibration and maintenance of the DFC 26, DFC 36 and DFC 46 digital mass flow controllers.

AMTC-MN-0008

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# About this manual

This manual explains how to install, wire, operate, calibrate and maintain Aalborg DFC digital mass flow controllers. It covers the three models: the DFC 26 for low flows, the DFC 36 for medium flows and the DFC 46 for high flows, from 10 mL/min to 100 L/min of nitrogen.

Read Safety (p. 6) before you install the controller. To set up a new controller, follow the chapters in order: Installation (p. 10) with the electrical connections (p. 11), Commissioning (p. 15), then Operation (p. 16). If you control the DFC from a computer, Communication (p. 18) lists every command. The Specifications (p. 27) and the gas conversion factors in Appendix A (p. 32) are reference material you can turn to at any time.

The DFC is manufactured by Aalborg. Service, calibration, repairs and technical support are provided by Analyt-MTC; the contact details are in Service, warranty and contacts (p. 30) and on the back cover.

Keep this manual for the lifetime of the product. The current revision is on the product page at analyt-mtc.com.

Conventions in this manual:

- Keys, buttons and menu entries are printed like this: **<CR>**.
- Commands you send and replies the device returns are set in monospace type, for example `!0F,S,50.0`.

## Abbreviations

| Abbreviation | Meaning |
|---|---|
| **A/D** | Analogue-to-digital |
| **ASCII** | American Standard Code for Information Interchange |
| **D/A** | Digital-to-analogue |
| **EMC** | Electromagnetic compatibility |
| **EPR** | Ethylene propylene rubber |
| **FFKM** | Perfluoroelastomer |
| **FKM** | Fluoroelastomer |
| **GND** | Ground |
| **NPN** | Negative-positive-negative, a type of bipolar transistor |
| **PLC** | Programmable logic controller |
| **RTS** | Request to send, a serial handshake line |
| **RX** | Receive |
| **sccs** | Standard cubic centimetres per second, a leak rate unit |
| **SPDT** | Single-pole, double-throw (changeover contact) |
| **TD** | Transmit data, a serial line |
| **TX** | Transmit |
| **WEEE** | Waste electrical and electronic equipment |

## Safety notices in this manual

**⚠ WARNING**

A hazardous situation which, if not avoided, could result in death or serious injury.

**⚠ CAUTION**

A hazardous situation which, if not avoided, could result in minor or moderate injury.

**NOTICE**

Practices not related to personal injury — damage to the product, the process or the sample.

**Note**

Information that helps understanding; never a hazard.

## Conventions

- **FS** stands for full scale: the highest flow of the range your controller is calibrated for. Accuracies given as “% FS” are a percentage of that value.
- Flows are standard flows of nitrogen at 21.11 °C, 1013.25 mbar unless stated otherwise. For other gases, see Gas conversion factors (p. 22).
- Pressures are gauge pressures unless marked “abs” or “psia” (absolute); the value in psi follows in brackets where useful, and “psid” is a pressure difference.
- Pin numbers, such as “pin 4”, refer to the 25-pin D connector on the side of the controller (pin assignment (p. 12)).
- **<CR>** is the carriage return that ends every serial command.

## Document information

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# Contents


1 **Safety** 6
- Intended use 6
- Before you start 6
- Qualified personnel 7

2 **Product description** 8
- How the DFC measures and controls 8
- Models and flow ranges 8
- Functions 9
- What you need to operate it 9
- Circuit boards 9

3 **Installation** 10
- Unpacking and inspection 10
- Gas quality 10
- Location and orientation 10
- Inlet pressure and pressure difference 10
- Connecting the gas lines 11
- Electrical connections 11
  - Electrical safety 11
  - Power supply 11
  - Pin assignment 12
  - Wiring for analogue operation 13
  - Analogue signal configuration 13
  - Serial interface 14

4 **Commissioning** 15
- Switching on and warming up 15

5 **Operation** 16
- Reading the flow 16
- Giving the set point 16
- Valve off 16
- Purge: valve fully open 17

6 **Communication** 18
- Command format 18
- Examples 18
- Command reference 18

7 **Calibration and verification** 21
- Calibration service 21
- Calibrating in the field 21

Changing the flow range 22
Gas conversion factors 22

8 **Maintenance** 23
Before you start 23
Cleaning the flow path 23
Valve 24

9 **Troubleshooting** 25
First checks 25
Fault finding 25
Technical support 26

10 **Specifications** 27
Performance 27
Operating conditions 27
Electrical data 27
Materials and connections 28
CE marking 28

11 **Ordering information** 29
Controllers 29
Accessories 29

12 **Service, warranty and contacts** 30
Contact 30
Sending in a controller 30
Warranty 31
Disposal 31

A **Gas conversion factors** 32

B **Dimensions** 35
DFC 26 35
DFC 36 and DFC 46 35

C **Calibration memory** 36

CHAPTER 1

# Safety

Read this chapter before you install or operate the controller. Each point is repeated, with its context, in the section where it applies.

## Intended use

The DFC measures and controls the mass flow of clean gases. It does not work with liquids: never let liquid enter the controller. Filter any gas that may carry particles before it reaches the controller, because they block the sensor tube and the flow passages.

The protection built into the controller works only when it is installed and operated the way this manual describes. If your application calls for anything else, agree it in writing with Analyt-MTC first.

**⚠ WARNING**

The DFC is not intended for life-support applications. There, a failure or a wrong flow could endanger a person's life or health. Do not use the DFC where its failure or a wrong flow could endanger anyone.

## Before you start

Keep these points in mind whenever you install, wire, adjust or service the controller.

**⚠ WARNING**

A controller that has carried toxic, infectious, corrosive or radioactive media holds residues. Residues endanger the people who service it. Before you open such a controller, purge it completely and neutralise all residues.

**⚠ WARNING**

A controller that is not suitable or not cleaned for oxygen service can cause damage or personal injury when it is used with oxygen. It is your responsibility to decide whether the controller is suitable for your oxygen application. If your application requires it, specify oxygen cleaning when you order.

**⚠ CAUTION**

When the valve stays in automatic control or fully open for a long time, it can become warm or even hot. Touching it then can burn you. Avoid touching the valve while the controller is in operation.

**NOTICE**

Some components on the circuit boards are sensitive to electrostatic discharge, which can damage them. Wear a grounded wrist strap whenever you open the controller to change jumpers or service it.

**NOTICE**

Connecting or disconnecting a cable with the power on can damage the controller. Switch the power off before you connect or disconnect any cable in the system.

**Gas compatibility.** You choose the model and its wetted materials for your gas; corrosion resistance against a particular gas is not guaranteed. The materials are listed in Materials and

connections (p. 28).

**K factors.** Gas conversion factors are approximations. Do not rely on them where you need an accuracy better than ±5 to 10 % (Gas conversion factors (p. 22)).

## Qualified personnel

Field calibration and adjustment of the control loop are work for qualified staff with suitable equipment (Calibration and verification (p. 21)). Wear a grounded wrist strap when you adjust or service the controller (electrical safety (p. 11)).

CHAPTER 2

# Product description

The DFC is a thermal mass flow controller with a microprocessor at its core. It measures the flow, compares it with your set point and drives its built-in solenoid valve to hold the flow there. You can give the set point as an analogue signal or over the serial interface.

## How the DFC measures and controls

Inside the controller the gas stream divides. A small part flows through a thin stainless-steel sensor tube; the rest passes through the main flow path, where the **restrictor flow element (RFE)** sets the split. Both paths are laminar, so the flow in the sensor tube stays in a fixed proportion to the total flow. Which RFE a controller has depends on its gas and flow range.

Two precision-wound coils on the sensor tube heat it. Flowing gas carries heat from the upstream coil to the downstream coil, and the electronics measure the resulting difference in coil resistance. This difference is linear with the flow, and because it depends on how much heat the gas carries, the DFC measures mass flow rather than volume.

All calibration data are stored in non-volatile memory. The microprocessor compares the measured flow with the set point continuously and corrects any deviation through the proportional solenoid valve. The valve is normally closed: without power, it stays shut.

## Models and flow ranges

The three models differ in flow capacity, body size and process fittings. Every controller is calibrated for one range; the range and the calibration gas are on its front label. Ranges are given for nitrogen; for other gases, multiply by the gas's K factor (Appendix A (p. 32)).

**Table 2-1 DFC 26, low flow**

| Range code | Full scale ($N_2$) |
|---|---|
| 01 | 10 mL/min |
| 02 | 20 mL/min |
| 03 | 50 mL/min |
| 04 | 100 mL/min |
| 05 | 200 mL/min |
| 06 | 500 mL/min |
| 07 | 1 L/min |
| 08 | 2 L/min |
| 09 | 5 L/min |
| 10 | 10 L/min |

**Table 2-2 DFC 36, medium flow**

| Range code | Full scale ($N_2$) |
|---|---|
| 11 | 15 L/min |
| 30 | 20 L/min |
| 31 | 30 L/min |
| 32 | 40 L/min |
| 33 | 50 L/min |

**Table 2-3 DFC 46, high flow**

| Range code | Full scale ($N_2$) |
|---|---|
| 40 | 60 L/min |
| 41 | 80 L/min |
| 42 | 100 L/min |

All ranges start at zero. Standard flows of nitrogen at 21.11 °C, 1013.25 mbar.

## Functions

| | |
|---|---|
| Analogue interface | 0–5 V DC flow output and set point input as standard; 4–20 mA or a 0–10 V DC output selectable with jumpers (Analogue signal configuration (p. 13)). |
| Serial interface | RS-485 as standard, RS-232 as an option. In digital mode the set point is sent as a command and the flow is read back in the engineering unit you choose (Communication (p. 18)). |
| Valve control inputs | Two contacts on the connector force the valve fully closed or fully open, independent of the set point (Valve off (p. 16), Purge (p. 17)). |
| Gas tables | Up to ten calibration tables for different gases, selected by command; K factors for further gases. |
| Auto zero | The sensor zero is corrected automatically whenever the valve is fully closed. |
| Alarms and relays | High and low flow alarms and two changeover (SPDT) relays that can follow the alarms or the totaliser. |
| Totaliser | Adds up the gas volume; can start at a set flow and stop, or close the valve, at a set total. |
| Auto-tune | Tunes the control loop automatically, on controllers up to 80 L/min full scale. |

## What you need to operate it

- A regulated power supply with +15 V DC and −15 V DC outputs (Power supply (p. 11)).
- For analogue operation: a variable 0–5 V DC set point source and a panel meter, digital multimeter or other readout for the flow signal.
- For digital operation: a computer or controller with an RS-485 port or converter (RS-232 on controllers with that option).
- A 25-pin D-sub cable no longer than 3 m.

## Circuit boards

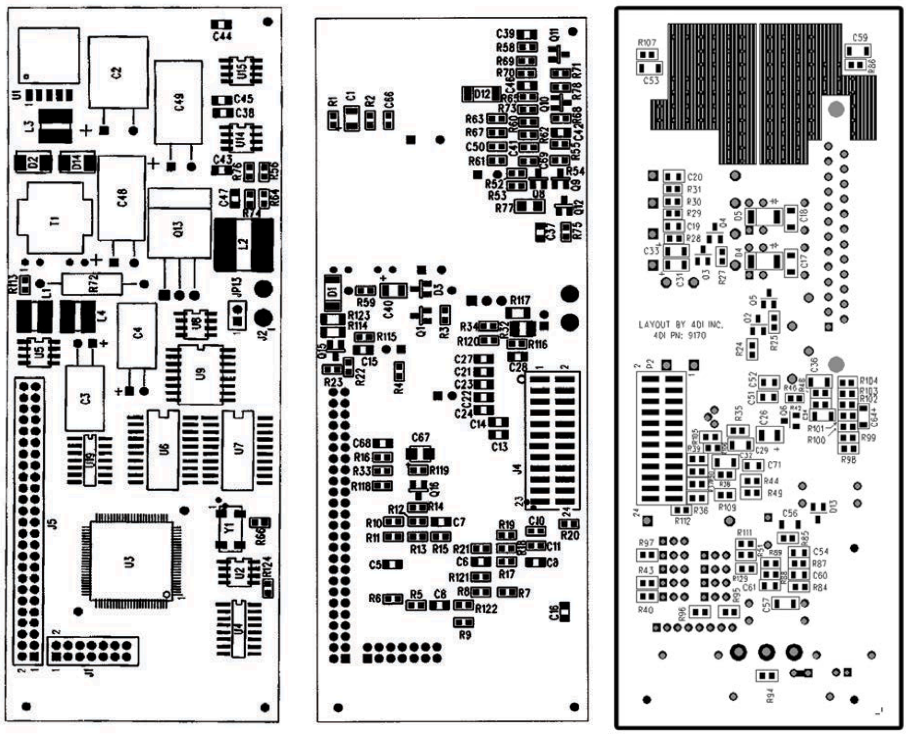


**Figure 2-1.** Digital circuit board, primary side (left) and secondary side (centre); analogue circuit board, secondary side (right). Figure 3-3 shows the primary side of the analogue board.

CHAPTER 3

# Installation

## Unpacking and inspection

The controller is shipped in a sturdy carton with anti-static cushioning. When it arrives:

1. Inspect the outside of the carton. If it is damaged, report the damage to the carrier immediately.
2. Open the carton carefully from the top and check the controller for hidden transport damage. If you find any, report it to the carrier and send a copy of the damage report to Analyt-MTC.
3. Check the contents against the packing list and report anything missing to Analyt-MTC straight away.

To send a controller back to Analyt-MTC for repair or calibration, follow Sending in a controller (p. 30).

## Gas quality

Only clean gases may enter the controller. The sensor is a fine capillary tube that particles or crystallizing gas components block easily, and the other flow passages are narrow too. Filter any gas that may carry contaminants, and never let liquid into the controller. The inlet filter screen — 50 µm in the DFC 26, 60 µm in the DFC 36 and DFC 46 — is a last line of defence, not a substitute for a clean gas supply.

**⚠ WARNING**

A controller that is not suitable or not cleaned for oxygen service can cause damage or personal injury when it is used with oxygen. It is your responsibility to decide whether the controller is suitable for your oxygen application. If your application requires it, specify oxygen cleaning when you order.

## Location and orientation

Mount the controller with its flow path horizontal. It is calibrated in this position and tolerates a tilt of up to ±15°. Turning it from horizontal to vertical shifts the reading by about 1 %; if you have to mount it in another orientation, have it recalibrated for that position.

Choose a stable location, free from frequent or sudden temperature changes, high humidity and draughts. Keep the controller away from vibration, heat, corrosive atmospheres and strong radio-frequency or magnetic fields.

## Inlet pressure and pressure difference

The valve needs a pressure difference between inlet and outlet to pass the full-scale flow. Keep within these limits; the pressure drop of each model at its flow rates is in Maximum pressure drop (p. 28).

| | |
|---|---|
| Maximum gas pressure | 68.9 bar g (1000 psig) |
| Optimum inlet pressure | 1.4 bar (20 psig); DFC 46: 1.7 bar (25 psig) |
| Pressure difference needed | 5–50 psig; optimum 1.7 bar (25 psi) |
| Maximum pressure difference | DFC 26 and DFC 36: 3.45 bar (50 psid); DFC 46: 2.76 bar (40 psid) |

## Connecting the gas lines

Leave the fittings on the controller once they are installed; remove them only to clean the flow path or to recalibrate for a new flow range. The DFC 26 and DFC 36 have 1/4 in compression fittings, the DFC 46 has 3/8 in fittings; for other sizes and VCR fittings, ask Analyt-MTC (Materials and connections (p. 28)).

1. Inspect the pipework, fittings and ferrules and remove any dust or other contamination.
2. Find the flow-direction arrow on the front of the controller and connect the gas supply to the inlet side.
3. Push the tubing into each compression fitting until the tube end sits against the shoulder of the fitting.

   **NOTICE**

   Excessive force on the fittings seriously damages the restrictor flow element (RFE) inside the flow body. Do not over-tighten.

4. Tighten each fitting by one and a quarter turns, following the fitting manufacturer's instructions.
5. Leak-test the whole installation with a helium leak detector or an equivalent method. Every controller is leak-tested before shipment to the limits in Specifications (p. 27).

## Electrical connections

All power, analogue signals, valve control inputs, relay contacts and the serial interface share one 25-pin D connector on the side of the controller.

### Electrical safety

**NOTICE**

Some components on the circuit boards are sensitive to electrostatic discharge, which can damage them. Wear a grounded wrist strap whenever you open the controller to change jumpers or service it.

**NOTICE**

Connecting or disconnecting a cable with the power on can damage the controller. Switch the power off before you connect or disconnect any cable in the system.

### Power supply

The DFC needs a dual supply: +15 V DC and −15 V DC, each ±5 %, able to deliver up to 450 mA (6.75 W) per output. If several controllers share one supply, size it for the current of all of them.

#### Fuse protection

Each supply input has a resettable 500 mA medium time-lag fuse and a diode that protects against reversed polarity. A short circuit or reversed polarity makes the fuse cut the power to the controller. To recover, disconnect the power, correct the fault and reconnect: the fuse resets itself once the fault is gone.

## Pin assignment

**NOTICE**

Most D connectors follow the standard numbering, but not all. A cable wired by nonconforming numbers connects signals to the wrong pins, and the controller does not work correctly. Wire by the standard pin position in this table, not by the number moulded on your mating connector. Check cables taken from other makes of instrument: they rarely match.

**Note**

The cable between the controller and its supply and readout may be at most 3 m long. The standard cable is a flat ribbon cable with a 25-pin D connector at each end; for a shielded cable with male and female connectors, ask Analyt-MTC.

### Table 3-1 25-pin D connector

| Pin | Function |
|---|---|
| 1 | +15 V DC supply |
| 2 | Flow signal output, 0–5 V DC (4–20 mA option) |
| 3 | Set point input, 0–5 V DC (4–20 mA option) |
| 4 | Force valve open |
| 5 | Force valve closed |
| 6 | Reserved |
| 7 | Reserved |
| 8 | Relay 1, common |
| 9 | Relay 1, normally open |
| 10 | Relay 2, normally closed |
| 11 | RS-485 (−); RS-232 TX on the RS-232 option |
| 12 | Not connected |
| 13 | Common, signal ground |

| Pin | Function |
|---|---|
| 14 | −15 V DC supply |
| 15 | Common, signal ground for pin 2 |
| 16 | Common, signal ground for pin 3 |
| 17 | RS-232 common (RS-232 option) |
| 18 | Common, power supply |
| 19 | Common |
| 20 | Common |
| 21 | Relay 1, normally closed |
| 22 | Relay 2, common |
| 23 | Relay 2, normally open |
| 24 | RS-485 (+); RS-232 RX on the RS-232 option |
| 25 | Return for pin 2 (4–20 mA output only) |

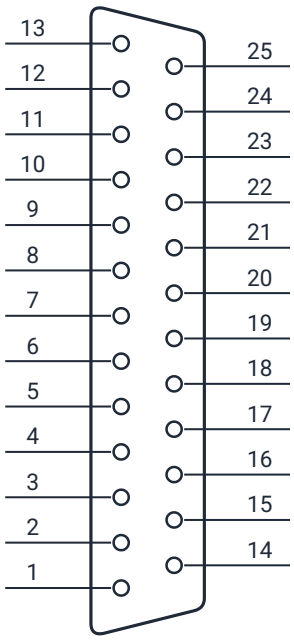



**Figure 3-1.** 25-pin D connector of the controller: pin positions. Wire by these positions and the functions in Table 3-1.

## Wiring for analogue operation

For analogue operation you need the supply, a set point source and a readout. Connect them as in Figure 3-2.

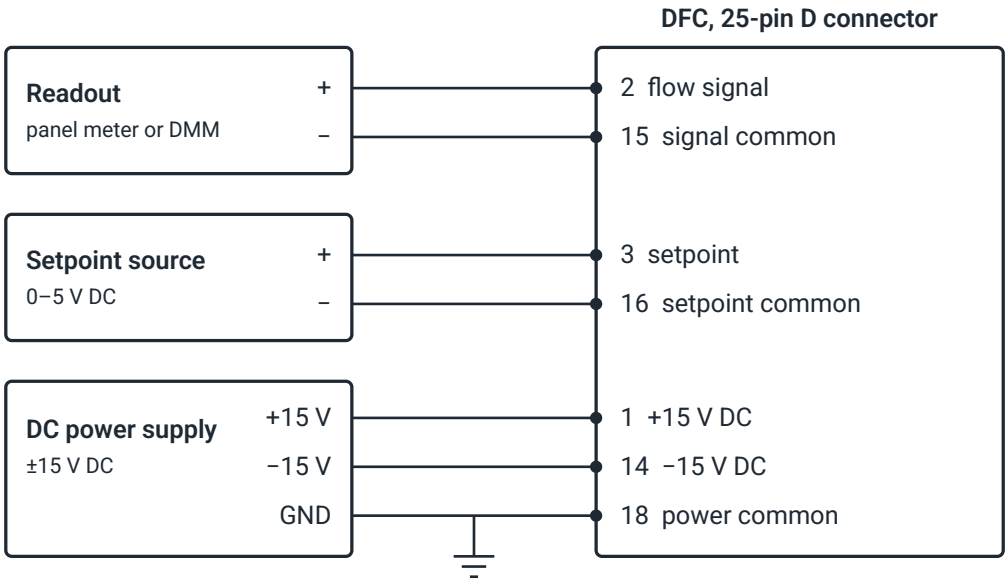



**Figure 3-2.** Analogue operation: the readout on pins 2 and 15, the set point source on pins 3 and 16, the supply on pins 1, 14 and 18. The supply's ground is connected to earth.

## Analogue signal configuration

Unless it was ordered otherwise, the controller is delivered with a 0–5 V DC output and a 0–5 V DC set point input. Jumpers on the analogue circuit board select the signal types. Make jumper changes only with the power off and with a grounded wrist strap.

### Table 3-2 Jumper settings

| Signal | Jumpers (pins bridged) |
|---|---|
| **FLOW OUTPUT** | |
| 0–5 V DC | JP3 2–3, JP5 2–3, JP6 2–3, JP12 1–2 |
| 0–10 V DC | JP3 2–3, JP5 2–3, JP6 2–3, JP12 2–3 |
| 4–20 mA | JP3 1–2, JP5 1–2, JP6 1–2, JP12 1–2 |
| **SET POINT INPUT** | |
| 0–5 V DC | JP2 2–3, JP4 2–3, JP11 1–2 |
| 4–20 mA | JP2 1–2, JP4 1–2, JP11 1–2 |

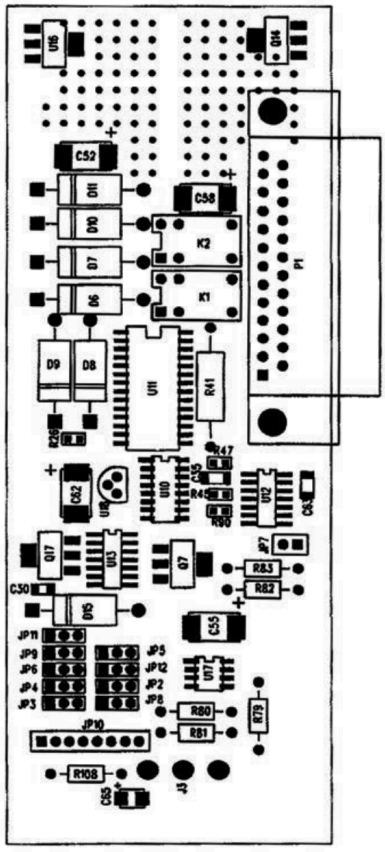



**Figure 3-3.** Analogue circuit board, component side. The jumpers JP2 to JP12 are grouped at the lower left of the board, above the header JP10.

## Serial interface

The interface runs at 9600 baud with 8 data bits, 1 stop bit and no parity. Commands and responses are described in Communication (p. 18).

### RS-485 (standard)

Set the RS-485 converter to two-wire, half-duplex multidrop operation. Its transmitter must be enabled by the TD or RTS line, whichever the converter offers; set the receiver to follow the transmitter so that the converter does not echo your own commands back.

| DFC pin | Converter |
|---|---|
| 11 (–) | T– / R– |
| 24 (+) | T+ / R+ |
| 20 (common) | GND |

### RS-232 (option)

Connect transmit to receive and receive to transmit (a crossover connection) to the 9-pin serial port of the computer:

| DFC pin | 9-pin D (computer) |
|---|---|
| 11 (TX) | pin 2 (RX) |
| 24 (RX) | pin 3 (TX) |
| 20 (common) | pin 5 (GND) |

CHAPTER 4

# Commissioning

## Switching on and warming up

1. Check that the controller is installed and leak-tested (Installation (p. 10)) and that the gas supply is shut off.
2. Switch on the power supply.
3. Let the controller warm up for at least 15 minutes before you rely on its readings.

**Note**
Right after power-up the flow signal reads higher than normal, because the sensor has not yet reached its operating temperature. This clears by itself within a few minutes, and the signal settles at zero.

CHAPTER 5

# Operation

This chapter covers analogue operation: reading the flow signal, giving the set point and using the two valve control inputs. The controller starts in analogue mode; to work over the serial interface instead, see Communication (p. 18).

## Reading the flow

The flow signal is on pin 2 of the 25-pin connector, referenced to pin 15: 0–5 V DC as standard, or 4–20 mA or 0–10 V DC if the controller is configured for it (Analogue signal configuration (p. 13)). Read it with a panel meter, a digital multimeter or your control system as shown in Figure 3-2 (Wiring for analogue operation (p. 13)).

The signal is linear with the mass flow: 0 V is no flow, 5 V is the full-scale flow on the front label, for the gas named there.

### Flow above the range

If the flow rises more than 10 % above full scale, the sensor is *swamped*: its readings are then neither accurate nor linear. Bring the flow back below 110 % of full scale; once it is within the calibrated range again, the readings recover. The longer the controller runs above 110 %, the longer this recovery may take.

**⚠ CAUTION**

When the valve stays in automatic control or fully open for a long time, it can become warm or even hot. Touching it then can burn you. Avoid touching the valve while the controller is in operation.

## Giving the set point

In analogue mode the set point input on pin 3, referenced to pin 16, accepts 0–5 V DC (4–20 mA if configured). The signal is linear: 0 V asks for no flow, 5 V for full scale. The controller then drives its valve to hold the flow at that value, anywhere within the range of the model.

Any adjustable 0–5 V DC source will do. If you use a potentiometer, choose one between 5 kΩ and 100 kΩ with at least ten turns, so that the set point can be set finely.

**Note**

With a set point below 2 % of full scale the controller closes the valve fully and corrects its zero (Zero (p. 21)). A flow that does not follow a very low set point is therefore normal.

## Valve off

Sometimes you want to switch the flow off and on again without touching the set point. Pin 5 (force valve closed) does this:

- Pin 5 connected to common (0 V): the valve is unpowered and closes.
- Pin 5 open (not connected): the valve controls the flow normally.

The connection can be made with a switch, a relay contact or an NPN open-collector transistor. The simplest solution is a toggle switch between pin 5 and a common pin.

## Purge: valve fully open

To purge the gas system — typically with a neutral gas such as pure, dry nitrogen — the valve can be opened fully, whatever the set point. Pin 4 (force valve open) does this:

- Pin 4 connected to common (0 V): the valve opens fully.
- Pin 4 open: the valve returns to normal control.

As for pin 5, use a switch, a relay contact or an NPN open-collector transistor; a toggle switch between pin 4 and a common pin is the simplest. In digital mode, these hardware inputs take priority over valve commands sent over the serial interface.

CHAPTER 6

# Communication

Over its RS-485 interface — or RS-232 on controllers with that option — the DFC can be given set points, read and configured by a computer or programmable logic controller (PLC). Any serial terminal program will do; no special software is needed for the commands in this chapter.

## Command format

Set the port to 9600 baud, 8 data bits, no parity and 1 stop bit (Serial interface (p. 14)). Commands and responses are plain ASCII text. Every command starts with `!`, followed by the address of the controller, the command and its arguments, separated by commas, and ends with a carriage return:

```
!addr,command,arg1,arg2,arg3,arg4<CR>
```

| | |
|---|---|
| `addr` | The RS-485 address of the controller: two hexadecimal characters, `00` to `FF`. Every controller leaves the factory with address `11`. |
| `command` | One or two letters (Command reference (p. 18)). |
| `arg1` … `arg4` | The arguments the command needs; leave out the ones it does not use. |
| **`<CR>`** | Carriage return (ASCII 13, the Enter key in a terminal). The controller ignores line feeds. |

## Examples

These examples address a controller set to address 15 (hexadecimal `0F`). The response repeats `!` and the address, followed by the answer without commas.

| Task | Send | Response |
|---|---|---|
| Switch to digital mode | `!0F,M,D` | `!0FMD` |
| Set the flow to 50 % of full scale | `!0F,S,50.0` | `!0FS50.0` |
| Read the flow | `!0F,F` | `!0F50.0` (flow at 50 % of full scale) |
| Set the high alarm 5 % above the set point | `!0F,A,H,5.0` | `!0FA5.0` |

**Note**
Set points sent over the interface take effect only in digital mode. After power-up the controller is in analogue mode; send `M,D` first. Values are in the current engineering unit, which is % of full scale until you choose another with the `U` command.

## Command reference

The table lists each command with its arguments, without the leading `!` and address. An asterisk (*) marks the setting the controller takes at power-up.

**NOTICE**

The write memory command `MW` overwrites calibration and control data. A wrong value can make the controller malfunction. Read the value first with `MR`, note it, and change memory only together with an Analyt-MTC engineer.

| Function | Command | Meaning | Response | Remarks |
|---|---|---|---|---|
| **MODE, SET POINT AND FLOW** | | | | |
| Mode | M,A | analogue mode* | MA | Selects whether the set point and the flow signal are analogue or digital. |
| | M,D | digital mode | MD | |
| | M,S | status | MA or MD | |
| Set point | S,value | set the flow | Svalue | Desired flow in the current engineering unit; digital mode only. |
| Flow | F | read the flow | value | Actual flow in the current engineering unit. |
| Valve | V,A | automatic control* | VA | The hardware inputs on pins 4 and 5 take priority over this command. |
| | V,O | force open | VO | |
| | V,C | force closed | VC | |
| | V,S | status | VA, VO or VC | |
| **GAS AND UNITS** | | | | |
| Gas select | G,n | n = 0*–9 | G1–G10 | Selects one of the ten gas calibration tables, which are entered in the memory at calibration. |
| K factor | K,D | off, K = 1* | KD | Applies a correction factor to the selected gas table. Not with the unit % FS. Takes effect with the next set point command. |
| | K,I,index | factor from the internal table | KI index name value | |
| | K,E,value | your own factor | KEvalue | |
| Units | U,% | % of full scale* | U% | Unit of the digital set point, the flow reading and the totaliser. The totaliser shows the volume unit, without the time base. For a user unit, factor converts from sL/min (21.11 °C, 1013.25 mbar) and t is the time base: S seconds, M minutes, H hours. |
| | U,SLPM | standard L/min | USLPM | |
| | U,SLPH | standard L/h | USLPH | |
| | U,MLPM | standard mL/min | UMLPM | |
| | U,MLPH | standard mL/h | UMLPH | |
| | U,SCFM | standard ft³/min | USCFM | |
| | U,SCFH | standard ft³/h | USCFH | |
| | U,LBPM | lb/min | ULBPM | |
| | U,LBPH | lb/h | ULBPH | |
| | U,UD,factor,t | user-defined | UUDvalue | |
| Full scale | E | read full scale | value | Full-scale flow in sL/min, without the K factor. |
| **ZERO, ALARMS, RELAYS AND TOTALISER** | | | | |
| Auto zero | Z,E | on: zero when set point < 2 % FS* | ZE | Z,N can take several minutes; the controller does not answer other commands until it has finished. |
| | Z,D | off | ZD | |
| | Z,N | zero now | ZN | |
| | Z,W | write zero | ZW when done | |
| | Z,S | status | ZE, ZD, or ZIN,value during Z,N | |

| Function | Command | Meaning | Response | Remarks |
|---|---|---|---|---|
| Flow alarms | A,H,value | high deviation | AHvalue | The value is the permitted deviation from the set point. Status: no alarm, high alarm or low alarm. |
| | A,L,value | low deviation | ALvalue | |
| | A,D | off* | AD | |
| | A,S | status | N, H or L | |
| Relays | R,r,N | no action, relay off* | RN | r = 1 or 2. The relay coil is energized when its condition is true. Contacts: pin assignment (p. 12). |
| | R,r,T | totaliser above its limit | RT | |
| | R,r,H | high flow alarm | RH | |
| | R,r,L | low flow alarm | RL | |
| | R,r,R | between high and low alarm | RR | |
| | R,r,S | status | RN, RT, RH, RL or RR | |
| Totaliser | T,Z | reset to zero | TZ | The read value is the total gas volume. |
| | T,S,N | start now | TSN | |
| | T,S,F,flow | start at a flow | TSvalue | |
| | T,P,N | stop now | TPN | |
| | T,P,T,volume,N | stop at a total | TPTNvalue | |
| | T,P,T,volume,C | stop at a total and close the valve | TPTCvalue | |
| | T,R | read | value | |
| | T,D | off* | TD | |
| **SERVICE** | | | | |
| Maintenance timer | C,R | read | value | Hours since the last calibration. |
| | C,C | reset to zero | CC | |
| Auto-tune | AT,value | start | ATvalue | Tunes the control loop at the flow value (current unit); 80–90 % of full scale gives the best result. Controllers up to 80 L/min full scale only. |
| | AT,S | status | ATSIKp,Ki,Kd running ATSDKp,Ki,Kd done | |
| Read memory | MR,index | read | value | index 0000–999; see Appendix C (p. 36). |
| Write memory | MW,index,value | write | MWindex value | Writes a value to the calibration memory. |

CHAPTER 7

# Calibration and verification

Every DFC leaves the factory calibrated for its gas and range. This chapter explains the calibration conditions, what a field calibration needs, when a range change needs new parts, and how to convert a calibration from one gas to another.

## Calibration service

Every DFC is calibrated at the factory for the gas and conditions of the order. A calibration as close as possible to your real operating conditions gives the best accuracy, so Analyt-MTC recommends sending the controller in for recalibration and repair (Service, warranty and contacts (p. 30)).

Unless your order specifies otherwise, controllers are calibrated with dry nitrogen at 21.1 °C (70 °F), 1.4 bar (20 psig) inlet pressure — 1.7 bar (25 psig) for the DFC 46 — and atmospheric pressure at the outlet. Flows refer to standard conditions of 21.11 °C, 1013.25 mbar.

**NOTICE**

Removing the factory calibration seals, or making the adjustments described in this chapter, voids the factory calibration. Before you remove a seal or make an adjustment, contact Analyt-MTC for the warranty terms that apply.

## Calibrating in the field

Field calibration is work for qualified staff with suitable equipment. All calibration settings and the tuning of the control loop are changed over the RS-485 interface (RS-232 on controllers with that option) by software; you do not need to adjust anything inside the controller. If you are not equipped for this, send the controller to Analyt-MTC (Service, warranty and contacts (p. 30)).

### Equipment

- A flow calibration standard at least four times more accurate than the controller.
- A certified high-sensitivity multimeter. The standard and the multimeter together must reach ±0.25 % or better.
- An insulated (plastic) screwdriver.
- A flow regulator upstream of the controller, for example a metering needle valve.
- A pressure-regulated supply of dry, filtered nitrogen or another suitable reference gas.

Set the gas and ambient temperature and the inlet and outlet pressures to the conditions under which the controller will be used.

### Zero

The controller corrects its sensor zero by itself whenever it is warmed up and its valve is fully closed, that is with a set point below 2 % of full scale. Auto zero is on at power-up and can be switched off or started with the `Z` command (Command reference (p. 18)).

## Changing the flow range

In the field, a controller can only be recalibrated or checked for the range it was originally calibrated for. A different range may need a different restrictor flow element (RFE) and a different valve orifice. Because a range change is a service job, send the controller to Analyt-MTC (Service, warranty and contacts (p. 30)) instead of converting it yourself.

**Table 7-1 Valve orifices**

| Orifice | Flow range ($N_2$) |
|---|---|
| OR.020 | 10–1000 mL/min |
| OR.040 | 1–5 L/min |
| OR.055 | 5–10 L/min |
| OR.063 | 10–15 L/min |
| OR.094 | 20–50 L/min |
| OR.125 | 50–100 L/min |

## Gas conversion factors

> **Note**
> K factors are approximations at best, accurate to no better than about ±5 to 10 %. Where you need a better accuracy, do not use them. Have the controller calibrated for the actual gas instead.

Controllers are normally calibrated with nitrogen. For another gas, the reading is converted with the gas's K factor, which depends on its density and specific heat. Where a reference gas has thermal properties closer to your gas than nitrogen, calibrating with that reference gas gives a better result; the relative factor is then recalculated as shown below.

**K factor of a gas** (diatomic gases):

$$K = 1 / (d \times c_p)$$

d = density in g/L, $c_p$ = specific heat in cal/g, both at 1 atm and 25 °C.

**Relative factor** between the actual gas a and the reference gas r:

$$Q_a / Q_r = K_a / K_r$$

Q = mass flow in standard mL/min, K = K factor of each gas (Appendix A (p. 32)).

**Example.** A controller calibrated with nitrogen reads 1000 mL/min while oxygen flows. The K factor of oxygen relative to nitrogen is 0.9926, so the oxygen flow is 1000 × 0.9926 = 992.6 mL/min.

Over the serial interface the controller can apply a K factor itself (K command, Command reference (p. 18)).

CHAPTER 8

# Maintenance

A DFC that flows clean, filtered gas needs no routine maintenance apart from an occasional cleaning of the inlet filter screen and the flow path. Keep it away from vibration, heat, corrosive atmospheres and strong radio-frequency or magnetic fields.

## Before you start

**⚠ WARNING**

A controller that has carried toxic, infectious, corrosive or radioactive media holds residues. Residues endanger the people who service it. Before you open such a controller, purge it completely and neutralise all residues.

The sensor is a thin stainless-steel capillary. Particles and gas components that crystallize block it easily, and the other flow passages are narrow too. A filter screen in the inlet protects them: 50 µm in the DFC 26, 60 µm in the DFC 36 and DFC 46. When it clogs, the controller can no longer reach its set point or reads wrongly (Troubleshooting (p. 25)).

If you prefer, send the controller to Analyt-MTC for cleaning (Service, warranty and contacts (p. 30)).

## Cleaning the flow path

First look into the inlet and outlet of the controller. Debris you can see there can often be removed without opening anything. If the flow path is still blocked, clean it as described for your model.

**NOTICE**

Taking the sensor apart invalidates its calibration. Never take the sensor apart. If flushing does not clear a blocked sensor tube, return the controller to Analyt-MTC.

### DFC 26

On the DFC 26 the restrictor flow element (RFE) is attached to the inlet fitting.

1. Unscrew the inlet compression fitting from the controller, together with the RFE.
2. Carefully separate the RFE from the inlet fitting. The 50 µm filter screen is now visible.
3. Push the screen out through the inlet fitting.
4. Clean or replace the parts as necessary. If you clean them with alcohol, let them dry completely.
5. Look into the flow path inside the controller for contamination. If necessary, flush it with alcohol, then dry it thoroughly by flowing clean, dry gas through it.

   **NOTICE**

   Over-tightening the inlet fitting deforms the RFE and makes it unusable. Do not over-tighten the inlet fitting.
6. Refit the screen, the RFE and the inlet fitting without twisting or bending the RFE. Make sure the O-ring seal is free of dust.
7. Check the calibration at one flow point at least (Calibration and verification (p. 21)).

### DFC 36 and DFC 46

1. On the inlet side, undo the four socket-head cap screws (two 10-24 and two 6-32). This releases the short square block that carries the inlet fitting.

   **NOTICE**

   The RFE inside the controller is a precision flow divider that splits the gas between the sensor and the main flow path. Removing it disturbs that split. Leave the RFE inside the controller in place.

2. Remove the 60 µm filter screen behind it.
3. Clean or replace the screen and the inlet parts as necessary. If you clean them with alcohol, let them dry completely.
4. Look into the flow path for contamination. If necessary, flush it with alcohol, then dry it thoroughly by flowing clean, dry gas through it.
5. Refit the filter screen and the inlet block. Make sure the O-ring seal is free of dust.
6. Check the calibration at one flow point at least (Calibration and verification (p. 21)).

## Valve

The proportional solenoid valve is made of 316 and 416 stainless steel with FKM O-rings and seals; EPR or FFKM seals are options. Apart from periodic cleaning it needs no maintenance. Corrosive gases can make it necessary to replace the O-rings and seals more often. Make sure the seal material suits your gas; ask Analyt-MTC for the alternatives.

### Flushing the valve

Open the valve fully with the purge input or the `V,0` command (Purge (p. 17)) and flush it with a clean, filtered, neutral gas such as nitrogen.

### Adjusting the valve closure

If the valve does not close completely, adjust it with the set screw on top of the valve, under its plastic cap. Turning the set screw counter-clockwise as far as it goes opens the valve fully — an alternative way to flush it.

1. Close the valve: connect pin 5 to common, or send `V,C`.
2. Apply 0.34 bar (5 psig) to the inlet and leave the outlet at atmospheric pressure.
3. Remove the plastic cap on top of the valve.
4. If gas still flows, turn the set screw clockwise until the flow just stops.
5. Refit the plastic cap.

CHAPTER 9

# Troubleshooting

## First checks

Each controller is tested during manufacture and calibrated for the gas and conditions on your order, so most faults in the field come from the installation. Before you look at the fault table, rule out these causes:

- Cables: are they all connected, and do they match the pin assignment (p. 12)? A cable taken from another make of instrument is a frequent culprit, because the pins rarely match.
- Supply: does it deliver ±15 V DC and enough current for every controller connected to it?
- Gas side: are the connections leak-tight, and is the pressure difference across the controller large enough (Inlet pressure and pressure difference (p. 10))?

## Fault finding

| Likely cause | Remedy |
|---|---|
| **NO READING OR NO OUTPUT SIGNAL** | |
| Power supply off | Check the power supply and its connection. |
| Fuse tripped | Disconnect the power, remove the short circuit or correct the polarity; the fuse resets itself (Fuse protection (p. 11)). |
| Inlet filter screen blocked | Flush it clean, or dismantle and clean or replace it (Cleaning the flow path (p. 23)). |
| Sensor tube blocked | Flush it clean, or return the controller. |
| Circuit board defective | Return the controller. |
| Valve misadjusted | Readjust it (Adjusting the valve closure (p. 24)). |
| **OUTPUT STAYS AT ITS POSITIVE OR NEGATIVE LIMIT** | |
| Fuse tripped | Disconnect the power, remove the short circuit or correct the polarity; the fuse resets itself. |
| **FLOW DOES NOT MATCH THE SET POINT** | |
| Gas pressure too low | Apply the correct gas pressure. |
| Inlet filter screen blocked | Flush it clean, or dismantle and clean or replace it. |
| Ground loop | Signal common and power-supply common are at different potentials; connect them to the same common. |
| **NO RESPONSE TO THE SET POINT** | |
| Gas pressure too low | Apply the correct gas pressure. |
| Cable or connector fault | Check all cables and connections; replace if necessary. |
| Set point below 2 % of full scale | Raise the set point. |
| Valve misadjusted | Readjust it (Adjusting the valve closure (p. 24)). |
| **UNSTABLE ZERO, OR NO ZERO READING** | |
| Gas leak | Find and repair the leak. |
| Circuit board defective | Return the controller. |
| **FULL-SCALE READING WITH NO FLOW OR WITH THE VALVE CLOSED** | |
| Sensor defective | Return the controller. |
| Gas leak | Find and repair the leak. |

| Likely cause | Remedy |
|---|---|
| **CALIBRATION OFF** | |
| Gas differs from the calibration gas | Use a controller calibrated for this gas. |
| Gas composition has changed | Correct with the K factors (Gas conversion factors (p. 22)). |
| Gas leak | Find and repair the leak. |
| Circuit board defective | Return the controller. |
| RFE dirty | Flush it clean or dismantle and clean it. |
| Sensor tube blocked | Flush it clean, or return the controller. |
| Inlet filter screen blocked | Flush it clean, or dismantle and clean or replace it. |
| Controller not mounted correctly | Check for tilt or a changed mounting position. Controllers are calibrated with the sensor horizontal (Location and orientation (p. 10)). |
| **VALVE DOES NOT OPEN** | |
| Valve misadjusted | Readjust it (Adjusting the valve closure (p. 24)). |
| Circuit board defective | Return the controller. |
| Cable or connector fault | Check the cable and connectors; replace if necessary. |
| Pressure difference too high | Reduce the pressure to the correct level. |
| Inlet pressure too low | Raise it to the correct level. |
| **VALVE DOES NOT CLOSE** | |
| Valve misadjusted | Readjust it (Adjusting the valve closure (p. 24)). |
| Circuit board defective | Return the controller. |
| Cable or connector fault | Check the cable and connectors; replace if necessary. |
| Valve orifice obstructed | Dismantle the valve and clean the orifice, or return the controller. |

## Technical support

Analyt-MTC gives technical support to qualified personnel. Have the model number and the serial number of the controller ready; both are on its labels. The contact details are in Service, warranty and contacts (p. 30) and on the back cover. For the best result, have repairs done by Analyt-MTC (Service, warranty and contacts (p. 30)).

CHAPTER 10

# Specifications

The data apply to DFC 26, DFC 36 and DFC 46 controllers calibrated with nitrogen under standard conditions (21.11 °C, 1013.25 mbar), unless stated otherwise.

## Performance

| | |
|---|---|
| Accuracy | ±1 % of full scale, including linearity, at gas temperatures of 15–25 °C (59–77 °F) and pressures of 0.7–4.1 bar a (10–60 psia) |
| Repeatability | ±0.15 % of full scale |
| Temperature coefficient | 0.1 % FS per °C |
| Pressure coefficient | 0.01 % FS per psi (0.07 bar) |
| Response time | 1.0–2.0 s to within ±2 % of the set point, for set points of 20–100 % FS |
| Attitude sensitivity | 1 % shift for a 90° turn from horizontal to vertical; calibrated horizontal |
| Internal leakage | 0.5 % FS maximum |
| Leak integrity to the outside | $1 \times 10^{-9}$ sccs helium maximum |

## Operating conditions

| | |
|---|---|
| Flow medium | Clean gases only; no liquids |
| Maximum gas pressure | 68.9 bar g (1000 psig) |
| Optimum inlet pressure | 1.4 bar (20 psig); DFC 46: 1.7 bar (25 psig) |
| Pressure difference needed | 5–50 psig; optimum 1.7 bar (25 psi) |
| Maximum pressure difference | DFC 26, DFC 36: 3.45 bar (50 psid); DFC 46: 2.76 bar (40 psid) |
| Gas and ambient temperature | 0–50 °C (32–122 °F); −10 to 50 °C (14–122 °F) with dry gases only |
| Relative humidity of the gas | Up to 70 % |
| Environment (IEC 664) | Installation level II, pollution degree II |

## Electrical data

| | |
|---|---|
| Supply | +15 V DC ±5 %, 450 mA, 6.75 W maximum, and −15 V DC ±5 %, 450 mA, 6.75 W maximum |
| Protection | Resettable 500 mA medium time-lag fuse and reverse-polarity diode on each supply input |
| Flow output | 0–5 V DC, linear, minimum load 2000 Ω (standard); 4–20 mA, loop resistance 50–500 Ω (option); 0–10 V DC by jumper; noise 20 mV peak-to-peak maximum |
| Set point input | 0–5 V DC, input impedance 200 kΩ (standard); 4–20 mA (option) |
| Serial interface | RS-485 (standard), RS-232 (option); 9600 baud, 8 data bits, no parity, 1 stop bit |
| Relays | Two changeover (SPDT) contacts |
| Connector and cable | 25-pin D connector (male on the controller); flat cable standard, shielded cable optional; maximum length 3 m |

## Materials and connections

| | |
|---|---|
| Wetted materials | 316 stainless steel, 416 stainless steel, FKM O-rings; Buna-N, EPR or FFKM O-rings as options |
| Process connections, standard | 1/4 in compression fittings (DFC 26, DFC 36); 3/8 in compression fittings (DFC 46) |
| Process connections, options | 1/8 in compression (DFC 26); 3/8 in compression (DFC 26, DFC 36); 1/4 in VCR (DFC 26, DFC 36) |

You are responsible for choosing wetted materials that are compatible with your gas; resistance to a particular gas is not guaranteed.

### Table 10-1 Maximum pressure drop

| Model | Flow L/min | mm $H_2O$ | mbar | psid |
|---|---|---|---|---|
| DFC 26 | up to 10 | 720 | 75 | 1.06 |
| DFC 36 | 15 | 2630 | 266 | 3.87 |
| | 20 | 1360 | 138 | 2.00 |
| | 30 | 2380 | 241 | 3.50 |
| | 40 | 3740 | 379 | 5.50 |
| | 50 | 5440 | 551 | 8.00 |
| DFC 46 | 60 | 7480 | 758 | 11.00 |
| | 100 | 12850 | 1302 | 18.89 |

Maximum values, as published; on the DFC 36 they do not rise steadily with the flow. For flows between the listed values, ask Analyt-MTC for the pressure drop of your configuration.

### Table 10-2 Weights

| Model | Controller | Shipping |
|---|---|---|
| DFC 26 | 1.00 kg (2.20 lb) | 1.68 kg (3.70 lb) |
| DFC 36, DFC 46 | 1.29 kg (2.84 lb) | 1.97 kg (4.34 lb) |

Dimensions: Appendix B (p. 35).

## CE marking

Controllers that carry the CE mark comply with the EMC directive 89/336/EEC as amended. Emission: EN 55011:1991, group 1, class A. Immunity: EN 55082-1:1992.

CHAPTER 11

# Ordering information

Order controllers and accessories from Analyt-MTC, quoting the order code. The controllers below are the standard versions; for any other version, contact Analyt-MTC.

## Controllers

The standard versions are calibrated for air at standard conditions (21.11 °C, 1013.25 mbar). They have a stainless steel body, FKM seals, no display, a 0–5 V DC set point input and flow output, and the RS-485 interface; the DFC 26 and DFC 36 have 1/4 in compression fittings, the DFC 46 3/8 in compression fittings. For another gas, range, seal material, fitting, signal or interface, give Analyt-MTC your gas, flow range, and inlet and outlet pressures.

**Table 11-1 Controllers, standard versions (full scale at 21.11 °C, 1013.25 mbar)**

| Model | Full scale | Order code |
|---|---|---|
| DFC 26 | 10 smL/min | 35381 |
| DFC 26 | 20 smL/min | 35382 |
| DFC 26 | 50 smL/min | 35383 |
| DFC 26 | 100 smL/min | 35384 |
| DFC 26 | 200 smL/min | 35385 |
| DFC 26 | 500 smL/min | 35386 |
| DFC 26 | 1 sL/min | 35387 |
| DFC 26 | 2 sL/min | 35388 |
| DFC 26 | 5 sL/min | 35389 |
| DFC 26 | 10 sL/min | 35390 |
| DFC 36 | 15 sL/min | 35391 |
| DFC 36 | 20 sL/min | 35392 |
| DFC 36 | 30 sL/min | 35393 |
| DFC 36 | 40 sL/min | 35394 |
| DFC 36 | 50 sL/min | 35395 |
| DFC 46 | 60 sL/min | 35396 |
| DFC 46 | 80 sL/min | 35397 |
| DFC 46 | 100 sL/min | 35398 |

## Accessories

**Table 11-2 Accessories**

| Description | Order code |
|---|---|
| Interface cable with 25-pin D connector, 6 ft leads to the computer port and to the power supply | CBL-DFC |
| Power supply 230 V AC (Europe), ±15 V DC, serial interface | PS-DFC-230EU-5-S |
| Power supply 230 V AC (Europe), ±15 V DC, analogue interface | PS-DFC-230EU-5-A |
| Digital panel meter with backlight | BCKUPDFC |

CHAPTER 12

# Service, warranty and contacts

Calibration, repair, cleaning and technical support for your DFC are provided by Analyt-MTC. Talk to Analyt-MTC before you send anything: many problems turn out to be wiring or settings that can be sorted out on the phone.

## Contact and support


**ANALYT-MTC Messtechnik GmbH**

**German Headquarters**

Klosterrunsstraße 18, 79379 Müllheim
Germany

+49 7631 5545

info@analyt-mtc.de

**French Subsidiary**

175 Avenue d'Alsace, 68000 Colmar
France

+33 3 89 41 47 78

info@analyt-mtc.fr

www.analyt-mtc.com


**Before you contact Analyt-MTC**

Have the following at hand so that Analyt-MTC can help you quickly:

- the model number and serial number from the labels on the controller;
- the gas and the full-scale range on the front label;
- your inlet and outlet pressures and how you give the set point (analogue signal or serial command);
- a description of the fault and of what you have already checked (Troubleshooting (p. 25)).

## Contact

The contact details are given above and on the back cover. Have the model number, the serial number, and the gas and range from the front label at hand.

Open and follow every service request in the Analyt-MTC customer portal at portal.analyt-mtc.com: where your controller is in the process, and, once the work is done, its certificates, digitally signed.

## Sending in a controller

1. **Open a service request.** Open it online in the Analyt-MTC customer portal, portal.analyt-mtc.com, with the model, the serial number and the reason for service: calibration, repair or cleaning. Do not put paper forms in the box: the service request carries everything Analyt-MTC needs.

> **⚠ WARNING**
>
> A controller that has carried hazardous media holds residues. Residues endanger the people who unpack and service it. Never ship such a controller without purging and neutralising it.

2. **Decontaminate the controller.** Purge it and neutralize all residues of toxic, infectious, corrosive or radioactive media. In the service request, state the substances the controller has been in contact with and their hazards, and confirm the safety declaration online. If you are not sure, do not send it.
3. **Pack the controller alone.** Send the controller without power supply, cables, fittings or case unless they are part of the problem; Analyt-MTC is not responsible for accessories sent. Close the process connections so that nothing enters the flow path, protect the connectors against electrostatic discharge, and pack each controller individually for transport.
4. **Ship it to Müllheim.** Send the parcel to the Analyt-MTC service centre in Müllheim, Germany, never to the Colmar address.

When the controller arrives, it is registered and assessed, and you receive a quote before any work begins: no work is done without your agreement. If you decline the quote, a bench fee and return transport are charged. Every instrument passes a final check before it is returned with its documentation. A standard service typically takes one to two weeks from arrival to dispatch; this lead time is indicative. Express service can be requested in the service request.

## Warranty

The warranty terms for your controller are those agreed in your order confirmation. Warranty claims are handled by Analyt-MTC: give Analyt-MTC the serial number and a description of the fault before returning the controller.

## Disposal

Do not dispose of the controller with household waste. Dispose of it as electrical and electronic equipment under local regulations (WEEE). Remove batteries first where fitted and dispose of them separately.

APPENDIX A

# Gas conversion factors

K factors relative to nitrogen, with the specific heat $c_p$ and the density d from which they are derived. For a controller calibrated with nitrogen, multiply the reading by the K factor of the gas you are using (Gas conversion factors (p. 22)). For argon, carbon dioxide, helium, hydrogen and methane the factor depends on the full-scale flow of the controller.

**Note**
K factors are approximations at best, accurate to no better than about ±5 to 10 %. Do not rely on them where you need a better accuracy.

| Gas | K | $c_p$ cal/g | d g/L |
|---|---|---|---|
| **A** | | | |
| Acetylene $C_2H_2$ | **0.5829** | 0.4036 | 1.162 |
| Air | **1.0000** | 0.240 | 1.293 |
| Allene (propadiene) $C_3H_4$ | **0.4346** | 0.352 | 1.787 |
| Ammonia $NH_3$ | **0.7310** | 0.492 | 0.760 |
| Argon, up to 10 L/min Ar | **1.4573** | 0.1244 | 1.782 |
| Argon, above 10 L/min Ar | **1.205** | 0.1244 | 1.782 |
| Arsine $AsH_3$ | **0.6735** | 0.1167 | 3.478 |
| **B** | | | |
| Boron tribromide $BBr_3$ | **0.38** | 0.0647 | 11.18 |
| Boron trichloride $BCl_3$ | **0.4089** | 0.1279 | 5.227 |
| Boron trifluoride $BF_3$ | **0.5082** | 0.1778 | 3.025 |
| Bromine $Br_2$ | **0.8083** | 0.0539 | 7.130 |
| Bromine pentafluoride $BrF_5$ | **0.26** | 0.1369 | 7.803 |
| Bromine trifluoride $BrF_3$ | **0.3855** | 0.1161 | 6.108 |
| Bromotrifluoromethane (Freon-13B1) $CBrF_3$ | **0.3697** | 0.1113 | 6.644 |
| 1,3-Butadiene $C_4H_6$ | **0.3224** | 0.3514 | 2.413 |
| Butane $C_4H_{10}$ | **0.2631** | 0.4007 | 2.593 |
| 1-Butene $C_4H_8$ | **0.2994** | 0.3648 | 2.503 |
| cis-2-Butene $C_4H_8$ | **0.324** | 0.336 | 2.503 |
| trans-2-Butene $C_4H_8$ | **0.291** | 0.374 | 2.503 |
| **C** | | | |
| Carbon dioxide, up to 10 L/min $CO_2$ | **0.7382** | 0.2016 | 1.964 |
| Carbon dioxide, above 10 L/min $CO_2$ | **0.658** | 0.2016 | 1.964 |
| Carbon disulfide $CS_2$ | **0.6026** | 0.1428 | 3.397 |
| Carbon monoxide CO | **1.00** | 0.2488 | 1.250 |
| Carbon tetrachloride $CCl_4$ | **0.31** | 0.1655 | 6.860 |
| Carbon tetrafluoride (Freon-14) $CF_4$ | **0.4210** | 0.1654 | 3.926 |
| Carbonyl fluoride $COF_2$ | **0.5428** | 0.1710 | 2.945 |
| Carbonyl sulfide COS | **0.6606** | 0.1651 | 2.680 |
| Chlorine $Cl_2$ | **0.86** | 0.114 | 3.163 |
| Chlorine trifluoride $ClF_3$ | **0.4016** | 0.1650 | 4.125 |
| Chlorodifluoromethane (Freon-22) $CHClF_2$ | **0.4589** | 0.1544 | 3.858 |
| Chloroform $CHCl_3$ | **0.3912** | 0.1309 | 5.326 |
| Chloropentafluoroethane (Freon-115) $C_2ClF_5$ | **0.2418** | 0.164 | 6.892 |
| Chlorotrifluoromethane (Freon-13) $CClF_3$ | **0.3834** | 0.153 | 4.660 |
| Cyanogen $C_2N_2$ | **0.61** | 0.2613 | 2.322 |
| Cyanogen chloride ClCN | **0.6130** | 0.1739 | 2.742 |
| Cyclopropane $C_3H_6$ | **0.4584** | 0.3177 | 1.877 |
| **D** | | | |
| Deuterium $D_2$ | **1.00** | 1.722 | 1.799 |
| Diborane $B_2H_6$ | **0.4357** | 0.508 | 1.235 |
| Dibromodifluoromethane $CBr_2F_2$ | **0.1947** | 0.15 | 9.362 |
| Dichlorodifluoromethane (Freon-12) $CCl_2F_2$ | **0.3538** | 0.1432 | 5.395 |
| Dichlorofluoromethane (Freon-21) $CHCl_2F$ | **0.4252** | 0.140 | 4.592 |
| Dichloromethylsilane $(CH_3)_2SiCl_2$ | **0.2522** | 0.1882 | 5.758 |
| Dichlorosilane $SiH_2Cl_2$ | **0.4044** | 0.150 | 4.506 |
| Dichlorotetrafluoroethane (Freon-114) $C_2Cl_2F_4$ | **0.2235** | 0.1604 | 7.626 |
| 1,1-Difluoroethylene (Freon-1132A) $C_2H_2F_2$ | **0.4271** | 0.224 | 2.857 |
| Dimethyl ether $(CH_3)_2O$ | **0.3896** | 0.3414 | 2.055 |
| Dimethylamine $(CH_3)_2NH$ | **0.3714** | 0.366 | 2.011 |
| 2,2-Dimethylpropane $C_5H_{12}$ | **0.2170** | 0.3914 | 3.219 |

| Gas | K | $c_p$ cal/g | d g/L |
|---|---|---|---|
| **E** | | | |
| Ethane $C_2H_6$ | **0.50** | 0.420 | 1.342 |
| Ethanol $C_2H_6O$ | **0.3918** | 0.3395 | 2.055 |
| Ethyl acetylene $C_4H_6$ | **0.3225** | 0.3513 | 2.413 |
| Ethyl chloride $C_2H_5Cl$ | **0.3891** | 0.244 | 2.879 |
| Ethylene $C_2H_4$ | **0.60** | 0.365 | 1.251 |
| Ethylene oxide $C_2H_4O$ | **0.5191** | 0.268 | 1.965 |
| **F** | | | |
| Fluorine $F_2$ | **0.9784** | 0.1873 | 1.695 |
| Fluoroform (Freon-23) $CHF_3$ | **0.4967** | 0.176 | 3.127 |
| Freon refrigerants are listed under their chemical names, with the Freon number in brackets: Freon-14, for example, under Carbon tetrafluoride. | | | |
| **G** | | | |
| Germane $GeH_4$ | **0.5696** | 0.1404 | 3.418 |
| Germanium tetrachloride $GeCl_4$ | **0.2668** | 0.1071 | 9.565 |
| **H** | | | |
| Helium, up to 10 L/min He | **1.454** | 1.241 | 0.1786 |
| Helium, above 10–50 L/min He | **2.05** | 1.241 | 0.1786 |
| Helium, above 50 L/min He | **2.43** | 1.241 | 0.1786 |
| Hexafluoroethane (Freon-116) $C_2F_6$ | **0.2421** | 0.1834 | 6.157 |
| Hexane $C_6H_{14}$ | **0.1792** | 0.3968 | 3.845 |
| Hydrogen bromide HBr | **1.000** | 0.0861 | 3.610 |
| Hydrogen chloride HCl | **1.000** | 0.1912 | 1.627 |
| Hydrogen cyanide HCN | **0.764** | 0.3171 | 1.206 |
| Hydrogen fluoride HF | **0.9998** | 0.3479 | 0.893 |
| Hydrogen iodide HI | **0.9987** | 0.0545 | 5.707 |
| Hydrogen selenide $H_2Se$ | **0.7893** | 0.1025 | 3.613 |
| Hydrogen sulfide $H_2S$ | **0.80** | 0.2397 | 1.520 |
| Hydrogen, up to 10 L/min $H_2$ | **1.0106** | 3.419 | 0.0899 |
| Hydrogen, above 10–100 L/min $H_2$ | **1.35** | 3.419 | 0.0899 |
| Hydrogen, above 100 L/min $H_2$ | **1.9** | 3.419 | 0.0899 |
| **I** | | | |
| Iodine pentafluoride $IF_5$ | **0.2492** | 0.1108 | 9.90 |
| Isobutane $CH(CH_3)_3$ | **0.27** | 0.3872 | 3.593 |
| Isobutylene $C_4H_8$ | **0.2951** | 0.3701 | 2.503 |
| **K** | | | |
| Krypton Kr | **1.453** | 0.0593 | 3.739 |
| **M** | | | |
| Methane, up to 10 L/min $CH_4$ | **0.7175** | 0.5328 | 0.715 |
| Methane, above 10 L/min $CH_4$ | **0.75** | 0.5328 | 0.715 |
| Methanol $CH_3OH$ | **0.5843** | 0.3274 | 1.429 |
| Methyl acetylene $C_3H_4$ | **0.4313** | 0.3547 | 1.787 |
| Methyl bromide $CH_3Br$ | **0.5835** | 0.1106 | 4.236 |
| Methyl chloride $CH_3Cl$ | **0.6299** | 0.1926 | 2.253 |
| Methyl fluoride $CH_3F$ | **0.68** | 0.3221 | 1.518 |
| Methyl mercaptan $CH_3SH$ | **0.5180** | 0.2459 | 2.146 |
| Methyltrichlorosilane $(CH_3)SiCl_3$ | **0.2499** | 0.164 | 6.669 |
| Molybdenum hexafluoride $MoF_6$ | **0.2126** | 0.1373 | 9.366 |
| Monoethylamine $C_2H_5NH_2$ | **0.3512** | 0.387 | 2.011 |
| Monomethylamine $CH_3NH_2$ | **0.51** | 0.4343 | 1.386 |
| **N** | | | |
| Neon Ne | **1.46** | 0.246 | 0.900 |
| Nitric oxide NO | **0.990** | 0.2328 | 1.339 |
| Nitrogen $N_2$ | **1.000** | 0.2485 | 1.25 |
| Nitrogen dioxide $NO_2$ | **0.737** | 0.1933 | 2.052 |
| Nitrogen trifluoride $NF_3$ | **0.4802** | 0.1797 | 3.168 |
| Nitrosyl chloride NOCl | **0.6134** | 0.1632 | 2.920 |
| Nitrous oxide $N_2O$ | **0.7128** | 0.2088 | 1.964 |
| **O** | | | |
| Octafluorocyclobutane (Freon-C318) $C_4F_8$ | **0.176** | 0.185 | 8.397 |
| Oxygen $O_2$ | **0.9926** | 0.2193 | 1.427 |
| Oxygen difluoride $OF_2$ | **0.6337** | 0.1917 | 2.406 |
| Ozone $O_3$ | **0.446** | 0.195 | 2.144 |
| **P** | | | |
| Pentaborane $B_5H_9$ | **0.2554** | 0.38 | 2.816 |
| Pentane $C_5H_{12}$ | **0.2134** | 0.398 | 3.219 |
| Perchloryl fluoride $ClO_3F$ | **0.3950** | 0.1514 | 4.571 |
| Perfluoropropane $C_3F_8$ | **0.174** | 0.197 | 8.388 |
| Phosgene $COCl_2$ | **0.4438** | 0.1394 | 4.418 |
| Phosphine $PH_3$ | **0.759** | 0.2374 | 1.517 |
| Phosphorus oxychloride $POCl_3$ | **0.36** | 0.1324 | 6.843 |
| Phosphorus pentafluoride $PF_5$ | **0.3021** | 0.1610 | 5.620 |
| Phosphorus trichloride $PCl_3$ | **0.30** | 0.1250 | 6.127 |
| Propane $C_3H_8$ | **0.35** | 0.399 | 1.967 |
| Propylene $C_3H_6$ | **0.40** | 0.366 | 1.877 |
| **S** | | | |
| Silane $SiH_4$ | **0.5982** | 0.3189 | 1.433 |
| Silicon tetrachloride $SiCl_4$ | **0.284** | 0.1270 | 7.580 |
| Silicon tetrafluoride $SiF_4$ | **0.3482** | 0.1691 | 4.643 |
| Sulfur dioxide $SO_2$ | **0.69** | 0.1488 | 2.858 |
| Sulfur hexafluoride $SF_6$ | **0.2635** | 0.1592 | 6.516 |
| Sulfuryl fluoride $SO_2F_2$ | **0.3883** | 0.1543 | 4.562 |

| Gas | K | $c_p$ cal/g | d g/L |
|---|---|---|---|
| **T** | | | |
| Tetrafluoroethane (R-134a) $CF_3CH_2F$ | **0.5096** | 0.127 | 4.224 |
| Tetrafluorohydrazine $N_2F_4$ | **0.3237** | 0.182 | 4.64 |
| Titanium tetrachloride $TiCl_4$ | **0.2691** | 0.120 | 8.465 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113) $CCl_2FCClF_2$ | **0.2031** | 0.161 | 8.36 |
| Trichloroethylene $C_2HCl_3$ | **0.32** | 0.163 | 5.95 |
| Trichlorofluoromethane (Freon-11) $CCl_3F$ | **0.3287** | 0.1357 | 6.129 |
| Trichlorosilane $SiHCl_3$ | **0.3278** | 0.1380 | 6.043 |
| Triisobutylaluminium $(C_4H_9)_3Al$ | **0.0608** | 0.508 | 8.848 |
| Trimethylamine $(CH_3)_3N$ | **0.2792** | 0.3710 | 2.639 |
| Tungsten hexafluoride $WF_6$ | **0.2541** | 0.0810 | 13.28 |
| **V** | | | |
| Vinyl bromide $CH_2CHBr$ | **0.4616** | 0.1241 | 4.772 |
| Vinyl chloride $CH_2CHCl$ | **0.48** | 0.12054 | 2.788 |
| **X** | | | |
| Xenon Xe | **1.44** | 0.0378 | 5.858 |

APPENDIX B

# Dimensions

Dimensions in inches, with millimetres in square brackets. The drawings show the front view with the 25-pin D connector, the side view with the flow direction and the base with its 6-32 mounting thread. Designs and dimensions can change; for certified drawings of your configuration, ask Analyt-MTC.

## DFC 26

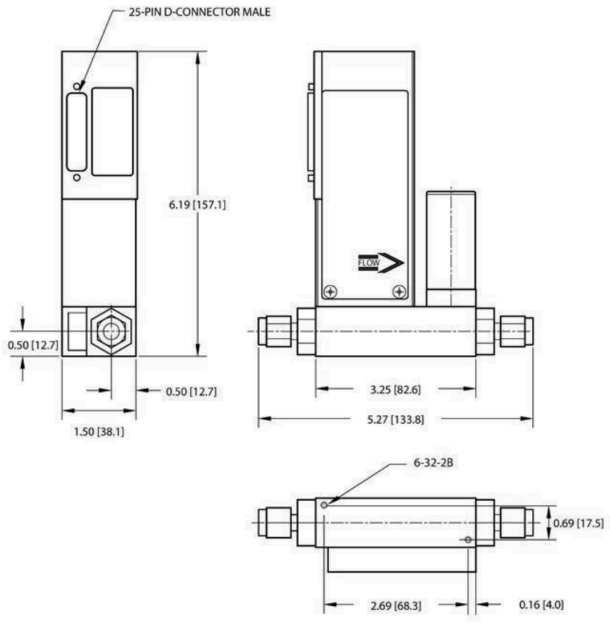



**Figure B-1.** DFC 26. Height 6.19 in [157.1 mm], overall length with fittings 5.27 in [133.8 mm], width 1.50 in [38.1 mm].

## DFC 36 and DFC 46

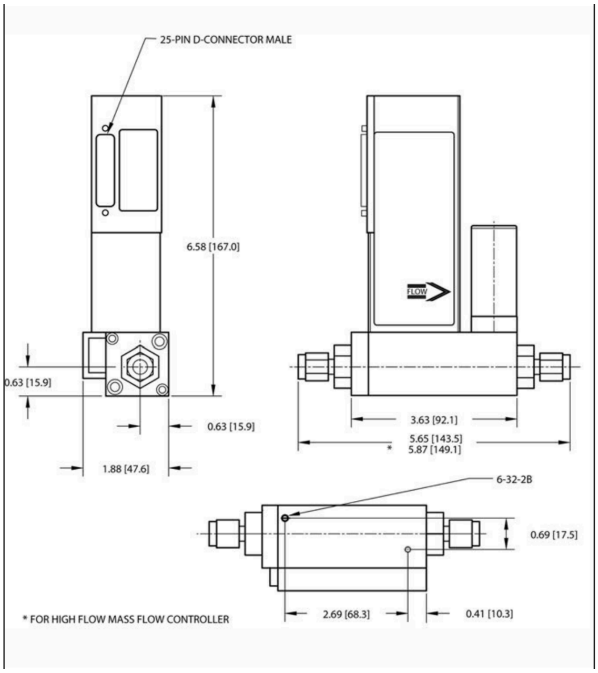



**Figure B-2.** DFC 36 and DFC 46. Height 6.58 in [167.0 mm], width 1.88 in [47.6 mm]; overall length with fittings 5.65 in [143.5 mm], or 5.87 in [149.1 mm] for the high-flow DFC 46 (marked *).

APPENDIX C

# Calibration memory

The controller keeps its identity, calibration and control data in a table in non-volatile memory. Each entry has an index, which you give to the read memory command `MR` (Command reference (p. 18)). Indexes 0 to 59 apply to the controller as a whole; indexes 100 to 134 belong to a gas table and are available only for the gas currently selected.

**NOTICE**

Writing with `MW` changes how the controller measures and controls. A wrong value can make it malfunction. Reading is safe. Never change the entries marked “do not alter”, and change memory only together with an Analyt-MTC engineer.

### Table C-1 Controller data

| Index | Name | Type | Notes |
|---|---|---|---|
| 0 | — | char[10] | Internal use; do not alter |
| 1 | SerialNumber | char[20] | |
| 2 | ModelNumber | char[20] | |
| 3 | SoftwareVer | char[10] | |
| 4 | TimeSinceCalHr | float | Hours since last calibration |
| 5 | Options | uint | Miscellaneous options |
| 6 | AOutOffset_mA | int | |
| 7 | AddressRS485 | char[3] | Two-character RS-485 address |
| 8 | AInScaleV | float | |
| 9 | AInOffsetV | float | |
| 10 | AInScale_mA | float | |
| 11 | AInOffset_mA | float | |
| 12 | AoutScaleV | float | |
| 13 | AoutScale_mA | float | |
| 14 | SensorZero | uint | |
| 15–20 | Klag[0] to Klag[5] | float | |
| 21–26 | Reserved | float | |
| 27–32 | Kgain[0] to Kgain[5] | float | |
| 33–38 | Reserved | float | |
| 39–58 | ValveTbl[0] to [9] | float, uint | Valve table: pairs of valve opening (% FS, float) and valve D/A count (uint). Do not alter |
| 59 | AutoTune time constant | uint | Do not alter |

### Table C-2 Gas table data

| Index | Name | 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 | Control loop, proportional |
| 111 | PID_Ki | float | Control loop, integral |
| 112 | PID_Kd | float | Control loop, derivative |
| 113–134 | SensorTbl[0] to [10] | uint, float | Sensor table: pairs of sensor A/D value (uint) and actual flow as a fraction of full scale (float) |

Fixed values in the tables: index 39 = 0.0 (start of valve actuation), 57 = 1.0 (valve fully open), 58 = 4095 (D/A count for a fully open valve), 113 = 120 and 114 = 0.0 (sensor zero), 134 = 1.0 (full scale).

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