

OPERATING MANUAL

GC MASS FLOW CONTROLLER



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TABLE OF CONTENTS

| | |
|--|-----------|
| 1. UNPACKING THE GC MASS FLOW CONTROLLER..... | 1 |
| 1.1 Inspect Package for External Damage..... | 1 |
| 1.2 Unpack the Mass Flow Controller..... | 1 |
| 1.3 Returning Merchandise for Repair..... | 1 |
| 2. INSTALLATION..... | 2 |
| 2.1 Primary Gas Connections..... | 2 |
| 2.2 Electrical Connections..... | 2 |
| 2.2.1 Valve Control Configuration..... | 5 |
| 2.2.2 Remote LCD Readouts..... | 6 |
| 2.2.3 Panel Mounting Readouts..... | 6 |
| 3. PRINCIPLE OF OPERATION..... | 7 |
| 4. SPECIFICATIONS..... | 7 |
| 4.1 CE Compliance..... | 10 |
| 4.2 Flow Capacities..... | 10 |
| 5. OPERATING INSTRUCTIONS..... | 11 |
| 5.1 Preparation and Warm Up..... | 11 |
| 5.2 Flow Signal Output Readings..... | 12 |
| 5.3 Swamping Condition..... | 12 |
| 5.4 Setpoint Reference Signal..... | 13 |
| 5.5 Valve OFF Control (Open Collector NPN Compatible)..... | 14 |
| 5.6 Valve Test/Purge..... | 14 |
| 6. MAINTENANCE..... | 15 |
| 6.1 Introduction..... | 15 |
| 6.2 Flow Path Cleaning..... | 15 |
| 6.2.1 Cleaning the Inlet Filter Screen in GC Models..... | 15 |
| 6.2.2 Valve Maintenance for GC 1/3/4 Models..... | 16 |
| 7. CALIBRATION PROCEDURES..... | 18 |
| 7.1 Flow Calibration..... | 18 |
| 7.2 Calibration of GC 1/3/4 Mass Flow Controllers..... | 19 |
| 7.2.1 Connections and Initial Warm Up..... | 19 |
| 7.2.2 Zero Adjustment..... | 20 |
| 7.2.3 SPAN Adjustment..... | 20 |
| 7.2.4 Linearity Adjustment..... | 20 |
| 7.2.4.1 Disable Solenoid Valve in GC 1/3/4 Models..... | 20 |

| | | |
|----------|--|----|
| 7.2.5 | Connections and Initial Warm Up..... | 21 |
| 7.2.6 | ZERO Adjustment..... | 21 |
| 7.2.7 | 25% Flow Adjustment Using R33 Potentiometer..... | 21 |
| 7.2.8 | 10% Flow Adjustment..... | 22 |
| 7.2.9 | 25% Flow Adjustment (using R52 potentiometer)..... | 22 |
| 7.2.10 | 50% Flow Adjustment..... | 22 |
| 7.2.11 | 75% Flow Adjustment..... | 22 |
| 7.2.12 | 100% Flow Adjustment..... | 22 |
| 7.2.13. | Valve adjustment..... | 23 |
| 7.2.13.1 | Valve Adjustment for GC 1/3/4..... | 23 |
| 7.2.14 | Close Loop Full Scale Flow Adjustment..... | 23 |
| 7.2.15 | 10% Close Loop Flow Adjustment (using R33 potentiometer)..... | 23 |
| 7.2.16 | 25% Close Loop Flow Adjustment (using R52 potentiometer)..... | 23 |
| 7.2.17 | Close Loop 25% Flow Adjustment (using R33 potentiometer)..... | 23 |
| 7.2.18 | Close Loop 50% Flow Adjustment..... | 24 |
| 7.2.19 | Close Loop 75% Flow Adjustment..... | 24 |
| 7.2.20 | Close Loop 100% Flow Adjustment..... | 24 |
| 7.3 | Calibration of GC 5/6/7 Mass Flow Controllers..... | 24 |
| 7.3.1 | Connections and Initial Warm Up..... | 25 |
| 7.3.2 | ZERO Adjustment..... | 25 |
| 7.3.3 | SPAN Adjustment..... | 25 |
| 7.3.4 | Linearity Adjustment..... | 26 |
| 7.3.4.1 | Open Motorized Valve in GC 5/6/7 Models..... | 26 |
| 7.3.5 | Connections and Initial Warm Up..... | 26 |
| 7.3.6 | ZERO Adjustment..... | 26 |
| 7.3.7 | 25% Flow Adjustment..... | 26 |
| 7.3.8 | 50% Flow Adjustment..... | 27 |
| 7.3.9 | 75% Flow Adjustment..... | 27 |
| 7.3.10 | 100% Flow Adjustment..... | 27 |
| 7.3.11. | Valve adjustment..... | 27 |
| 7.3.11.1 | Valve Adjustment for GC 5/6/7..... | 27 |
| 7.3.12 | Full Scale Flow Adjustment..... | 28 |
| 7.3.13 | 25% Flow Adjustment..... | 28 |
| 7.3.14 | 50% Flow Adjustment..... | 28 |
| 7.3.15 | 75% Flow Adjustment..... | 28 |
| 7.3.16 | 100% Flow Adjustment..... | 28 |
| 7.4 | LCD Display Scaling..... | 28 |
| 7.4.1 | Access LCD Display Circuit..... | 28 |
| 7.4.2 | Adjust Scaling..... | 29 |
| 7.4.3 | Change Decimal Point..... | 29 |

| | |
|--|----|
| 8. TROUBLESHOOTING | 30 |
| 8.1 Common Conditions..... | 30 |
| 8.2 General Troubleshooting Guide..... | 31 |
| 8.3 GC 1/3/4 Valve Related Troubleshooting..... | 33 |
| 8.4 Technical Assistance..... | 36 |
| 9. CALIBRATION CONVERSIONS FROM REFERENCE GASES | 36 |
| APPENDIX 1 COMPONENT DIAGRAM..... | 37 |
| APPENDIX 2 GAS FACTOR TABLE (“K” FACTORS)..... | 39 |
| APPENDIX 3 DIMENSIONAL DRAWINGS..... | 43 |
| APPENDIX 4 WARRANTY..... | 48 |

1. UNPACKING THE GC MASS FLOW CONTROLLER

1.1 Inspect Package for External Damage



CAUTION: Some of the IC devices used in the GC are Electro Static Discharge (ESD) sensitive and may be damaged by improper handling. When wiring the interface connector, adjusting or servicing the meter, use of a grounded ESD protection wrist strap is required to prevent inadvertent damage to the CMOS integral solid state circuitry. When 15 pins inter face D-connector is not used do not remove factory installed ESD protection cover.

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

1.2 Unpack the Mass Flow Controller

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

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

1.3 Returning Merchandise for Repair

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

Shipping charges are borne by the customer. Items returned “collect” will not be accepted!

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

2. INSTALLATION

2.1 Primary Gas Connections

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



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

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

Prior to connecting gas lines inspect all parts of the piping system including ferules and fittings for dust or other contaminants. Be sure to observe the direction of gas flow as indicated by the arrow on the front of the meter when connecting the gas system to be monitored.

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

Compression fittings should not be removed unless the meter is being cleaned or calibrated for a new flow range.

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

2.2 Electrical Connection



CAUTION: Some of the IC devices used in the GC are Electro Static Discharge (ESD) sensitive and may be damaged by improper handling. When wiring the interface connector, adjusting or servicing the meter, use of a grounded ESD protection wrist strap is required to prevent inadvertent damage to the CMOS integral solid state circuitry. When 15 pins interface D-connector is not used do not remove factory installed ESD protection cover.



CAUTION: WIRING THE GC METER OR CHANGING NJ1 JUMPERS CONFIGURATION WITH THE POWER ON MAY RESULT IN INTERNAL DAMAGE! PLEASE MAKE ALL WIRING CONNECTIONS AND NJ1 JUMPERS INSTALLATIONS BEFORE SWITCHING ON THE POWER.



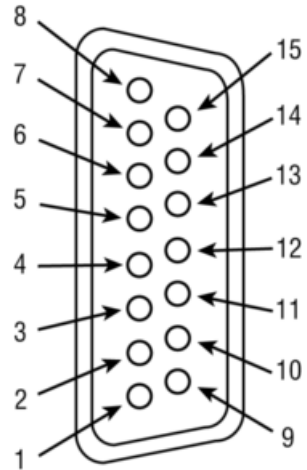
Base on the GC transducers model number it may require different power supply voltage: ether 12Vdc, 24Vdc or universal (any voltage between 12 and 26 Vdc). Before connecting power supply check controller power supply requirements label located on the controller back cover. If power supply requirements label states that power supply requirements is 12 Vdc, do not connect power supply with voltage above 15 Vdc. Exceeding specified maximum power supply voltage limit will result in device permanent damage.

The operating power input is supplied via the 15-pin “D” connector located at the side of the flow transducer enclosure. On GC's purchased without an LCD read-out, a readout panel meter, digital multimeter, or other equivalent device is required to facilitate visual flow readings.

A built in SETPOINT potentiometer is used for local control of the flow. Variable analog 0 to 5 Vdc (or 4 to 20 mA) reference input is required for remote control.

PIN FUNCTION

- 1 0 to 5 Vdc Flow Signal Common
- 2 0 to 5 Vdc Flow Signal Output
- 3 Common
- 4 Open (Purge)
- 5 Common, Power Supply
- 6 (unassigned)
- 7 +12 Vdc (Optional +24 Vdc*) Power Supply
- 8 Remote Setpoint Input
- 9 4 to 20 mA (-) Flow Signal Return (use with 14)
- 10 Remote Setpoint Common (use with 8)
- 11 +5 Vdc Reference Output for Remote Setpoint
- 12 Valve Off Control
- 13 Auxiliary +12 Vdc (Optional +24 Vdc*) Power Output (For Loads <100 mA)
- 14 4 to 20 mA (+) Flow Signal Output
- 15 Chassis Ground



| | | | |
|--------|--|---------|---|
| 1 & 2 | 0-5 Vdc OUTPUT | 5 & 7 | +12 Vdc (Optional +24 Vdc*) POWER SUPPLY |
| 3 & 4 | PURGE | 8 & 10 | 0-5 Vdc OR 4-20 mA (FROM 3 WIRE LOOP SOURCING DEVICE) REMOTE SETPOINT |
| 3 & 12 | VALVE OFF CONTROL | 9 & 14 | 4-20 mA OUTPUT (SOURCING, ONLY FOR PASSIVE LOAD) |
| 5 & 13 | AUXILIARY +12 Vdc (Optional +24 Vdc*) POWER OUTPUT (FOR LOADS <100 mA) | 10 & 11 | +5 Vdc CONTROL SOURCE |

FIGURE 2-1 GC 15-PIN “D” CONNECTOR CONFIGURATION

*Do not connect +24 Vdc power supply unless your GC controller was ordered and configured for 24 Vdc



CAUTION: BEFORE CONNECTING THE POWER SUPPLY CHECK YOUR CONTROLLER MODEL NUMBER AND POWER SUPPLY REQUIREMENTS LABEL LOCATED ON THE CONTROLLER BACK COVER. DO NOT CONNECT 24 Vdc POWER SUPPLY UNLESS YOUR GC CONTROLLER WAS ORDERED AND CONFIGURED FOR 24 Vdc. EXCEEDING THE SPECIFIED MAXIMUM POWER SUPPLY VOLTAGE LIMIT MAY RESULT IN PERMANENT DEVICE DAMAGE.

Important Notes:

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

Power must be turned OFF when connecting or disconnecting any cables in the system.

The power input is protected by a 900mA (GC 1/3/4) 1600mA M (GC 5/6/7) M (medium time-lag) resettable fuse. If a shorting condition or polarity reversal occurs, the fuse will cut power to the flow transducer circuit. Disconnect the power to the unit, remove the faulty condition, and reconnect the power. The fuse will reset once the faulty condition has been removed.



CAUTION: Fuse will not protect controller if power supply voltage exceeds maximum voltage specified for a particular model.

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

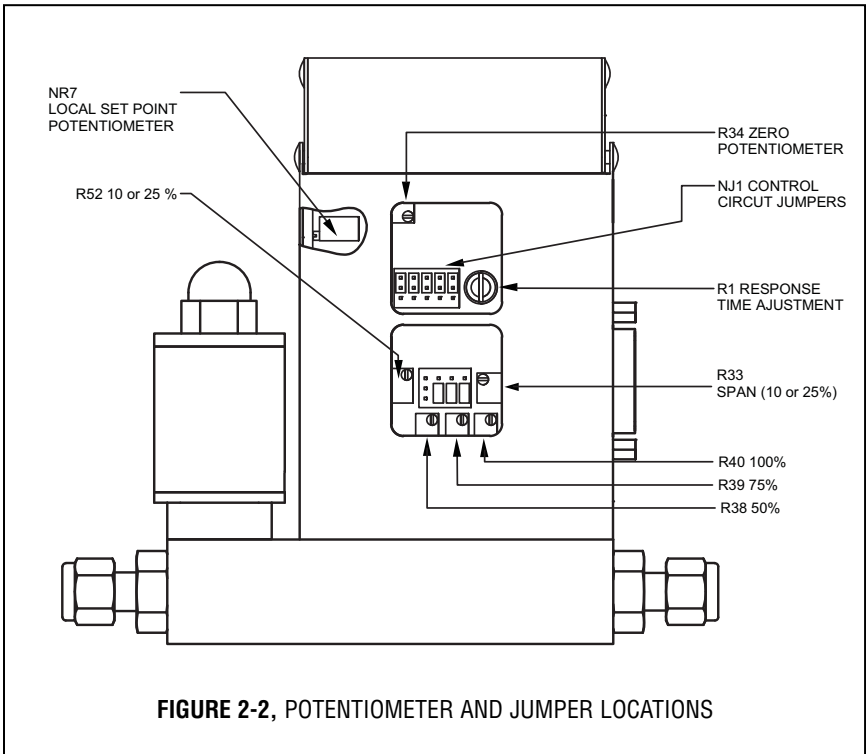


FIGURE 2-2, POTENTIOMETER AND JUMPER LOCATIONS

2.2.1 Valve Control Configuration

There are three basic valve control options.

- (a) LOCAL or REMOTE control.
- (b) 0 to 5 VDC or 4 to 20 mA setpoint signal -
*Note: this only applies for the REMOTE control configuration.
- (c) 2% cutoff active or not active. **Note:** 2% cutoff not available for GC 5/6/7.

When active, the 2% cutoff will shut off the power to the valve when a setpoint of less than 2% of the full scale flow range is set. Figure 2-3 shows the jumper configurations for the three basic valve control options.

The factory default jumper settings are: LOCAL control, 2% cutoff off.

| FUNCTION | | NJ1A | NJ1B | NJ1C | NJ1D | NJ1E |
|----------|--------------------------|-------|-------|-------|---------|---------|
| Remote | 0 to 5 Vdc 2% cutoff ON | 2 - 3 | 5 - 6 | 8 - 9 | 10 - 11 | 13 - 14 |
| | 0 to 5 Vdc 2% cutoff OFF | | | | | 14 - 15 |
| | 4 to 20 mA 2% cutoff ON | 1 - 2 | 4 - 5 | 7 - 8 | 10 - 11 | 13 - 14 |
| | 4 to 20 mA 2% cutoff OFF | | | | | 14 - 15 |
| Local | 2% cutoff ON | 2 - 3 | 5 - 6 | 8 - 9 | 11 - 12 | 13 - 14 |
| | 2% cutoff OFF | | | | | 14 - 15 |

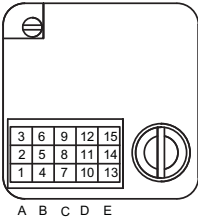


FIGURE 2-3, VALVE CONTROL CONFIGURATION JUMPERS

2.2.2 Remote LCD Readouts

GC Mass Flow Controllers are available with optional remote reading LCD displays supplied with a three foot long wire to accommodate most applications. This configuration includes the upper block element which serves as the LCD readout mounting. Special lengths of remote extension wiring (up to 9.5 feet [3 meters]) are available on request.

2.2.3 Panel Mounting Readouts

Another option for the GC Mass Flow Controller is the Panel Mounting Remote Readout.

In this configuration the LCD readout is supplied with a three foot long extension wire, and no aluminum housing around the LCD. The LCD readout for panel mounting includes a bezel with two plastic screws which conveniently fit into a rectangular cut-out for panel mounting (see Figure 2-4).

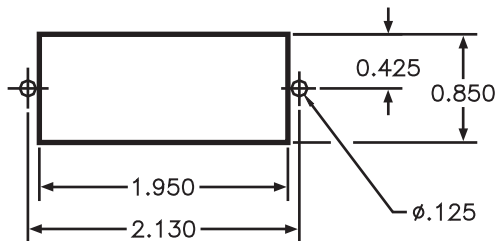


FIGURE 2-4 CUTOUT DIMENSIONS FOR LCD PANEL MOUNTING

3. PRINCIPLE OF OPERATION

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

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

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

GC Mass Flow Controller models GC 1/3/4 also incorporate a proportionating solenoid valve and models GC 5/6/7 a motorized valve. The closed loop control circuit of the GC continuously compares the mass flow output with the selected flow rate. Deviations from the setpoint are corrected by compensating valve adjustments, thus maintaining the desired flow parameters.

4. SPECIFICATIONS

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

CALIBRATIONS: Supplied at Standard Conditions (14.7 psia and 70° F), or Normal Conditions (0 °C and 1.01 bar abs) unless otherwise requested or stated.

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

ACCURACY: GC 1/3/4: $\pm 1.0\%$ F.S.

GC 5/6/7: See table below.

| ACCURACY % FS | | | OPTIONAL ENHANCED ACCURACY % FS | | |
|---------------|-------------|-----------|---------------------------------|------------|-------------------------|
| MODEL | GC 5, 6, 7 | | MODEL | GC 5, 6, 7 | |
| FLOW RANGE | 20-100% | 0-20% | FLOW RANGE | 20-100% | 0-20% |
| ACCURACY | $\pm 1.5\%$ | $\pm 3\%$ | ACCURACY | $\pm 1\%$ | REF DATA with $\pm 1\%$ |

REPEATABILITY: $\pm 0.5\%$ of full scale.

TEMPERATURE COEFFICIENT: 0.15% of full scale/ °C.

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

RESPONSE TIME: GC 1: 300ms time constant; approximately 1 second to within $\pm 2\%$ of set flow rate for 25% to 100% of full scale flow.

GC 3/4: 600ms time constant; approximately 2 seconds to within $\pm 2\%$ of set flow rate for 25% to 100% of full scale flow.

GC 5/6/7: 1800ms time constant; approximately 5 seconds to within $\pm 2\%$ of set flow rate for 25% to 100% of full scale flow.

MAX GAS PRESSURE: 1000 psig (69 bars) GC 1, 3 and 4; 500 psig (34.5 bars) GC 5, 6 and 7. Optimum pressure is 20 psig (1.4 bars).

TURNDOWN RATIO: 40:1.

MAX DIFFERENTIAL PRESSURE: 50 psid (345 kPa) for GC 1/3/5/6/7 AND 40 psid (276 kPa) for GC 4.

GAS TEMPERATURE: 32 °F to 122 °F (0 °C to 50 °C).

AMBIENT TEMPERATURE: 14 °F to 122 °F (-10 °C to 50 °C).

GAS RELATIVE HUMIDITY: Up to 70%.

MAXIMUM INTERNAL LEAK: 0.5% FS.

LEAK INTEGRITY: 1×10^{-7} sccs He max to the outside environment.

ATTITUDE SENSITIVITY: No greater than ± 15 degree rotation from horizontal to vertical; standard calibration is in horizontal position.

OUTPUT SIGNALS: Linear 0 to 5 VDC (1000 Ω minimum load impedance) and 4 to 20 mA (0 to 500 Ω loop resistance, sourcing only for passive load); 20 mV peak to peak max noise for GC 1/3/4 and 100 mV peak to peak max noise for GC 5/6/7.

COMMAND SIGNAL: Analog 0 to 5 Vdc (100 K minimum input impedance) or 4 to 20 mA (250 Ω input impedance, use only with 3 wire 4-20 mA loop sourcing device).

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

TRANSDUCER INPUT POWER:

- GC 1/3/4:** Models with 12 Vdc power input 12 Vdc, 650 mA maximum;
- GC 1/3/4:** Models with 24 Vdc power input +24 Vdc, 650 mA maximum;
- GC 5/6/7:** Models with 12 Vdc power input 12 Vdc, 800 mA maximum;
- GC 5/6/7:** Models with 24 Vdc power input 24 Vdc, 800 mA maximum;
- GC 1/3/4:** Models with universal power input any voltage between +12 and +26 Vdc, 650 mA maximum;

WETTED MATERIALS:

GC 1/3/4/5/6/7: Anodized aluminum, brass, 416 stainless steel and 316 stainless steel with VITON® O-rings seals; BUNA-N® EPR or KALREZ® O-rings are optional.

GC 1S/3S/4S/5S/6S/7S: 416 Stainless Steel and 316 stainless steel with VITON® O-rings seals; BUNA-N®, EPR or KALREZ® O-rings are optional.

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

INLET AND OUTLET CONNECTIONS:

- GC 1 and 3:** 1/4" compression fittings. **Optional:** 6mm compression, 1/4" VCR®, 3/8" or 1/8" compression fittings.
- GC 4:** 3/8" compression fittings.
- GC 5:** 3/8" compression fittings.
- GC 6:** 1/2" compression fittings.
- GC 7:** 3/4" FNPT fittings. **Optional:** 3/4" compression fittings.

LCD DISPLAY: 3½ digit LCD (maximum viewable digits "1999"), 0.5 inch high characters. The LCD display is built into the upper block element and may be tilted over 90 degrees for optimal viewing comfort. Remote or panel mounting remote reading is optional.

Standard readings are in direct engineering units for the given gas and flow rate (i.e. liters/minute [lpm], standard cubic centimeters/minute [sccm], standard cubic feet/hour [scfh], etc.). 0 to 100% LCD calibration scaling is available upon request at time of order. Contact your distributor or Dakota® when non-standard display settings are desired.

TRANSDUCER INTERFACE CABLE: Optional shielded cable is available mating to the GC transducer 15-pin "D" connector.

4.1 CE Compliance

GC Mass Flow Controllers are in compliance with CE test standards stated below:

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

4.2 Flow Capacities

FLOW RANGES

TABLE I GC 1 LOW FLOW MASS FLOW CONTROLLER*

| MODEL | CODE | mL/min [N ₂] | CODE | L/min [N ₂] |
|-------|------|--------------------------|------|-------------------------|
| GC1 | 01 | 0 to 10 | 07 | 0 to 1 |
| | 02 | 0 to 20 | 08 | 0 to 2 |
| | 03 | 0 to 50 | 09 | 0 to 5 |
| | 04 | 0 to 100 | 10 | 0 to 10 |
| | 05 | 0 to 200 | | |
| | 06 | 0 to 500 | | |

TABLE II GC 3 MEDIUM FLOW MASS FLOW CONTROLLER*

| MODEL | CODE | L/min [N ₂] |
|-------|------|-------------------------|
| GC3 | 11 | 0 to 15 |
| | 30 | 20 |
| | 31 | 30 |
| | 32 | 40 |
| | 33 | 50 |

TABLE III GC 4/5/6/7 HIGH FLOW MASS FLOW CONTROLLER*

| MODEL | CODE | L/min [N ₂] |
|-------|------|-------------------------|
| GC4 | 40 | 60 |
| | 41 | 80 |
| | 42 | 100 |
| GC5 | 50 | 200 |
| GC6 | 60 | 500 |
| GC7 | 70 | 1000 |

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

TABLE I PRESSURE DROPS

| MODEL | FLOW RATE [L/min] | MAXIMUM PRESSURE DROP | | |
|-------------|----------------------|-----------------------|--------|--------|
| | | [mm H ₂ O] | [psid] | [mbar] |
| GC 1 | UP to 10 | 720 | 1.06 | 75 |
| GC 3 | 15 | 2630 | 3.87 | 266 |
| | 20 | 1360 | 2.00 | 138 |
| | 30 | 2380 | 3.50 | 241 |
| | 40 | 3740 | 5.50 | 379 |
| | 50 | 5440 | 8.00 | 551 |
| GC 4 | 60 | 7480 | 11.00 | 758 |
| | 100 | 12850 | 18.89 | 1302 |
| GC 5 | 200 | 7031 | 10.00 | 690 |
| GC 6 | 500 | 8437 | 12.00 | 827 |
| GC 7 | 1000 | 10547 | 15.00 | 1034 |

5. OPERATING INSTRUCTIONS

5.1 Preparation and Warm Up

It is assumed that the Mass Flow Controller has been correctly installed and thoroughly leak tested as described in section (2). Shut the flow source OFF. Apply power to the unit via the 15-pin “D” connector. Before connecting the power supply check the controller power supply requirements label located on the controller back cover. If the power supply requirements label states that power supply requirement is 12 Vdc, do not connect the power supply with voltage above 15 Vdc. Exceeding the specified maximum power supply voltage limit will result in device permanent damage. Allow the Mass Flow Controller to warm-up for at least 15 minutes.

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

If after the 15 minutes warm-up period, the display still indicates a reading of less than $\pm 3.0\%$ of F.S., readjust the ZERO potentiometer [R34] through the access window. Before zero adjustment temporarily disconnect the gas source, to ensure that no seepage or leak occurs in to the meter.



CAUTION: Adjusting Zero Reading more than $\pm 3.0\%$ F.S. from the factory settings may affect device calibration accuracy. If such adjustment is required it is recommended to perform controller recalibration to preserve device accuracy.

GC 1/3/4 CAUTION



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

Do not run GC1/3/4 models for extended periods of time with the valve in AUTO or PURGE mode without the flow of gas through the transducer. Doing so may result in up to 2% f.s. shift in calibration.

5.2 Flow Signal Output Readings

The flow signal output can be viewed on the LCD display, remote panel meter, digital multimeter, or other display device connected as shown in Figure 2.1.

If an LCD display has been ordered with the GC the observed reading is in direct engineering units, for example, 0 to 10 sccm or 0 to 100 slpm (0 to 100% indication is optional). Engineering units for a specific GC are shown on the flow transducer's front label.

Analog output flow signals of 0 to 5 VDC and 4 to 20 mA are available at the appropriate pins of the 15-pin "D" connector at the side of the GC transducer (see Figure 2-1).

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

Default calibration is performed for 0 to 5 VDC input/output signal. If 4-20 mA output signal is used for flow indication on the GC, which was calibrated against 0 to 5 VDC input signal, the accuracy of the actual flow rate will be in the specified range (+1.0% GC 17/37/47, +1.5% GC 57/67/77) of full scale, but the total of the output reading may be in the range of $\pm 2.5\%$ of full scale. Optional calibration for 4-20 mA output signal is available upon request at time of order.

For optional RS232 or RS485 IEEE488 interfaces please contact your distributor or Dakota®.

5.3 Swamping Condition

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

5.4 Setpoint Reference Signal

GC flow controllers have built-in solenoid valves (GC 1/3/4) or motorized valves (GC 5/6/7), and allow the user to set the flow to any desired flow rate within the range of the particular model installed. The solenoid valve is normally closed (NC) when no power is applied.

The motorized valve can be in any position depending on the operation mode of the GC during disconnecting of the power. For example if the motorized valve was left in the OPEN purge position after disconnecting power from the GC it will be in the OPEN position. It is the customers responsibility to provide a solution to shut down the flow in case of a power outage. When power is applied to the GC 5/6/7 models the valve automatically closes within the first ten seconds regardless of the set point and valve override signals.

Setpoints are controlled locally or remotely. Setpoints inputs respond to analog 0 to 5 Vdc or 4 to 20 mA reference voltages (default jumper setting is 0 to 5 Vdc). Voltage is a linear representation of 0 to 100% of the full scale mass flow rate. Response times to setpoint changes are 1 second (GC 1), 2 seconds (GC 3/4) and 5 seconds (GC 5/6/7) within 2% of the final flow over 25 to 100% of full scale.

For LOCAL flow control, use the built-in setpoint potentiometer located at the same side as the solenoid valve of the GC transducer. While applying flow to the transducer, adjust the setpoint with an insulated screwdriver until the flow reading is the same as the desired control point. [Display will only show actual instantaneous flow rates. There is no separate display for setpoints].

For REMOTE control of the GC, an analog reference signal must be supplied. On pin [11] of the GC transducer is a regulated and constant +5 Vdc output signal. This signal may be used in conjunction with a local setpoint potentiometer for flow setting.

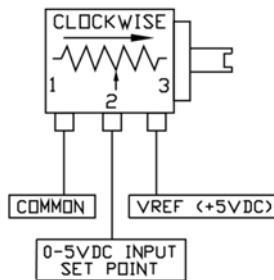


FIGURE 5-1 LOCAL SETPOINT POTENTIOMETER CONNECTIONS

It is recommended that a potentiometer between 5K to 10K ohm and capable of at least 10-turns or more for adjustment be used. Use the control potentiometer to command the percentage of flow desired.

Alternatively, a variable 0 to 5VDC or 4 to 20 mA analog signal may be applied directly to the SETPOINT and COMMON connections of the GC transducer (see Figure 2-1). Be sure to apply the appropriate signal for the designated NJ1 jumper settings.

5.5 Valve OFF Control (Open Collector NPN Compatible)

It may be necessary or desirable to set the flow and maintain that setting while being able to turn the flow control valve off and on again. Closing of the valve (without changing the setpoint adjustment) can be accomplished by connecting pin 12 of the 15-pin “D” connector to COMMON pin [3]. When pin [12] is connected to COMMON, the solenoid valve is not powered and therefore will remain normally closed regardless of the setpoint. The Motorized valve will be given the command to close indicated by a green light on top of the unit).

Conversely, when the connection is left open or pin [12] remains unconnected the valve remains active. The valve will remain active when the VALVE OFF pin remains “floating”. This feature is compatible with open collector NPN transistor switches, as found in DC output ports of programmable controllers and similar devices.

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

5.6 Valve Test/Purge

At times, it may be necessary to purge the flow system with a neutralizing gas such as pure dry nitrogen. The GC transducer is capable of a full open condition for the valve, regardless of setpoint conditions. Connecting the OPEN (PURGE) pin (pin 4 on 15-pin “D” connector) to ground will fully open the valve.

The Motorized Valve: Connect pins [3] and [4] to OPEN the motorized control valve. A red light on top of the valve will indicate an OPEN valve, normal for flow conditions.



NOTE: The motorized control valve stays OPEN even if power is no longer applied. To CLOSE the Motorized Control Valve, connect pins [3] and [12].

6. MAINTENANCE

6.1 Introduction

It is important that the Mass Flow Controller is used with clean, filtered gases only. Liquids may not be metered. Since the RTD sensor consists, in part, of a small capillary stainless steel tube, it is prone to occlusion due to impediments or gas crystallization. Other flow passages are also easily obstructed. Therefore, great care must be exercised to avoid the introduction of any potential flow impediment. To protect the instrument a 50 micron (GC 1) or 60 micron (GC 3/4) filter is built into the inlet of the flow transducer. The filter screen and the flow paths may require occasional cleaning as described below. There is no other recommended maintenance required. It is good practice, however, to keep the meter away from vibration, hot or corrosive environments and excessive RF or magnetic interference.

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



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

6.2 Flow Path Cleaning

Inspect visually the flow paths at the inlet and outlet ends of the meter for any debris that may be clogging the flow through the meter. Remove debris carefully using tweezers and blowing low pressure clean air or Nitrogen from the inlet side. If the flow path is not unclogged, please return meter to Dakota® for servicing.



Do not attempt to disassemble the sensor.
Disassembly will invalidate calibration.

6.2.1 Cleaning the Inlet Filter Screen in GC 1 Models

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

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

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

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



NOTE: Over tightening will deform and render the RFE defective.

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



IT IS NOT RECOMMENDED TO ATTEMPT TO DISASSEMBLE, OR REPAIR GC 3, GC 4, GC 5, GC 6 AND GC 7 MODELS. DISASSEMBLY NECESSITATES RE-CALIBRATION.

6.2.2 Valve Maintenance for GC 1/3/4 Models

The solenoid valve consists of 316 and 416 stainless steel, and VITON® (or optional EPR or KALREZ®) O-rings and seal materials. No regular maintenance is required except for periodic cleaning.

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

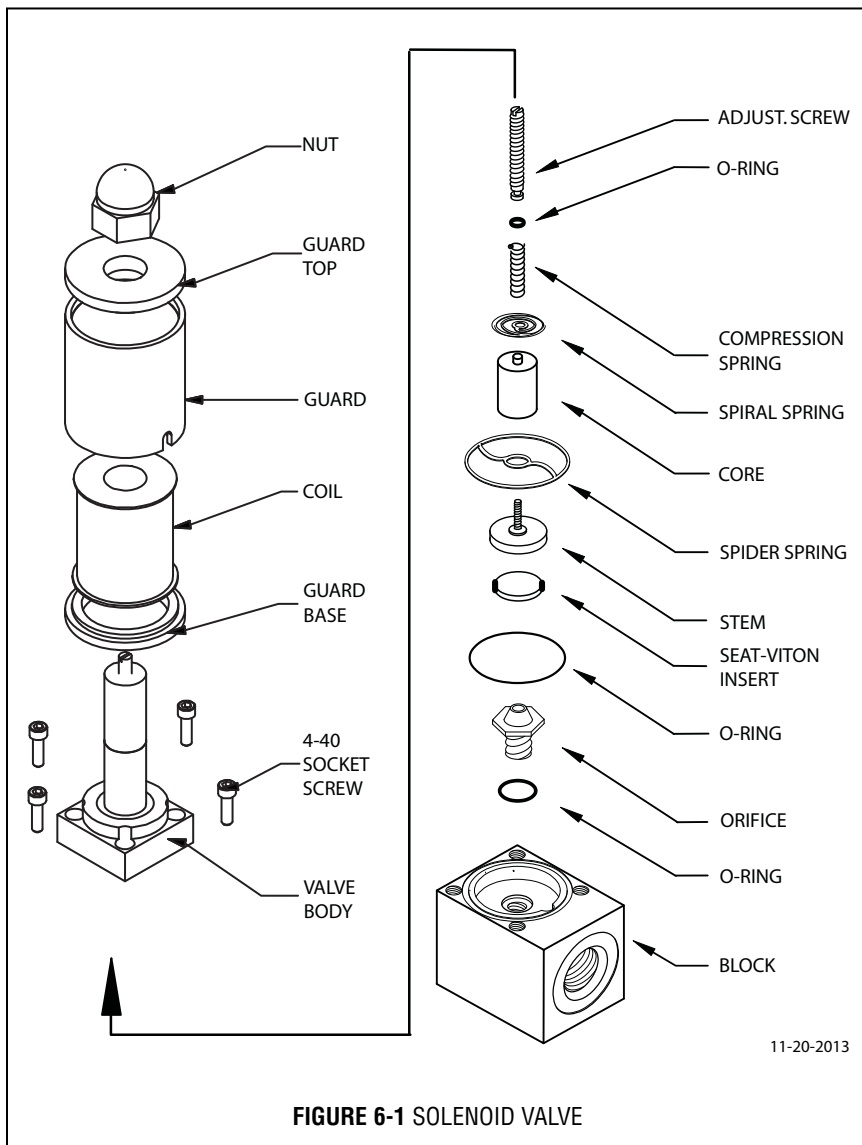


FIGURE 6-1 SOLENOID VALVE

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

Set the GC into PURGE mode, (see Figure 2-1), and attempt to flush through with a clean, filtered, and neutral gas such as nitrogen. [Another option for fully opening the valve is to remove the plastic cap on top of the valve, and turning the set screw counterclockwise until it stops. See section 7.3 for valve adjustment, to return the valve to functional use.]

7. CALIBRATION PROCEDURES



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

7.1 Flow Calibration

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

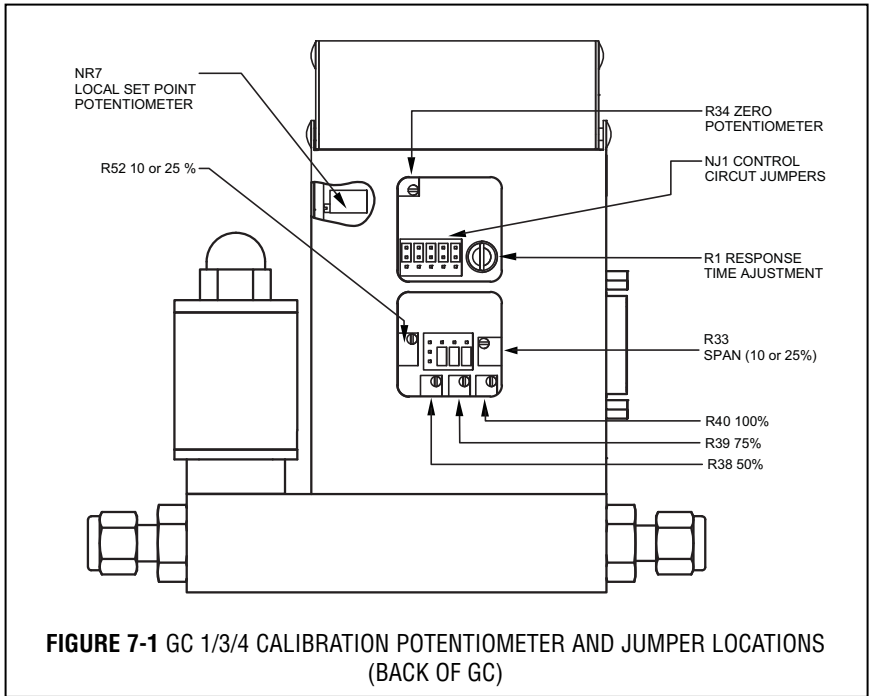
Factory calibrations are performed using state of the art NIST traceable precision volumetric calibrators.

Calibrations are performed using dry nitrogen gas. Calibration can then be corrected to the appropriate gas desired based on relative correction [K] factors shown in the gas factor table - see Appendix 2. A reference gas, other than nitrogen, may be used to approximate the flow characteristics of certain gases closer. This practice is recommended when a reference gas is found with thermodynamic properties similar to the actual gas under consideration. The appropriate relative correction factor should be recalculated - see section (9).

It is standard practice to calibrate Mass Flow Controllers with dry nitrogen gas. It is best to calibrate the GC transducers to actual operating conditions. Specific gas calibrations of non-toxic and non-corrosive gases are available at specific conditions. Please contact your distributor or Dakota® for a price quotation.

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

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



7.2 Calibration of GC 1/3/4 Mass Flow Controllers

All adjustments in this section are made from the outside of the meter, there is no need to disassemble any part of the instrument.

GC Mass Flow Controllers may be field recalibrated/checked for the same range they were originally factory calibrated for. When linearity adjustment is needed, or flow range changes are being made proceed to step 7.2.4. Flow range changes may require a different Restrictor Flow Element (RFE). Additionally, a different Solenoid Valve Orifice may also be required (see Table VI). Consult your distributor or Dakota® for more information.

7.2.1 Connections and Initial Warm Up

At the 15-pin “D” connector of the GC transducer, connect the multimeter to output pins [1] and [2] for 0 to 5 VDC (or pins [9] and [14] for 4 to 20 mA) - (see Figure 2-1).

When using a remote setpoint for flow control, the appropriate reference signal should also be connected to the 15-pin “D” connector at pins [8] and [10] - (see Figure 2-1). Power up the Mass Flow Controller for at least 30 minutes prior to commencing the calibration procedure.

7.2.2 ZERO Adjustment

Shut off the flow of gas into the Mass Flow Controller. To ensure that no seepage or leak occurs into the meter, temporarily disconnect the gas source.

Using the multimeter and the insulated screwdriver, adjust the ZERO potentiometer [R34] through the access window for 0 VDC (or 4 mA respectively) at zero flow.

7.2.3 SPAN Adjustment

Reconnect the gas source. Adjust the control setpoint to 100% of full scale flow. Check the flow rate indicated against a flow calibrator. If the deviation is less than $\pm 10\%$ of full scale reading, correct the SPAN potentiometer [R33] setting by using the insulated screwdriver through the access window, to eliminate any deviation. If the deviation is larger than $\pm 10\%$ of full scale reading, a defective condition may be present.

LIKELY REASONS FOR A MALFUNCTIONING SIGNAL MAY BE:

- ✓ Occluded or contaminated sensor tube.
- ✓ Leaking condition in the GC transducer or the gas line and fittings.
- ✓ For gases other than nitrogen, recheck appropriate “K” factor from Gas Factor Table.
- ✓ Temperature and/or pressure correction errors.

See also section (8) TROUBLESHOOTING. If after attempting to remedy the above conditions, a malfunction still persists, return the meter for factory service, see section (1).

At this point the calibration is complete. However, it is advisable that several additional points between 0 and 100%, such as 25%, 50%, and 75% flow be checked. If discrepancies are found, proceed to step 7.2.4 for Linearity Adjustment.

7.2.4 Linearity Adjustment

All adjustments in this section are made from the outside of the meter, there is no need to disassemble any part of the instrument.

7.2.4.1 Disable Solenoid Valve in GC 1/3/4 Models

Set the valve into PURGE mode. This step essentially bypasses the flow control properties of the transducer. The unit will now act as a Mass Flow Controller.



CAUTION: FOR GC 1/3/4: If the valve is left in the AUTO (control) or OPEN (PURGE) mode for an extended period of time, it may become warm or even hot to the touch. Use care in avoiding direct contact with the valve during operation.

7.2.5 Connections and Initial Warm Up

Connect the multimeter to output pins [1] and [2] for 0 to 5 VDC (or pins [9] and [14] for 4 to 20 mA) of the 15-pin “D” connector - (see Figure 2-1).

If calibration to a new flow range or different gas is being performed, it may be necessary to remove any jumpers at J1A, J1B, J1C and J1D before beginning linearizing procedure.

Power up the Mass Flow Controller for at least 30 minutes prior to commencing the calibration procedure.

7.2.6 ZERO Adjustment

Shut off the flow of gas into the Mass Flow Controller. To ensure that no seepage or leak occurs into the meter, it is good practice to temporarily disconnect the gas source.

Using the multimeter and the insulated screwdriver, adjust the ZERO LCD reading and 0 Vdc (or 4 mA respectively) analog output reading at zero flow by adjusting the zero potentiometer [R34] through the access window.



CAUTION: The minimum voltage on 0-5 Vdc output can be in the range of 7 to 25 mV. Trying to reduce voltage below this level may increase negative zero shift. This shift may be invisible on devices without LCD display. Stop R34 zero potentiometer adjustment if voltage on 0-5 Vdc output is in the range from 7 to 25 mV and does not decrease any lower.

7.2.7 25% Flow Adjustment Using R33 Potentiometer

Reconnect the gas source. Using the flow regulator, adjust the flow rate to 25% of full scale flow. Check the flow rate indicated against a flow calibrator. Adjust the setting for potentiometer [R33] by using the insulated screwdriver through the access window, until the output of the flow controller reads 1.25VDC \pm 63mV (or 8mA \pm 0.25mA).

Using the flow regulator, adjust the flow rate until the output of the flow meter reads 0.5 Vdc (or 5.6mA). Check the flow rate against the flow calibrator. If the flow rate indicated by the calibrator is within 10% \pm 1.5% of F.S. then skip paragraphs 7.2.8, 7.2.9 and proceed directly to paragraph 7.2.10, if not, perform 10% flow adjustment according to paragraph 7.2.8.

| LINEARIZER FUNCTION | J1A (10 or 25%) | J1B (50%) | J1C (75%) | J1D (100%) |
|---------------------|-----------------|-----------|-----------|------------|
| Decrease | 1 - 2 | 4 - 5 | 7 - 8 | 10 - 11 |
| Increase | 2 - 3 | 5 - 6 | 8 - 9 | 11 - 12 |

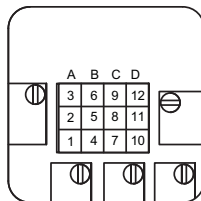


FIGURE 7-2 GC 1/3/4 CALIBRATION POTENTIOMETER AND JUMPERS

7.2.8 10% Flow Adjustment

Using the flow regulator, adjust the flow rate to 10% of full scale flow according to the calibrator. Check the flow rate indicated against the flow calibrator. Adjust the setting for potentiometer [R33] by using the insulated screwdriver through the access window, until the output of the flow meter reads 0.5 Vdc \pm 63mV (or 5.6mA \pm 0.25mA).

7.2.9 25% Flow Adjustment (using R52 potentiometer)

Using the flow regulator, adjust the flow rate to 25% of full scale flow according to the calibrator. Check the flow rate indicated against the flow calibrator. The output of the flow meter should read 1.25 Vdc \pm 63mV (or 8.0mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1.A] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R52] by using the insulated screwdriver through the access window, until reading is within specification.

7.2.10 50% Flow Adjustment

Using the flow regulator, increase the flow rate to 50% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow controller should read 2.50VDC \pm 63mV (or 12mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1B] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R38] by using the insulated screwdriver through the access window, until reading is within specification.

7.2.11 75% Flow Adjustment

Using the flow regulator, increase the flow rate to 75% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow meter should read 3.75VDC \pm 63mV (or 16mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1B] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R39] by using the insulated screwdriver through the access window, until reading is within specification.

7.2.12 100% Flow Adjustment

Using the flow regulator, increase the flow rate to 100% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow controller

should read 5.00VDC \pm 63mV (or 20mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1C] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R40] by using the insulated screwdriver through the access window, until reading is within specification.

Repeat steps 7.2.7 to 7.2.12 at least once more.

7.2.13. VALVE ADJUSTMENT

7.2.13.1 Valve Adjustment for GC 1/3/4

Discontinue the PURGE mode (set valve for the closed position). Apply an inlet pressure of 5 psig, and atmospheric pressure at the outlet. If a small flow occurs, turn the set screw on top of the solenoid valve clockwise until the flow through the GC just stops

7.2.14. Close Loop Valve Adjustment for GC 5/6/7

Fully open the flow regulator upstream of the GC. Increase the inlet pressure to 20 psig (25 psig for GC 4). Apply a +5.00 Vdc (100% full scale flow) setpoint reference. Using the calibrator check the flow rate. If necessary, adjust R33 to match the desired full scale flow rate. [In control mode, turning R33 clockwise will decrease the flow. Conversely, turning R33 counterclockwise will increase the flow through the GC.]

7.2.15 10% Close Loop Flow Adjustment (using R33 potentiometer)

If the J1A jumper is not installed in upper or lower position (paragraphs 7.2.8 and 7.2.9 were skipped) then skip this paragraph and paragraph 7.2.16. Proceed directly to paragraph 7.2.17. Change the setpoint to 0.5 Vdc to control at 10% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within \pm 0.75% of full scale, re-adjust the setting for potentiometer [R33], until the flow output is correct.

7.2.16 25% Close Loop Flow Adjustment (using R52 potentiometer)

Change the setpoint to 1.25 Vdc to control at 25% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within \pm 0.75% of full scale, re-adjust the setting for potentiometer [R52], until the flow output is correct.

7.2.17 Close Loop 25% Flow Adjustment (using R33 potentiometer)

Change the setpoint to 1.25 Vdc to control at 25% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within \pm 0.75% of full scale, re-adjust the setting for potentiometer [R33], until the flow output is correct.

7.2.18 Close Loop 50% Flow Adjustment

Change the setpoint to 2.50 VDC to control at 50% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R38], until the flow output is correct.

7.2.19 Close Loop 75% Flow Adjustment

Change the setpoint to 3.75 VDC to control at 75% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R39], until the flow output is correct.

7.2.20 Close Loop % 100 Flow Adjustment

Change the setpoint to 5.00 VDC to control at 100% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R40], until the flow output is correct.

Repeat steps 7.2.15 to 7.2.20 at least once more.

| ORIFICE PART NUMBER | FLOW RATE [N₂] |
|----------------------------|----------------------------------|
| OR.020 | 10 to 1000 sccm |
| OR.040 | 1 to 5 slpm |
| OR.055 | 5 to 10 slpm |
| OR.063 | 10 to 15 slpm |
| OR.094 | 20 to 50 slpm |
| OR.125 | 50 to 100 slpm |

TABLE II GC SOLENOID VALVE ORIFICE SELECTION TABLE

7.3 Calibration of GC 5/6/7 Mass Flow Controllers

All adjustments in this section are made from the outside of the meter, there is no need to disassemble any part of the instrument. GC Mass Flow Controllers may be field recalibrated/checked for the same range they were originally factory calibrated for. When linearity adjustment is needed, or flow range changes are being made proceed to step 7.2.4. Flow range changes may require a different Restrictor Flow Element (RFE). Additionally, a different Solenoid Valve Orifice may also be required (see Table VI). Consult your distributor or Dakota® for more information.

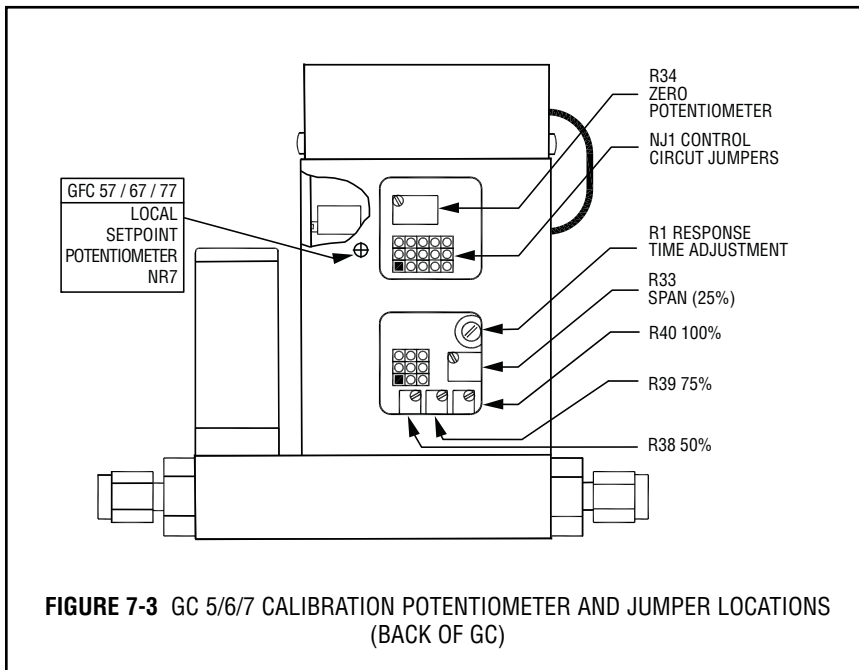


FIGURE 7-3 GC 5/6/7 CALIBRATION POTENTIOMETER AND JUMPER LOCATIONS (BACK OF GC)

7.3.1 Connections and Initial Warm Up

At the 15-pin “D” connector of the GC transducer, connect the multimeter to output pins [1] and [2] for 0 to 5 Vdc (or pins [9] and [14] for 4 to 20 mA) - (see Figure 2-1). When using a remote setpoint for flow control, the appropriate reference signal should also be connected to the 15-pin “D” connector at pins [8] and [10] - (see Figure 2-1). Power up the Mass Flow Controller for at least 30 minutes prior to commencing the calibration procedure.

7.3.2 ZERO Adjustment

Shut off the flow of gas into the Mass Flow Controller. To ensure that no seepage or leak occurs into the meter, temporarily disconnect the gas source. Using the multimeter and the insulated screwdriver, adjust the ZERO potentiometer [R34] through the access window for 0 Vdc (or 4 mA respectively) at zero flow.

7.3.3 SPAN Adjustment

Reconnect the gas source. Adjust the control setpoint to 100% of full scale flow. Check the flow rate indicated against the flow calibrator. If the deviation is less than $\pm 10\%$ of full scale reading, correct the SPAN potentiometer [R33] setting by using the insulated screwdriver through the access window, to eliminate any deviation. If the deviation is larger than $\pm 10\%$ of full scale reading, a defective condition may be present.

LIKELY REASONS FOR A MALFUNCTIONING SIGNAL MAY BE:

- ✓ Occluded or contaminated sensor tube.
- ✓ Leaking condition in the GC transducer or the gas line and fittings.
- ✓ For gases other than nitrogen, recheck appropriate “K” factor from Gas Factor Table.
- ✓ Temperature and/or pressure correction errors.

See also section (8) TROUBLESHOOTING. If after attempting to remedy the above conditions, a malfunction still persists, return the meter for factory service, **see section (1)**. At this point the calibration is complete. However, it is advisable that several additional points between 0 and 100%, such as 25%, 50%, and 75% flow be checked. If discrepancies are found, proceed to step 7.3.4 for Linearity Adjustment.

7.3.4 Linearity Adjustment

All adjustments in this section are made from the outside of the meter, there is no need to disassemble any part of the instrument.

7.3.4.1 Open Motorized Valve in GC 5/6/7 Models

Set the valve to PURGE mode by connecting pin [4] to pin [3], at the 15 pin D-connector.

7.3.5 Connections and Initial Warm Up

Connect the multimeter to output pins [1] and [2] for 0 to 5 Vdc (or pins [9] and [14] for 4 to 20 mA) of the 15-pin “D” connector - (see Figure 2-1). If calibration to a new flow range or different gas is being performed, it may be necessary to remove any jumpers at J1A, J1B, and J1C before beginning linearizing procedure.

Power up the Mass Flow Controller for at least 30 minutes prior to commencing the calibration procedure.

7.3.6 ZERO Adjustment

Shut off the flow of gas into the Mass Flow Controller. To ensure that no seepage or leak occurs into the meter, it is good practice to temporarily disconnect the gas source. Using the multimeter and the insulated screwdriver, adjust the ZERO potentiometer [R34] through the access window for 0 Vdc (or 4 mA respectively) at zero flow.

7.3.7 25% Flow Adjustment

Reconnect the gas source. Using the flow regulator, adjust the flow rate to 25% of full scale flow. Check the flow rate indicated against the flow calibrator. Adjust the setting for potentiometer [R33] by using the insulated screwdriver through the access window, until the output of the flow meter reads 1.25 Vdc \pm 63mV (or 8mA \pm 0.25mA).

| LINEARIZER FUNCTION | J1A (50%) | J1B (75%) | J1C (100%) |
|---------------------|-----------|-----------|------------|
| Decrease | 1 - 2 | 4 - 5 | 7 - 8 |
| Increase | 2 - 3 | 5 - 6 | 8 - 9 |

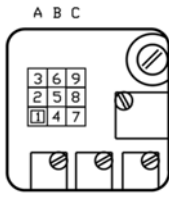


FIGURE 7-4 GC 5/6/7 CALIBRATION POTENTIOMETER AND JUMPERS

7.3.8 50% Flow Adjustment

Using the flow regulator, increase the flow rate to 50% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow meter should read 2.50 Vdc \pm 63mV (or 12mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1A] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R38] by using the insulated screwdriver through the access window, until reading is within specification.

7.3.9 75% Flow Adjustment

Using the flow regulator, increase the flow rate to 75% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow meter should read 3.75 Vdc \pm 63mV (or 16mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1B] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R39] by using the insulated screwdriver through the access window, until reading is within specification.

7.3.10 100% Flow Adjustment

Using the flow regulator, increase the flow rate to 100% of full scale flow. Check the flow rate indicated against the flow calibrator. The output of the flow meter should read 5.00 Vdc \pm 63mV (or 20mA \pm 0.25mA). If the reading is outside of that range, place the jumper at [J1C] as appropriate to increase or decrease the signal. Adjust the setting for potentiometer [R40] by using the insulated screwdriver through the access window, until reading is within specification. Repeat steps 7.2.7 to 7.2.10 at least once more.

7.3.11. VALVE ADJUSTMENT

7.3.11.1 Valve Adjustment for GC 5/6/7

Discontinue the PURGE mode (set valve for the Auto position). **DO NOT adjust** the motorized valve for GC 5/6/7. The motorized valve for these models has been pre-adjusted at the factory.

7.3.12 Full Scale Flow Adjustment

Fully open the flow regulator upstream of the GC. Increase the inlet pressure to 20 psig. Apply a +5.00 Vdc (100% full scale flow) setpoint reference. Using the calibrator check the flow rate. If necessary, adjust R33 to match the desired full scale flow rate. [In control mode, turning R33 clockwise will decrease the flow. Conversely, turning R33 counterclockwise will increase the flow through the GC.]

7.3.13 25% Flow Adjustment

Change the setpoint to 1.25 Vdc to control at 25% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R33], until the flow output is correct.

7.3.14 50% Flow Adjustment

Change the setpoint to 2.50 Vdc to control at 50% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R38], until the flow output is correct.

7.3.15 75% Flow Adjustment

Change the setpoint to 3.75 Vdc to control at 75% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R39], until the flow output is correct.

7.3.16 100% Flow Adjustment

Change the setpoint to 5.00 Vdc to control at 100% of full scale flow. Check the flow rate indicated against the flow calibrator. If the flow rate is not within $\pm 0.75\%$ of full scale, re-adjust the setting for potentiometer [R40], until the flow output is correct.

Repeat steps 7.3.13 to 7.3.16 at least once more.

7.4 LCD Display Scaling

It may be desirable to re-scale the output reading on the LCD readout supplied with certain model GC transducers. Re-calibration for a new flow range or different engineering units are two examples of when this may be necessary.

7.4.1 Access LCD Display Circuit

Carefully remove the LCD from the GC or panel mounted surface. Remove the aluminum housing on the side of the connection cable. Slide the LCD assembly out of the aluminum housing.

7.4.2 Adjust Scaling

Using a digital multimeter connected to either the 0 to 5 VDC or 4 to 20 mA signal at the 15-pin “D” connector, set the flow rate on the GC to full scale flow (5 VDC or 20mA). Maintain full scale flow, and adjust the potentiometer [R3] on the LCD printed circuit board to desired full scale flow reading.

7.4.3 Change Decimal Point

To change the decimal place on the LCD display readout, simply move the jumper to the appropriate location on the 8-pin header block. The numbers are printed to the side of the connections. Do not attempt to place more than one jumper for decimal setting.

| JUMPER POSITION | MAXIMUM SCALABLE DISPLAY READING |
|-----------------|----------------------------------|
| “0” | 1999 |
| “3” | 199.9 |
| “2” | 19.99 |
| “1” | 1.999 |

8. TROUBLESHOOTING

8.1 Common Conditions

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

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

- ✓ Are all cables connected correctly?
- ✓ Are there any leaks in the installation?
- ✓ Is the power supply correctly selected according to requirements?
When several meters are used a power supply with appropriate current rating should be selected.
- ✓ Were the connector pinouts matched properly? When interchanging with other manufacturers' equipment, cables and connectors must be carefully wired for correct pin configurations.
- ✓ Is the pressure differential across the instrument sufficient?

8.2 General Troubleshooting Guide

| INDICATION | LIKELY REASON | REMEDY |
|--|---|---|
| lack of reading or output | power supply off | check connection of power supply |
| | fuse blown | disconnect transducer from power supply; remove the shorting condition or check polarities; fuse resets automatically |
| | filter screen obstructed at inlet | flush clean or disassemble to remove impediments or replace |
| | occluded sensor tube | flush clean or disassemble to remove impediments or return to factory for replacement |
| | pc board defect | return to factory for replacement |
| | GC 1/3/4 valve adjustment wrong | re-adjust valve (section 8.3.3) |
| flow reading does not coincide with the setpoint | inadequate gas pressure | apply appropriate gas pressure |
| | filter screen obstructed at inlet | flush clean or disassemble to remove impediments or replace |
| | ground loop | signal and power supply commons are different |
| no response to setpoint | inadequate gas pressure | apply appropriate gas pressure |
| | cable or connector malfunction | check cables and all connections or replace |
| | setpoint is too low (<2% of full scale) | re adjust setpoint or disable 2% cutoff feature (section 2.2) |
| | GC 1/3/4 valve adjustment wrong | re-adjust valve (section 8.3.3 below) |
| unstable or no zero reading | gas leak | locate and correct |
| | pc board defective | return to factory for replacement |
| | GC 1/3/4 valve adjustment wrong | re-adjust valve (see section 8.3.2 below) |

| INDICATION | LIKELY REASON | REMEDY |
|---|--|---|
| full scale output at “no flow” condition or with valve closed | defective sensor | return to factory for replacement |
| | gas leak | locate and repair |
| | GC 1/3/4 valve adjustment wrong | re-adjust valve (section 8.3.1 below) |
| calibration off | gas metered is not the same as what meter was calibrated for | use matched calibration |
| | composition of gas changed | see K factor tables in APPENDIX 2 |
| | gas leak | locate and correct |
| | pc board defective | return to factory for replacement |
| | RFE dirty | flush clean or disassemble to remove impediments |
| | occluded sensor tube | flush clean or disassemble to remove impediments or return to factory for replacement |
| | filter screen obstructed at inlet | flush clean or disassemble to remove impediments or replace |
| | transducer is not mounted properly | check for any tilt or change in the mounting of the transducer; generally, units are calibrated for horizontal installation (relative to the sensor tube) |
| GC valve does not work in open position | GC 1/3/4 incorrect valve adjustment | re-adjust valve (section 8.3.3) |
| | pc board defect | return to factory for replacement |
| | cable or connectors malfunction | check cable and connectors or replace |
| | differential pressure too high | decrease pressure to correct level |
| | insufficient inlet pressure | adjust appropriately |

| INDICATION | LIKELY REASON | REMEDY |
|---|-------------------------------------|--|
| GC valve does not work in closed position | GC 1/3/4 incorrect valve adjustment | re-adjust valve (section 8.3.1) |
| | pc board defect | return to factory for replacement |
| | cable or connectors malfunction | check cable and connectors or replace |
| | orifice obstructed | disassemble to remove impediments or return to factory |

8.3 GC 1/3/4 Valve Related Troubleshooting

| 8.3.1 INDICATION: | LIKELY REASON: | REMEDY: |
|---|---|--|
| With “no flow conditions” (gas pipes are not connected to the GC) and valve closed (pins 3 and 12 are connected together) LCD reading is zero, but when 20 PSIG inlet pressure is applied the LCD reads more than 0.5% of full scale. | Valve is out of adjustment and leaking. | <ol style="list-style-type: none"> 1. Adjust control set point to zero. Set Valve mode to “CLOSE” position (connect pins 3 and 12 on the 15 pins D-connector together). This step is very important! 2. Apply 20 PSIG inlet pressure. 3. See operating manual page 17 (Figure 6-1). Unscrew hex nut cover on the top of the solenoid valve. 4. Using a screwdriver readjust adjustment screw on the top of the valve to CW (clock wise) direction until zero reading on the display. Be very careful during adjustment: make only 15 degree turn each time and wait one minute due to the sensor’s response time. If reading is still high make another 15 degree turn. Do not over adjust valve. If you made more than 5 complete (360 degree) turns and leakage still exists stop adjustment. In this case unit has to be returned to the factory for servicing. 5. This is not a shut off valve. It is normal to observe up to 0.5 % of F.S. leakage. 6. Adjust hex nut cover on the top of the solenoid valve. 7. Disable Valve “Close” mode, apply 100% control set point and check if reading can reach 100% reading. |

| 8.3.2 INDICATION: | LIKELY REASON: | REMEDY: |
|--|---|--|
| <p>Differential pressure across the GC controller is within specification but LCD reading and actual flow are not stable (oscillate 1-4 times per second).</p> | <p>Valve compression spring is over adjusted and PID control cannot handle stable flow.</p> | <ol style="list-style-type: none"> 1. Make sure differential pressure across the GC is within specification. 2. Install control set point to 100% F.S. This should remedy the oscillation conditions. 3. See operating manual page 17 (Figure 6-1). Unscrew hex nut cover on the top of the solenoid valve. 4. Using screwdriver readjust adjustment screw on the top of the valve to CCW (counter clock wise) direction until reading on the display will be stable. Be very careful during adjustment: make only 15 degree turn each time and wait about 15 seconds due to sensor's response time. If reading oscillates make another 15 degree turn. Do not over adjust valve. If you noticed that flow rate is constant and more than 105% of full scale, it means you over adjusted valve and it has leakage. In this case make adjustment to CW (clock wise) in order to fix this problem until reading will go back to 100% full scale. 5. Adjust zero set point (or valve close command), wait about 3 minutes and check if valve is able to close. 6. This is not a shut off valve. It is normal to observe up to 0.5 % of F.S. leakage. 7. Install hex nut cover on the top of the solenoid valve. |

| 8.3.3 INDICATION: | LIKELY REASON: | REMEDY: |
|--|--|---|
| <p>Differential pressure across the GC controller is within specification but flow rate reading is more than 1% F.S. below set point value when 100% set point is applied.</p> | <p>Valve compression spring is over adjusted and controller does not have enough power to open valve and reach 100% F.S. flow.</p> | <ol style="list-style-type: none"> 1. Make sure differential pressure across the GC is within specification. 2. Adjust control set point to 100% F.S. This should remedy initial fault conditions (flow reading is less than set point value and difference is more than 1% F.S.). 3. See operating manual page 17 (Figure 6-1). Unscrew hex nut cover on the top of the solenoid valve. 4. Using screwdriver readjust adjustment screw on the top of the valve to CCW (counter clock wise) direction until reading on the display will be equal to the set point value. Be very careful during adjustment: make only 15 degree turn each time and wait about 15 seconds due to sensors responds time. If reading still below 100% make another 15 degree turn. Do not over adjust valve. If you noticed that flow rate is constant and more than 105% of full scale, it means you over adjusted valve and it has leakage. In this case make adjustment to CW (clock wise) in order to fix this problem until reading will go back to 100% full scale. 5. Install zero set point (or valve close command), wait about 3 minutes and check if valve is able to close. 6. This is not a shut off valve. It is normal to observe up to 0.5 % of F.S. leakage. 7. Install hex nut cover on the top of the solenoid valve. |



NOTE: One common reason for proportional solenoid valve to be out of adjustment: keeping control set point even very small (2% for example) while disconnecting inlet pressure. In this case the valve becomes overheated within 15 minutes and mechanical characteristics of the seat insert and compression spring are compromised. Avoid this mode of operation in the future.

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

8.4 Technical Assistance

Dakota® Instruments will provide technical assistance over the phone to qualified repair personnel. Please call our Technical Assistance at 845-770-3200. Please have your Serial Number and Model Number ready when you call.

9. CALIBRATION CONVERSIONS FROM REFERENCE GASES

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

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

where d = gas density (gram/liter)

C_p = coefficient of specific heat (cal/gram)

Note: in the above relationship that d and C_p are chosen at the same conditions (temperature, pressure).

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

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

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

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

K_a = K factor of an actual gas

K_r = K factor of a reference gas

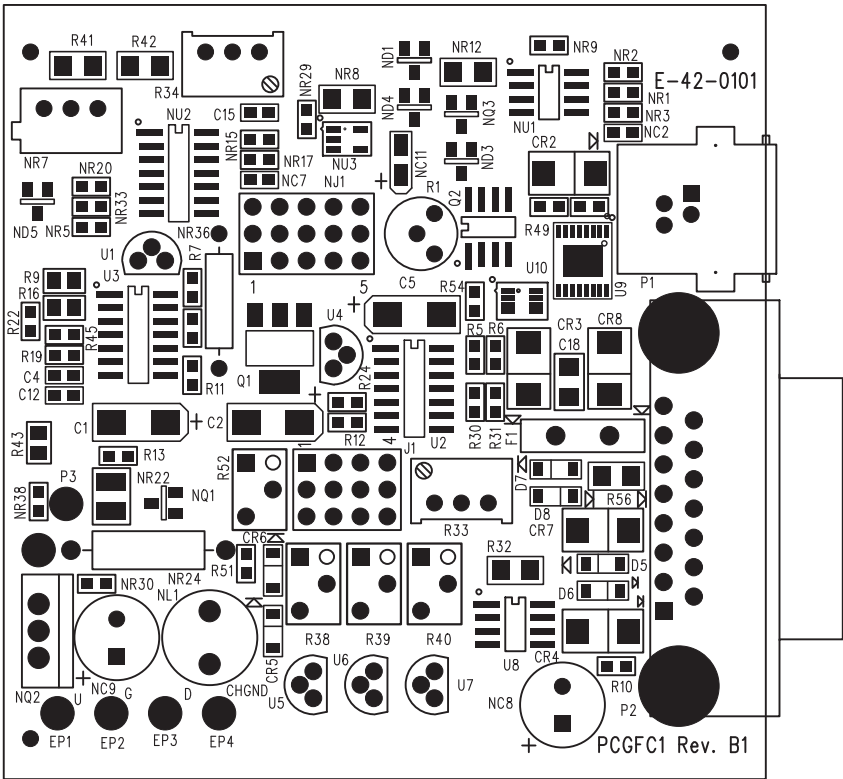
For example, if we want to know the flow rate of oxygen and wish to calibrate with nitrogen at 1000 SCCM, the flow rate of oxygen is:

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

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

APPENDIX 1

COMPONENTS DIAGRAM



GC 1/3/4 CONTROLLER PC BOARD (TOP SIDE)

APPENDIX 2

GAS FACTOR TABLE ("K" FACTORS)

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

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

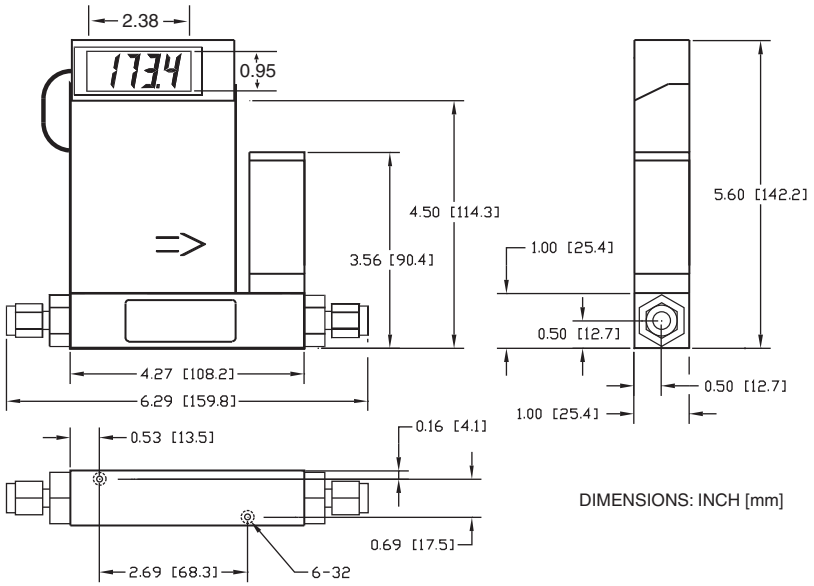
| ACTUAL GAS | K FACTOR Relative to N ₂ | Cp [Cal/g] | Density [g/l] |
|---|--|---------------|------------------|
| Deuterium D ₂ | 1.00 | 1.722 | 1.799 |
| Diborane B ₂ H ₆ | .4357 | .508 | 1.235 |
| Dibromodifluoromethane CBr ₂ F ₂ | .1947 | .15 | 9.362 |
| Dichlorodifluoromethane (Freon-12) CCl ₂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

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

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

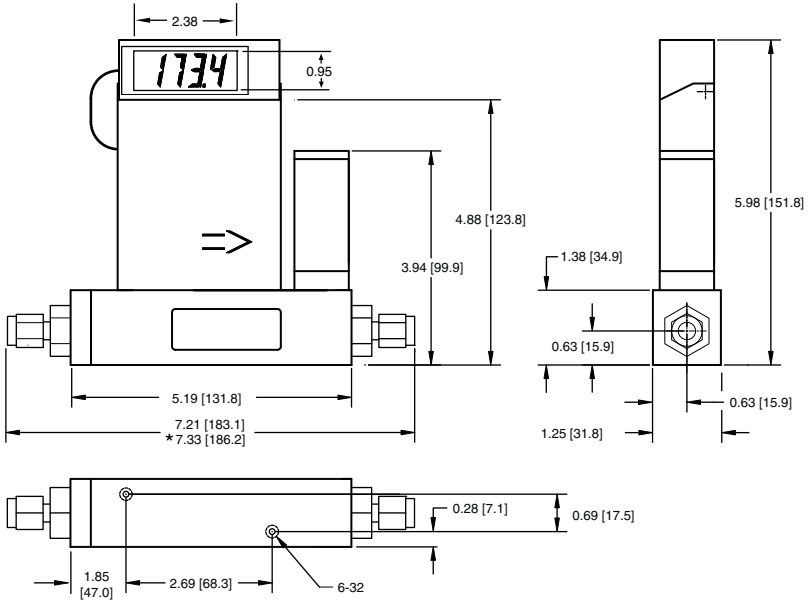
APPENDIX 3

DIMENSIONAL DRAWINGS



GC 1 MASS FLOW CONTROLLER

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

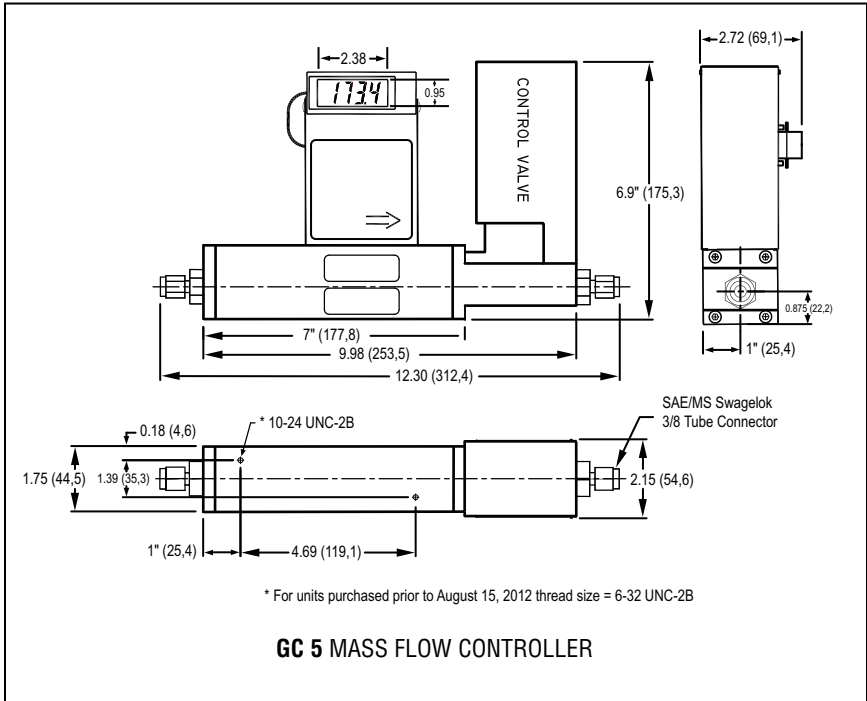


* FOR HIGH FLOW MASS FLOW CONTROLLER ONLY

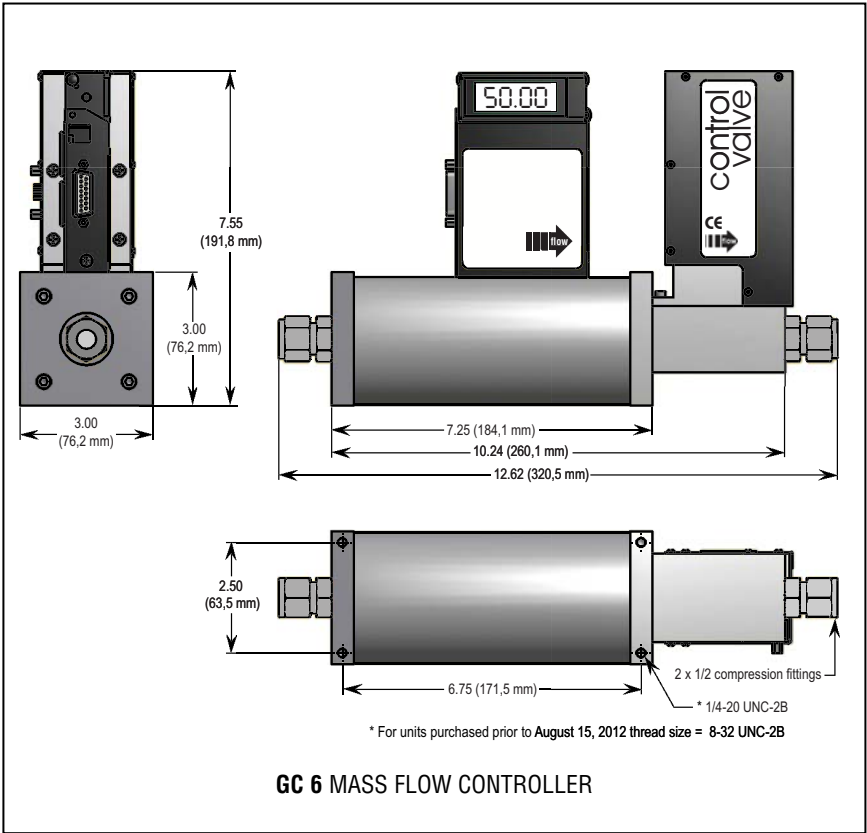
DIMENSIONS: INCH [mm]

GC 3/4 MASS FLOW CONTROLLER

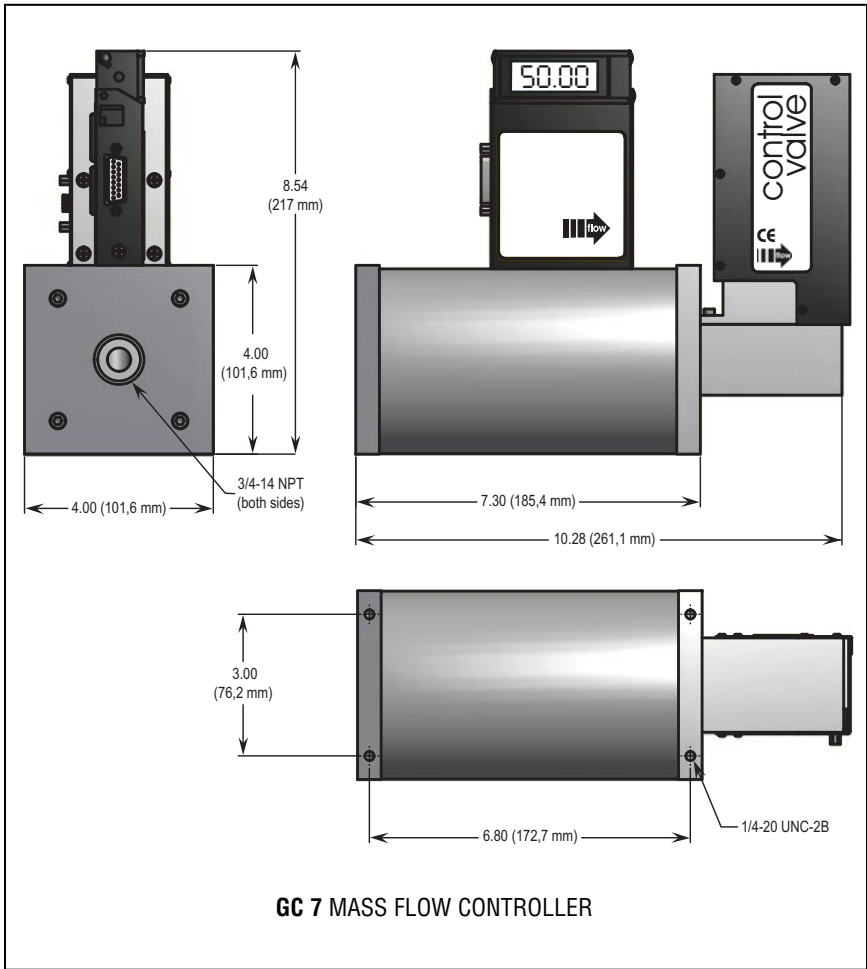
NOTE: Dakota® reserves the right to change designs and dimensions at its sole discretion at any time without notice. For certified dimensions please contact Dakota®.



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APPENDIX 4

WARRANTY

Dakota® Mass Flow Systems are warranted against parts and workmanship for a period of one year from the date of purchase. Calibrations are warranted for up to six months after date of purchase, provided calibration seals have not been tampered with. It is assumed that equipment selected by the customer is constructed of materials compatible with gases used. Proper selection is the responsibility of the customer. It is understood that gases under pressure present inherent hazards to the user and to equipment, and it is deemed the responsibility of the customer that only operators with basic knowledge of the equipment and its limitations are permitted to control and operate the equipment covered by this warranty. Anything to the contrary will automatically void the liability of Dakota® and the provisions of this warranty. Defective products will be repaired or replaced solely at the discretion of Dakota® at no charge. Shipping charges are borne by the customer. This warranty is void if the equipment is damaged by accident or misuse, or has been repaired or modified by anyone other than Dakota® or factory authorized service facility. This warranty defines the obligation of Dakota® and no other warranties expressed or implied are recognized.

NOTE: Follow Return Procedures In Section 1.3.

CAUTION:

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

CAUTION:

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

TRADEMARKS

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