Digital Flow Check™ Instruction Manual

September, 2000
Version 4.2
Manual Part No. 4720

Operator's Manual for Digital Flow Check™

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Introduction

The Digital Flow Check provides accurate, precise measurements of gas flow rates from 0.1 to 500 SCCM for air, nitrogen, oxygen, hydrogen, helium and 5% argon/methane and from 0.1 to 300 SCCM for carbon dioxide. The Digital Flow Check measures mass flow which is independent of temperature and pressure. The measurements of the Digital Flow Check do not have to be corrected for temperature and pressure as do bubble flowmeters and positive displacement flowmeters. In addition, no water vapor correction is necessary as with bubble meters. This means the performance of the Digital Flow Check is less susceptible to atmospheric changes resulting in a more consistent, stable day to day performance.

The Digital Flow Check will accurately measure flows generated by both positive and negative (vacuum) pressures, as long as the proper flow direction through the meter is maintained. However, the DFC is optimized for gas flow measurement in chromatography and therefore has an ultra-low flow resistance. Great care must be exercised to control flow rate in applications outside of chromatography, because excessive flow rates are easily and instantaneously generated by poorly regulated pressure and vacuum sources.

Calibration Caution

The following conditions may cause damage to the Alltech Digital Flow Check. Damages occurring due to these conditions are not covered by the warranty.

(1) Do not under any circumstances employ the DFC for gas flows that exceed 1000 SCCM. Keep in mind that instantaneous flows may easily exceed 1000 SCCM if the DFC is connected directly to a pressure or vacuum source, pressure regulated or unregulated, not equipped with flow control. If a DFC is subjected to excessive flow rates, erroneous readings will be evident and it will be necessary for you to return the unit for recalibration.

(2) Do not under any circumstances subject your DFC to pressures above 20psig (in line operation) or operate a DFC in a vacuum application without flow control (28" Hg vacuum » 14 PSI). This may result in sensor damage and/or negate the calibration of the unit resulting in erroneous readings. If this should occur, it will be necessary for you to return the unit for repair or recalibration. Refer to the section on “In-Line Operation” in this manual for the proper procedure for in-line operation.

(3) It is not recommended that you expose your Digital Flow Check to gases containing excessive amounts of water vapor. This can negate the calibration of your flowmeter. If your unit is exposed to excessive moisture we recommend purging the unit with dry gas at a flow rate of 100 SCCM for ~10 minutes to dry the sensor out. If this procedure does not recover the performance of your flowmeter, we recommend returning the unit for recalibration.

(4) Do not under any circumstances connect your Digital Flow Check to tubing which has been used on a soapfilm flowmeter. The tubing may contain bubble solution or liquid vapor. The bubble solution can corrode or damage the sensor. If this should occur, it will be necessary to return the unit for repair and recalibration.

(5) Do not under any circumstances use your Digital Flow Check to measure corrosive gases. This may damage the sensor and result in erroneous readings. If this should occur, it will be necessary to return the unit for repair and recalibration.

(6) Do not under any circumstances use your Digital Flow Check to measure SFC/SFE mobile phases containing modifiers. This may damage the sensor and result in erroneous readings. If this should occur, it will be necessary to return the unit for repair and recalibration.

(7) If using the DFC in applications outside of chromatography, please keep in mind that:

(a) The DFC is optimized for chromatography and has a very low flow impedance. It is possible to induce instantaneous excessive flows under “switched” or pulsating flow conditions.
(b) The DFC is not intended for use in measuring pulsating flow conditions with a repetition rate greater than 1 Hertz.
(c) Do not connect a DFC directly to the inlet or outlet of a vacuum pump without a pressure regulator and flow restriction in line (e.g. a reciprocating diaphragm vacuum with a 1 cc stroke can instantaneously produce a flow rate of 3 liters/min without regulation or flow restriction).
(d) Pneumatic circuits (pressure and vacuum) have internal volume elements large enough to exert excessive pressures or flows to the DFC and other circuit components if great care is not exercised in operation (e.g. disconnecting the flow control component with vacuum or pressure applied to the circuit).

How Does the Digital Flow Check Measure Flow?

The Digital Flow Check's sensor uses a hot-wire anemometer that has been micromachined onto a silicon/ceramic chip. Hot wire anemometry uses a heating element positioned between two temperature sensors placed in the gas flow stream. Refer to **Figure 1**. As gas enters the sensor, its initial temperature is measured. The gas flows over a heating element that imparts a specific and constant amount of heat into the gas stream. The gas temperature is measured again. The difference between the initial and final gas temperature is dependent on the gas' thermal conductivity, heat capacity and mass flow across the sensor. Sensor geometry and flow characteristics have been optimized for minimum volume and greatest accuracy.

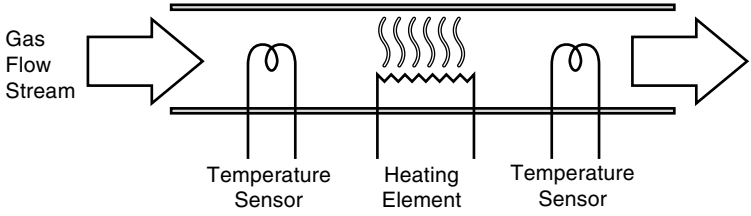


Figure 1

The Digital Flow Check's microprocessor determines the gas flow rate by comparing the sensor output against the appropriate calibration curve stored in the unit's memory. If the Linear Velocity or Split Ratio modes are chosen, mathematical calculations transform the gas flow rate to the appropriate values. Results are displayed on the front-panel LCD. Multipoint, NIST traceable gas-specific calibration curves are used to insure the highest level or accuracy and precision.

Serial Number Identification

A unique serial number is assigned to every Digital Flow Check to identify the unit. The serial number of your unit can be located in three places. It is written on the top of the calibration certificate. It is written inside the battery compartment of the unit. It also appears on the display of the unit prior to the unit being turned off.

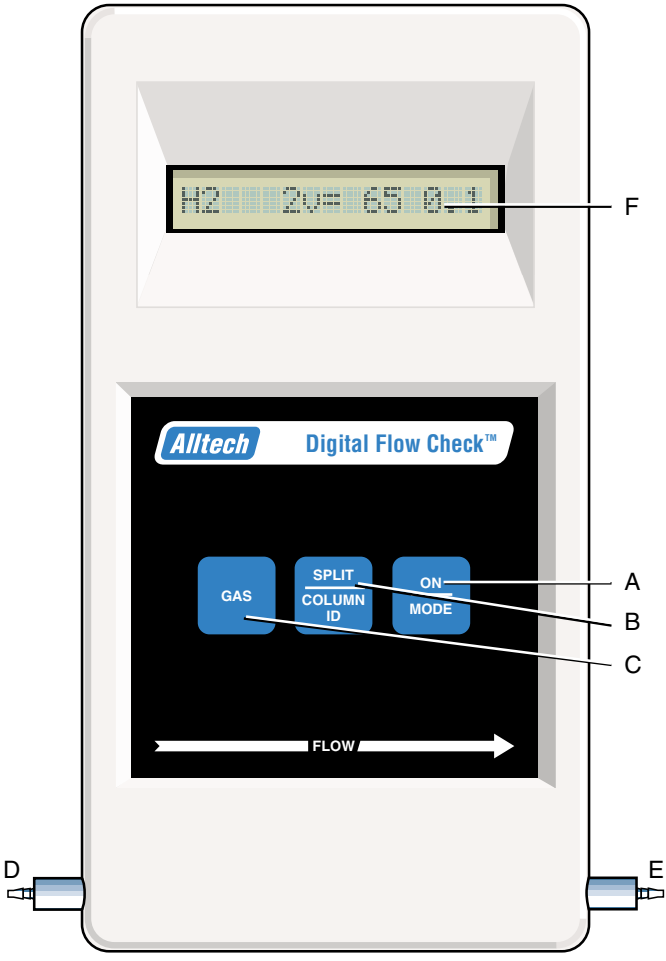


Figure 2 - Front View of Digital Flow Check

Description of Flowmeter Functions

(See page 5 for Figure 2)

A. On / Mode Button

The “On / Mode” button is a multifunctional button which is located on the right front of the unit. When the flowmeter is off, pressing this button turns the unit on. When the flowmeter is on, pressing the “On / Mode” button toggles between the two modes of the flowmeter: Flow and Linear Velocity. The unit can be manually turned off by pressing and holding the On / Mode key for 3 seconds. The sign-off messages: “Serial Number xxxx” followed by: “Have A Real Gas” are displayed, then the flowmeter shuts off.

B. Split / Column ID Button

The “Split / Column ID” button located in the center front is also multifunctional. In the Linear Velocity mode, the center button allows the selection of the appropriate column ID (referring to the table of column ID’s on the back of the unit) so the proper linear velocity can be computed. If the meter is in the Flow mode, the center button locks in the measured flow and toggles between the split ratio and flow rate.

C. Gas Button

The “Gas” button allows the user to select the type of gas they wish to measure. It is located on the left front of the unit. The unit is designed to measure He, H_2, Air, N_2, O_2, CO_2 and Argon/5% Methane.

D. Gas Inlet

The gas inlet is located on the lower left side of the unit. The flow being measured enters the unit at this point. The inlet fitting is removable. Two sizes of barbed fittings are included with every unit. The size of the fitting is clearly marked on the base of the fitting. The 1/16" fitting accepts 1/32" ID tubing. The 1/8" fitting accepts 1/8" /ID tubing. The fittings contain a filter to protect the sensor from particulates. To remove the inlet fitting, unscrew the fitting in a counter clockwise direction. It may be necessary to loosen the fitting with a pair of pliers prior to removing it.

To install the inlet fitting, screw the fitting in a clockwise direction into the inlet fitting port on the lower left side of the flowmeter body. Be sure the fitting is firmly in place and does not move. It may be necessary to turn the fitting one quarter of a turn in a clockwise direction with a pair of pliers to ensure no leaks occur at the base of the fitting. Caution should be taken to ensure the fitting is not overtightened. This could result in damage to the fitting or the inlet port on the flowmeter body.

E. Gas Outlet

The gas outlet is located on the bottom right side of the unit. The flow being measured exits from the unit at this point. The outlet fitting is removable. Two sizes of barbed fittings are included with every unit. The sizes of the fittings are clearly marked on the base of the fitting. The 1/16" fitting accepts 1/32"ID tubing. The 1/8" fitting accepts 1/8"ID tubing.

To remove the outlet fitting, unscrew the fitting in a counter clockwise direction. It may be necessary to loosen the fitting with a pair of pliers prior to removing it.

To install the outlet fitting, screw the fitting in a clockwise direction into the outlet fitting port on the lower right side of the flowmeter body. Be sure the fitting is firmly in place and does not move. It may be necessary to turn the fitting one quarter of a turn in a clockwise direction with a pair of pliers to ensure no leaks occur at the base of the fitting. Caution should be taken to ensure the fitting is not overtightened. This could result in damage to the fitting or the inlet port on the flowmeter body.

Note: Handle the inlet and outlet fittings with care. They are made out of plastic and will break if abused. If the barbed end of the fitting is damaged, broken or misformed in any way it should be replaced. The use of damaged fittings may obstruct gas flow or cause leaks which will result in erroneous readings.

F. LCD Digital Display

The LCD digital display is located at the top front of the unit. It is a 1 line, 16 character digital display which displays all measurement read outs from the flowmeter.

G. Connecting Tubing

Two sizes of silicone tubing are supplied with the Digital Flow Check to accommodate the two sizes of inlet and outlet fittings and connect the flowmeter to various gas sources. The 1' x 5/32"OD x 1/32"ID tubing is for use with the 1/16" fitting. The 1' x 1/4"OD x 1/8"ID tubing is for use with the 1/8" fitting. We recommend using the 1/32" tubing and 1/16" fitting for measuring flows below 5 SCCM. This tubing's low internal volume minimizes sensor sweep-out time during gas-type changes. Appropriate nuts and ferrules may be used to connect this tubing to standard 'swaged' fittings.

G

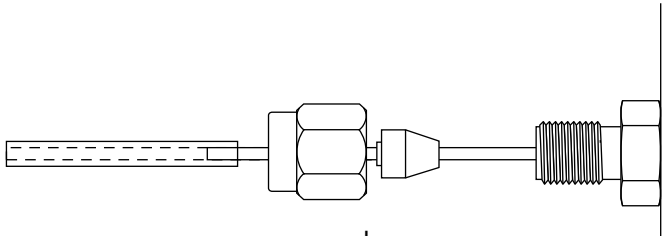
H. General Purpose Adaptor (Part No. 4704)

The General Purpose Flow Adaptor connects 1/32" silicone tubing (**G**) to larger diameter tubing. Because the Digital Flow Check generates a small amount of backpressure (compared to soapfilm flowmeters) a secure source-gas connection is required or leaks and erroneous readings may occur. Do not use the general purpose flow adaptor to connect the Digital Flow Check to GC detectors or directly to Hewlett Packard split vents as it will not provide a leak free seal. Instead, connect the Digital Flow Check to the GC's detector vent(s) using the detector adaptors supplied by the GC manufacturer. Use the Split Vent Adaptor (**I**) to connect the Digital Flow Check directly to Hewlett Packard GC Split Vents. The General Purpose Adaptor may be used to connect the Digital Flow Check to split vent traps.

H

I. Split Vent Adaptor (Part No. 4705)

Use the Split Vent Adaptor to measure flows directly from Hewlett Packard GC split vents. Do not use the General Purpose Flow Adaptor (**H**) or leaks and erroneous readings may occur. To use, thread the adaptor onto the split vent fitting until a snug connection is obtained. Slide the 1/32" silicone tubing (**G**) over the stainless steel tubing protruding from the adaptor and begin making measurements. It is convenient to leave the Split Vent Adaptor permanently attached to the GC.



I

J. Battery Compartment

This compartment holds a 9 volt alkaline battery which supplies power to the unit beneath the rear panel removable cover.

K. Tubing ID Chart

This chart is located in the center back of the flowmeter. It indicates what linear velocity setting corresponds to what tubing ID. i.e., 1v=0.10mm, 2v=0.18mm, 3v=0.20mm, 4v=0.25mm, 5v=0.32mm, 6v=0.53mm, 7v=0.75mm

L. Collapsible Stand

The collapsible stand is located on the back of flowmeter and may be used to elevate the flowmeter for easier viewing.

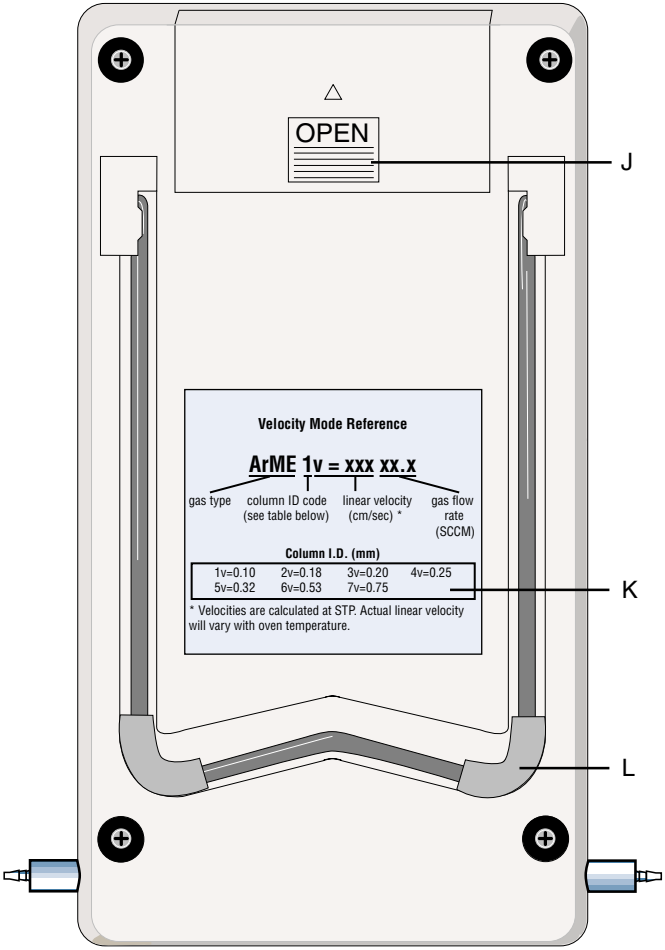


Figure 3 - Back View of Digital Flow Check

SPECIFICATIONS	
Flow Range	0.1 to 500 SCCM, Autoranging Except CO_2 0.1 to 300 SCCM, Autoranging CO_2
Sensor Type	True Mass Flow, Micromachined Silicon on Ceramic
Calibrated Gases	He, H_2, N_2, O_2, CO_2, Air, Ar/CH_3 (5%)
Maximum Pressure	20psig (In-line Operation)
Measurement Accuracy	± 2% of Reading or 0.1 SCCM Shift During Use, Calibrated Gases
Thermal Compensation	Automatic “On-chip” Compensation
Sensor Cal. Method	Multipoint Interpolation, All Calibrations NIST Traceable, Certificate Supplied
Sampling Rate	Real Time, 25Hz, Updated Every 40 Milliseconds
Chromatographic Modes	Flow, Split Ratio, Linear Velocity
Measurement Display Modes	Mass Flow, Split Ratio and Linear Velocity
Power	Standard 9 Volt Alkaline Battery Auto Off @ 5 Minutes, Low Battery Warning
Display Type	Alphanumeric 16 Character LCD
Connections	Plastic Barbed Tipped Low Dead Volume, Silicone Inlet Tubing
Size	190.5 x 57.4 x 101.6mm (4.5" x 2.26" x 4.0")
Weight	324 Grams (11.4 ounces)

Measurement of Gas Flow

1. Press the “On / Mode” button to turn on the Digital Flow Check™. The unit will power up and display the last mode of operation.

2. Press and release the “Gas” button to scroll through and select the type of gas to be measured.

3. Attach the flowmeter to the flow source to be measured. Allow the gas to purge the unit for several seconds. A stable reading indicates the unit is properly purged.

4. The unit will measure the flow rate in the units of SCCM, Standard Cubic Centimeters per Minute. A stable flow reading will be displayed within seconds.*

Note: When measuring low flow rates of 5 SCCM or less, it is advisable to use the 1/32" tubing and 1/16" fitting and purge the flowmeter with a higher flow rate of the gas being measured prior to measuring the low flow rate. This will result in more consistent, stable readings. Purge time is directly related to tubing volume and flow rate. The tubing supplied with the meter has been specially selected for minimal volume and backpressure. The backpressure generated by the Digital Flow Check is greater than that generated by a soapfilm flowmeter.

*See Appendix 1, located on pages 22-25, for a comparison of volumetric to mass flowmeters.

Why do I sometimes see a reading on my DFC when it is not connected to a flow source?

The DFC uses the thermal conductivity of the gas being measured to determine flow when the unit is sitting on the bench and air migrates in to the flow sensor, the unit will sometimes give a “pseudo” reading. This occurs more frequently when the unit is in the light gas modes – hydrogen and helium. Purging the unit with the appropriate gas will eliminate the “pseudo” reading. This in no way effects the accuracy of the unit.

Setting a Split Ratio

1. Press the “On / Mode” button to turn on the Digital Flow Check™.

2. Repeatedly press the “Gas” button to scroll through and select the type of gas to be measured.

3. Connect the flowmeter to the GC column flow and adjust the flow rate to the desired value.

4. Press the “Split / Column ID” button once after a stable reading of the GC column flow has been achieved. The digital display will now read the selected type of gas and SPL 1:1.0.

5. Disconnect the flowmeter from the GC column flow and connect it to the split vent flow. The digital display will now display the split ratio.

6. The split ratio can then be set by adjusting the split vent flow until the desired ratio is displayed on the digital display.

7. To return to the flow measurement mode, press the “Split / Column ID” button once. The digital display will again read the selected gas type and flow rate.

Measuring Linear Velocity

1. Press the “On / Mode” button to turn on the Digital Flow Check™.

2. Repeatedly press the “Gas” button to scroll through and select the type of gas to be measured.

3. Press the “On / Mode” button once. This will place the flowmeter in the linear velocity mode. The digital display will read the selected type of gas and #v=0.0. (#v= tubing ID reference number)

4. Refer to the tubing ID chart located on the back of the flowmeter to determine which reference number corresponds to the column inside diameter. Using the “Split / Column ID” button, scroll through the choices until the correct reference number is displayed.

5. Connect the flowmeter to the GC column flow. The flowmeter will now display the linear velocity of the column.*

* The linear velocity readings obtained from the flowmeter are at STP values. Due to variations in film thicknesses, variations in the actual ID of the column, inlet pressure and column temperature, this reading should only be used as an indicator of flow velocity. The unretained peak method is still the best method to determine linear velocity.

In-Line Operation

When using your Digital Flow Check for in-line use, the following procedure should be employed.

1) Turn off your gas source.

2) Install the Digital Flow Check in the flowpath.

3) Turn on the gas source, making sure that you do not exceed 1000 SCCM. Remember that your Flow Check will only read flows to 500 SCCM for N_2, H_2, He, O_2, Air and 5%Argon/Methane and 300 SCCM for CO_2. Regulate the pressure at the inlet of the Flow Check and do not allow it to exceed 20psig.

4) When you have completed taking measurements be sure to turn off the gas before disconnecting the Flow Check.

Note: In some situations it will be possible to achieve excessive flows (>1000 SCCM) with pressures that are less than 20psig. It is therefore necessary to carefully monitor flow rates in addition to inlet pressure. See Calibration Caution on pages 1-3.

Auto / Manual Power Shut Off

The Digital Flow Check is equipped with an automatic shut off feature. The unit will automatically shut off five minutes after the last key stroke. The unit may also be turned off manually at any time by holding the “On / Mode” button down for three seconds. The unit serial number and “Have a Real Gas” will flash across the LCD digital display and the unit will shut off.

Low Battery Indicator

The Digital Flow Check is equipped with a low battery indicator. To replace the 9 volt alkaline battery installed in the unit, remove the battery cover on the back of the flowmeter case, remove and replace the battery with a new battery and replace the cover. **Be sure to replace the battery with an alkaline battery.**
An alkaline battery will provide approximately 10 hours of continuous use. A non-alkaline battery will only provide 1-2 hours of continuous use. The Digital Flow Check will continue to give accurate precise readings even when the low battery message is displayed. A specially designed power circuit in the flowmeter will continue to give accurate readings until the battery is completely drained and can no longer provide the unit power to operate.

Calibration Accuracy

Each Alltech Digital Flow Check is calibrated for seven gasses using a multi-point, NIST-traceable calibration procedure. The interval between calibration points was chosen based on the flow sensor's characteristics and guarantees that the meter's stated accuracy specification (±2% of reading or 0.1 SCCM) will be met anywhere within the meter's stated operating range of 0-500 SCCM for air, oxygen, helium, hydrogen, nitrogen and 5%argon/methane and 0-300 SCCM for carbon dioxide.

Because the interval between calibration points were chosen based on the flow sensor's characteristics, the accuracy specification applies at any flow rate at or between the specific calibrations points.This includes all points between zero flow and the first calibration point (25 SCCM). Additional calibration points between zero and 25 SCCM are not necessary to meet the stated accuracy specifications because the sensor's output between these two points is essentially linear.

Measurements made with soap-film or other volume-based flow meters may not agree with mass flow measurements made with the Digital Flow Check. Mass flow measurements, like those made with the Digital Flow Check, are not subject to the water vapor error or

variations caused by ambient temperature and pressure fluctuations that effect soap-film or other volumetric flow meters. Please refer to pages 22 through 25 of this manual for procedures for correcting volume flow measurements to true mass flow.

Calibration Certificate

A calibration certificate is included with every Digital Flow Check. The certificate includes the following information: serial number of the Digital Flow Check, the serial number of the NIST standardized flowmeter used to calibrate the Digital Flow Check, the date the Digital Flow Check was calibrated, the temperature and barometric pressure at the time of the calibration, the calibration data for the unit for all seven gases and the signature of the technician performing the calibration procedure. The calibration data is comprised of the Master Reading, the Unit Reading and %Error. The Master Reading is the flow reading of the standardized flowmeter at that particular calibration point . The Unit Reading is the flow reading by the Digital Flow Check at that calibration point. The %Error is the error between the Master Reading and the Unit Reading.

The Alltech Digital Flow Check must be returned to Alltech for recalibration. The unit can not be recalibrated by the customer or by a third party calibration service. Alltech uses a proprietary procedure to calibrate the Digital Flow Check flowmeter. To order the recalibration service (Part No. **4702**) for your unit, use the order form and preprinted shipping label found at the back of this manual on pages 26 and 27. Completely fill out the order form and return your unit along with the order form and a purchase order specifying "Recalibration Service for Alltech Digital Flow Check, Part No. **4702**" to the address printed on the label. You do not need a Return Authorization Number (RA#) to order the recalibration service for your unit.

We recommend recalibration annually or as specified by your company's quality program.

Replacement Parts and Services

Description	Part No.
Alltech Digital Flow Check	**4700**
Standard Replacement Parts	
(These parts fit all versions of the Digital Flow Check.)	
1/8" ID Tubing, 1 meter	**4785**
1/32" ID Tubing, 10 feet	**4703**
General Purpose Adaptor	**4704**
HP Split Vent Adaptor	**4705**
Replacement Parts for Digital Flow Checks	
with Serial #7000 or Greater	
1/16" Inlet & Outlet Fittings, 1 pr	**4721**
1/8" Inlet & Outlet Fittings, 1 pr	**4722**
Operator's Manual,	**4720**
Recalibration & Repair Services	
Recalibration of Digital Flow Check	**4702**

Warranty

Alltech warrants its product against defects in workmanship or material under normal use or service for one year. Examples of defective materials include but are not limited to the following: defective sensors, transistors, battery connectors, faulty switches, malfunctioning software, etc. Examples of defects in workmanship include but are not limited to such things as soldering that comes loose or tubing that unconnected and becomes loose. It is routine for the defective unit to be recalibrated after the repairs to the unit are completed. In such cases, the recalibration of the unit would also be covered by warranty.

The calibration accuracy of the Alltech Digital Flow Check is warranted to be free of defects in calibration workmanship for 90 days from purchase. Any unit sent in by the user during this period as being perceived as being out of calibration and is determined to be out of calibration by Alltech will be recalibrated and covered under warranty. The warranty does not cover the recalibration of units that are found only to require recalibration returned after 90 days of purchase.

The following conditions will void the warranty of the unit. Units requiring repairs as a result of the conditions described in the “Calibration Caution” on page one of this manual. Units that have been modified without the written permission of Alltech will not be covered under warranty. Alltech reserves the right not to honor the warranty if the unit has obviously been mishandled or misused by the user.

All obligation or liabilities under this warranty are limited to repair or replacement at Alltech’s option, F.O.B. Deerfield, IL of parts that are returned freight prepaid and which are accepted as being defective upon inspection by Alltech.

Components that are subject to normal wear and/or are scheduled for routine replacement within the warranty period, and/or parts, that are subjected to effects of corrosion or deterioration by chemical or other action are excluded from the above warranty.

Repair or replacement will not be made under warranty for malfunction because of inadequate facilities, operating conditions or utilities. Equipment and components may only be returned with Alltech's prior approval and must bear an Alltech Return Authorization Numbers (RA#). Call Alltech's Service Department at 1-847-948-8600 to obtain a RA#.

A RA# is not required if the unit is not defective or damaged and is just being returned for a routine recalibration. To order the recalibration service (Part No. **4702**) for your unit, use the order form and preprinted shipping label found on pages 26 and 27 of this manual. Completely fill out the order form and return your unit along with the order form and a purchase order specifying "Recalibration Service for Alltech Digital Flow Check, Part No. **4702**" to the address printed on the label.

Alltech Associates, Inc. assumes no responsibility for consequential, economic or incidental damages of any nature or on-site reinstallation costs arising out of future alleged failure of any of its products or their accessories.

This warranty supersedes any and all previous warranties unless otherwise agreed upon at the time of sale, such as for customized equipment.

Shipments, Damages, Claims, Returns

Shipments

All shipments are made F.O.B. Deerfield, IL. Instruments and major components will be packed and shipped via surface unless otherwise requested. Supplies and/or replacement parts are packed and shipped via UPS, FedEx, Airborne air parcel post, or parcel post unless otherwise requested.

Damaged Shipments

The Interstate Commerce Commission has held that carriers are responsible for both concealed and visible damage occurring during transit. Unpack shipment promptly after receipt as there may be concealed damage even though no evidence of it is apparent. If concealed damage is discovered, cease further unpacking of the unit involved and request immediate inspection by the local agent of the carrier and secure a written report of the findings to support a claim. This request must be made within 15 days of receipt, otherwise, the claim will not be honored by the carrier. Do not return damaged goods to Alltech without first securing an inspection report and contacting Alltech for a Return Authorization Number.

Filing of Claims

After a damage inspection report has been secured, Alltech will cooperate in replacing damaged goods and in handling claims, which have been initiated by either party.

Returns

No returns of defective, damaged, or unwanted goods may be made without prior notification and authorization. If for any reason it is necessary to return material to us, please contact our Customer Service Department for a Return Authorization Number and forwarding instructions at (847) 948-8600.

Appendix 1

Comparing Mass Flow to Volumetric Flow

The Alltech's Digital Flow Check (Part No. **4700**) measures mass flow. Mass Flow is independent of the effects of temperature and barometric pressure, and thus provides more stable and consistent readings (compared to bubble meters) as laboratory temperature and pressure changes. As a result, measurements made from day to day and from lab to lab are more accurate and reliable.

Bubble meter readings vary with changing laboratory temperatures and pressures. These variables don't affect readings made with the Digital Flow Check. Consequently, if the reading given by the Digital Flow Check is compared to a bubble meter reading, the bubble meter readings must be corrected to Standard Temperature and Pressure (STP) conditions. These corrections account for the change in gas density that occurs with changing temperature and pressure, and for the amount of water vapor the bubble meter introduces into the gas stream as the gas contacts the bubble. A properly corrected bubble meter reading will agree with the Digital Flow Check's mass flow reading.

In order to compare a bubble meter reading to the Digital Flow Check, the bubble meter's wet gas flow reading (as a result of water vapor from the bubble) must first be converted to dry gas flow (F_a) using **Equation 1**. The dry gas flow (F_a) must then be adjusted to STP conditions (F_{STP}) using **Equation 2**. The corrected bubble meter reading, F_{STP}, can then be compared to the reading of the Digital Flow Check. Refer to **Example 1** for an example of how to perform the actual calculations.

Volumetric flowmeters which do not expose the gas to water vapors (i.e., positive displacement units) do not require correction to dry gas conditions with **Equation 1**, but do require correction to STP using **Equation 2**.

Equation 1

$$F_a = F(P_a - P_w)\, P_a$$

F_a = Dry gas flow at ambient temperature

F = Gas flow at ambient temperature using wet flowmeter (The Bubble Meter Reading.)

P_w = Partial Pressure of water vapor at the ambient temperature (Determine this value from **Table 1**.)

P_a = Atmospheric pressure at the time of measurement (Obtain this value from your local weather station or the National Weather Service.)

Table 1

Vapor Pressure of Water

Temp. in °C	Vapor Pressure in mm Hg	Temp. in °C	Vapor Pressure in mm Hg	Temp. in °C.	Vapor Pressure in mm Hg
0	4.6	22	19.8	40	55.3
5	6.5	23	21.1	45	71.9
10	9.2	24	22.4	50	92.5
15	12.8	25	23.8	60	149.4
16	13.6	26	25.2	70	233.7
17	14.5	27	26.7	80	355.1
18	15.5	28	28.4	90	525.8
19	16.5	29	30.0	100	760.0
20	17.5	30	31.8	200	11659.2
21	18.6	35	42.2	300	64432.8

Equation 2

$$F_{STP} = F_a (P_a/P_s) (T_s/T_a)$$

F_{STP} = Dry Gas Flow at Ambient Temperature

P_s = Absolute Barometric Pressure
(This is value is atmospheric pressure at standard conditions corrected for altitude. Obtain the correction value from your local weather station or the National Weather Service.)

T_a = Temperature at the Time of Measurement in °K
(°K = °C + 273.)

T_s = Temperature at Standard Conditions (298°K or 25°C.)

Example 1

You obtain a bubble meter reading of 102ml/min and you want to compare it to the reading of 100 SCCM you obtained with the Digital Flow Check.

1. Convert the wet gas flow (F) to dry gas flow (F_a):

Where F = 102 ml/min

P_w = 17.5 mm Hg at 20°C

P_a = 748.36 mm Hg

F_a = 102(748.36 - 17.5) / 748.36 = 99.6 ml/min

2. Adjust the calculated F_a value to STP conditions (F_{STP}):

Where P_a = 748.36 mm Hg

P_s = 760 mm Hg

T_s = 25°C = 298.2°K

T_a = 20.1° = 293.1°K

F_{STP} = 99.6 (748.36/760)(298.2/293.1)

= 99.8 ml/min

The F_{STP} value of 99.8 ml/min can now be compared to the mass flow reading from the Digital Flow Check reading of 100 SCCM. Comparing the two values, there is a 0.2% difference in the mass flow and adjusted volumetric flow rate.

Order Form for Recalibration Service of Alltech DFC (Part No. **4702**)

Customer Name: _____

Customer No.: _____

Company Name: _____

Billing Address: _____

City: _____

State/Country: _____ Zip:

Ship To Address: _____

City: _____

State/Country: _____ Zip:

PO: _____

DFC Serial #: _____

Attention: Alltech Digital Flow Check Recalibration Service

Alltech Associates, Inc.
2051 Waukegan Road
Deerfield, IL 60015-1899