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111155-P1
Rev K, 10/96
Instruction Manual

MKS Mass-Flo® Controller
Types 1159B/2159B, 1160B/2160B, 1162B/2162B, 1163B/2163B

Six Shattuck Road
Andover, MA 01810-2449
(800) 227-8766 or (508) 975-2350

Fax: (508) 975-0093
E-mail:mks@mksinst.com
Web site: http://www.mksinst.com

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WARRANTY

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1162B/2162B Equipment

MKS Instruments, Inc. (**MKS**) warrants that the equipment described above (the "equipment") manufactured by **MKS** shall be free from defects in materials and workmanship for a period of one year from date of shipment and will for a period of two years from the date of shipment, correctly perform all date-related operations, including without limitation accepting data entry, sequencing, sorting, comparing, and reporting, regardless of the date the operation is performed or the date involved in the operation, provided that, if the equipment exchanges data or is otherwise used with equipment, software, or other products of others, such products of others themselves correctly perform all date-related operations and store and transmit dates and date-related data in a format compatible with **MKS** equipment. THIS WARRANTY IS **MKS'** SOLE WARRANTY CONCERNING DATE-RELATED OPERATIONS.

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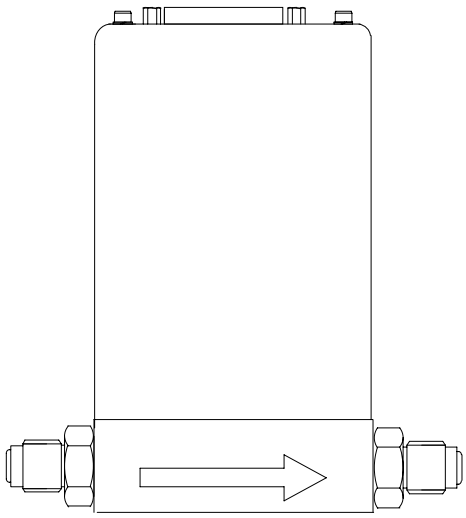
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MKS Mass-Flo® Controller Types 1159B/2159B, 1160B/2160B, 1162B/2162B, 1163B/2163B



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Safety Procedures and Precautions

Warning 

Before performing mass flow controller valve adjustments, you MUST purge your process equipment and the MFC with an inert gas, such as argon or nitrogen, and isolate the MFC from toxic and hazardous gases. Use an inert surrogate gas while adjusting the valve preload as a safeguard against inadvertent exposure to any toxic or hazardous gas. A release of hazardous or toxic gas could cause serious injury. If necessary, remove the MFC from the process equipment to adjust the valve.

Questions concerning the safe handling of toxic or hazardous gases may be answered by consulting your corporate policy, a government agency such as OSHA or NIOSH, or experts familiar with your process gas.

MKS assumes no liability for safe handling of toxic or hazardous gases.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an MKS Calibration and Service Center for service and repair to ensure that all safety features are maintained.

SERVICE BY QUALIFIED PERSONNEL ONLY

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel only.

USE CAUTION WHEN OPERATING WITH HAZARDOUS MATERIALS

If hazardous materials are used, users must take responsibility to observe the proper safety precautions, completely purge the instrument when necessary, and ensure that the material used is compatible with sealing materials.

PURGE THE INSTRUMENT

After installing the unit, or before its removal from a system, be sure to purge the unit completely with a clean dry gas to eliminate all traces of the previously used flow material.

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DO NOT OPERATE IN EXPLOSIVE ATMOSPHERES

To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

USE PROPER FITTINGS AND TIGHTENING PROCEDURES

All instrument fittings must be consistent with instrument specifications, and compatible with the intended use of the instrument. Assemble and tighten fittings according to manufacturer's directions.

CHECK FOR LEAK-TIGHT FITTINGS

Before proceeding to instrument setup, carefully check all plumbing connections to the instrument to ensure leak-tight installation.

OPERATE AT SAFE INLET PRESSURES

This unit should never be operated at pressures higher than the rated maximum pressure (refer to the product specifications for the maximum allowable pressure).

INSTALL A SUITABLE BURST DISC

When operating from a pressurized gas source, a suitable burst disc should be installed in the vacuum system to prevent system explosion should the system pressure rise.

KEEP THE UNIT FREE OF CONTAMINANTS

Do not allow contaminants of any kind to enter the unit before or during use. Contamination such as dust, dirt, lint, glass chips, and metal chips may permanently damage the unit.

ALLOW THE UNIT TO WARM UP

If the unit is used to control dangerous gases, they should not be applied before the unit has completely warmed up. A positive shutoff valve can be employed to ensure that no erroneous flow can occur during warm up.

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Definitions of WARNING, CAUTION, and NOTE messages used throughout the manual.

Warning 

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, condition, or the like, which, if not correctly performed or adhered to, could result in injury to personnel.

Caution 

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of all or part of the product.

Note 

The NOTE sign denotes important information. It calls attention to a procedure, practice, condition, or the like, which is essential to highlight.

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Chapter One: General Information

Introduction

The MKS Mass-Flo® Controllers covered in this manual include:

MFCs with normally closed valves

- Type 1159B - MFC with Type "D" connector/valve normally *closed*
- Type 1160B - MFC with Recessed P.C. Edge Card connector/valve normally *closed*
- Type 2159B - Type 1159B with a NUPRO® BN positive shut-off valve downstream
- Type 2160B - Type 1160B with a NUPRO BN positive shut-off valve downstream

MFCs with normally opened valves

- Type 1162B - MFC with Type "D" connector/valve normally *open*
- Type 1163B - MFC with Recessed P.C. Edge Card connector/valve normally *open*
- Type 2162B - Type 1162B with a NUPRO BN positive shut-off valve downstream
- Type 2163B - Type 1163B with a NUPRO BN positive shut-off valve downstream

These MKS Mass-Flo Controllers are elastomer sealed thermal flow controllers and will be collectively referred to as the 1100 Series in this manual.

These mass flow controllers (MFCs) accurately measure and control the mass flow rate of gases. Based upon an MKS patented measurement technique (U.S. Patent Nos. 4464932, 4679585; Foreign Patents - Patents Pending), each instrument is a laminar flow device whose precise indication of mass flow is achieved through the use of a range controlling changeable bypass and a parallel sensor tube. All controllers in the 1100 Series have a three-inch footprint and feature the ability to accept TTL level commands to remotely open and close the control valve. The controllers include a metal cover and RF bypass capacitors, and incorporate a design that virtually eliminates RFI and EMI interference.

The MFC 1100 Series instruments may be powered, set point commanded, and their output displayed by complimentary MKS equipment (Types 147/647, 160, 246, 247), or by customer supplied devices. (Additionally, the 167 unit can be used as a readout and set point generator, but it does not supply power; the 660 unit can be used as a power supply and readout, though it cannot send a set point to the flow controller.) Refer to the corresponding manuals for requirements and instructions.

The MKS MFC instruments are modular in concept and are available in a variety of types and configurations to suit specific needs.

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How This Manual is Organized

This manual is designed to provide instructions on how to set up and install an 1100 Series MFC unit.

Before installing your Type 1100 Series unit in a system and/or operating it, carefully read and familiarize yourself with all precautionary notes in the *Safety Messages and Procedures* section at the front of this manual. In addition, observe and obey all WARNING and CAUTION notes provided throughout the manual.

Chapter One, *General Information*, (this chapter) introduces the product and describes the organization of the manual.

Chapter Two, *Installation*, explains the environmental requirements and practical considerations to take into account when selecting the proper setting for the mass flow controller. Once the mass flow controller is placed in its appropriate environment, follow the instructions in the *Set Up* section on mechanical and electrical connections.

Chapter Three, *Overview*, lists the mechanical dimensions and electrical pinouts of the instruments. It also includes information about the NUPRO valve, interface cables, and the control valve.

Chapter Four, *Operation,* explains how to start up and operate the mass flow controller. Once the mass flow controller is in operation, review the next two sections to learn how to override the control valve and to understand how the controller adjusts flow rate to set point.

Chapter Five, *Theory of Operation,* describes in a general way how the 1100 Series Mass Flow Controller operates in a gas flow system. This chapter also provides information on how to use a Gas Correction Factor when interpreting the output signal for a gas other than Nitrogen.

Chapter Six, *Maintenance,* provides instructions on how to detect leakage in the unit and how to adjust the control valve.

Chapter Seven, *Troubleshooting,* contains information in the event that the MFC should malfunction.

Appendix A, *Product Specifications*, lists the specifications of the instrument.

Appendix B, *Gas Correction Factors,* provides a table listing the gas correction factors for the most commonly used gases.

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Customer Support

Standard maintenance and repair services are available at all of our regional MKS Calibration and Service Centers, listed on the back cover. In addition, MKS accepts the instruments of other manufacturers for recalibration using the Primary and Transfer Standard calibration equipment located at all of our regional service centers. Should any difficulties arise in the use of your Type 1100 Series instrument, or to obtain information about companion products MKS offers, contact any authorized MKS Calibration and Service Center. If it is necessary to return the instrument to MKS, please obtain an ERA Number (Equipment Return Authorization Number) from the MKS Calibration and Service Center before shipping. The ERA Number expedites handling and ensures proper servicing of your instrument.

Please refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

Warning  **All returns to MKS Instruments must be free of harmful, corrosive, radioactive, or toxic materials.**

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Chapter Two: Installation

How To Unpack the 1100 Series Unit

MKS has carefully packed the Type 1100 Series unit so that it will reach you in perfect operating order. Upon receiving the unit, however, you should check for defects, cracks, broken connectors, etc., to be certain that damage has not occurred during shipment.

Note Do *not* discard any packing materials until you have completed your inspection and are sure the unit arrived safely.

If you find any damage, notify your carrier and MKS immediately. If it is necessary to return the unit to MKS, obtain an ERA Number (Equipment Return Authorization Number) from the MKS Service Center before shipping. Please refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

Unpacking Checklist

Standard Equipment:

- Type 1100 Series MFC unit (Refer to *Introduction*, page 5, for a description of the units included in this series.)

Optional Equipment:

- Power Supply/Readout device
- Cabling to connect the flow controller to the readout device (refer to *Interface Connectors and Cables*, page 20)

CB259-5-10	Connects the 1159/2159 and 1162/2162 units to Type 246 and247 readouts
CB147-1-10	Connects the 1159/2159 and 1162/2162 units to Type 167 and 647 readouts
CB259-10-10	Connects the 1160/2160 and 1163/2163 units to Type 246 and 247 readouts
CB147-7-10	Connects the 1160/2160 and 1163/2163 units to Type 167 and 647 readouts

Note In order for the 1100 Series MFC to comply with CE Mark specifications you must use a metal braided, shielded cable.

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Environmental Requirements

Follow the requirements listed below when installing and using an 1100 Series MFC:

1. The normal operating temperature should remain between 15° and 40° C (59° and 104° F).
2. The maximum gas inlet pressure is 150 psig.
3. The power input required is ±15 VDC (±5%) @ 300 mA.
   A. The maximum voltage/current at startup is ±15 VDC (±5%) @ 300 mA.
   B. The typical steady state voltage/current should be ±15 VDC @ 180 mA.
4. The warm-up time is 30 minutes (for warm-up time on 10 sccm units, consult the factory).
5. For optimal performance, the instrument should remain powered at all times.

For additional MFC requirements refer to *Appendix A, Product Specifications,* page 39.

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Interface Cables

As of January 1, 1996, all products shipped to the European Community must comply with the EMC Directive 89/336/EEC, which covers radio frequency emissions and immunity tests. MKS products that meet these requirements are identified by application of the CE Mark.

The 1100 Series instruments meet CE Mark requirements, per EMC Directive 89/336/EEC. To ensure compliance when installed, an overall metal braided shielded cable, grounded at both ends, is required during use.

Generic Shielded Cable Description

MKS offers a full line of cables for all MKS equipment. Should you choose to manufacture your own cables, follow the guidelines listed below:

1. The cable must have a *braided* shield, covering all wires. Neither aluminum foil nor spiral shielding will be as effective; using either may nullify regulatory compliance.

2. The connectors must have a metal case which has direct contact to the cable's shield on the whole circumference of the cable. The inductance of a flying lead or wire from the shield to the connector will seriously degrade the shield's effectiveness. The shield should be grounded to the connector before its internal wires exit.

3. With very few exceptions, the connector(s) must make good contact to the device's case (ground). "Good contact" is about 0.01 ohms; and the ground should surround all wires. Contact to ground at just one point may not suffice.

4. For shielded cables with flying leads at one or both ends; it is important at each such end, to ground the shield *before* the wires exit. Make this ground with absolute minimum length. Refer to Figures 1 and 2, page 12. (A ¼ inch piece of #22 wire may be undesirably long since it has approximately 5 nH of inductance, equivalent to 31 ohms at 1000 MHz). After picking up the braid's ground, keep wires and braid flat against the case. With very few exceptions, grounded metal covers are not required over terminal strips. If one is required, it will be stated in the Declaration of Conformity or in this instruction manual.

5. In selecting the appropriate type and wire size for cables, consider:

   A. The voltage ratings;

   B. The cumulative I^2R heating of all the conductors (keep them safely cool);

   C. The IR drop of the conductors, so that adequate power or signal voltage gets to the device;

   D. The capacitance and inductance of cables which are handling fast signals, (such as data lines or stepper motor drive cables); and

   E. That some cables may need internal shielding from specific wires to others; please see the instruction manual for details regarding this matter.

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Example 1: Preferred Method To Connect Cable

(shown on a transducer)

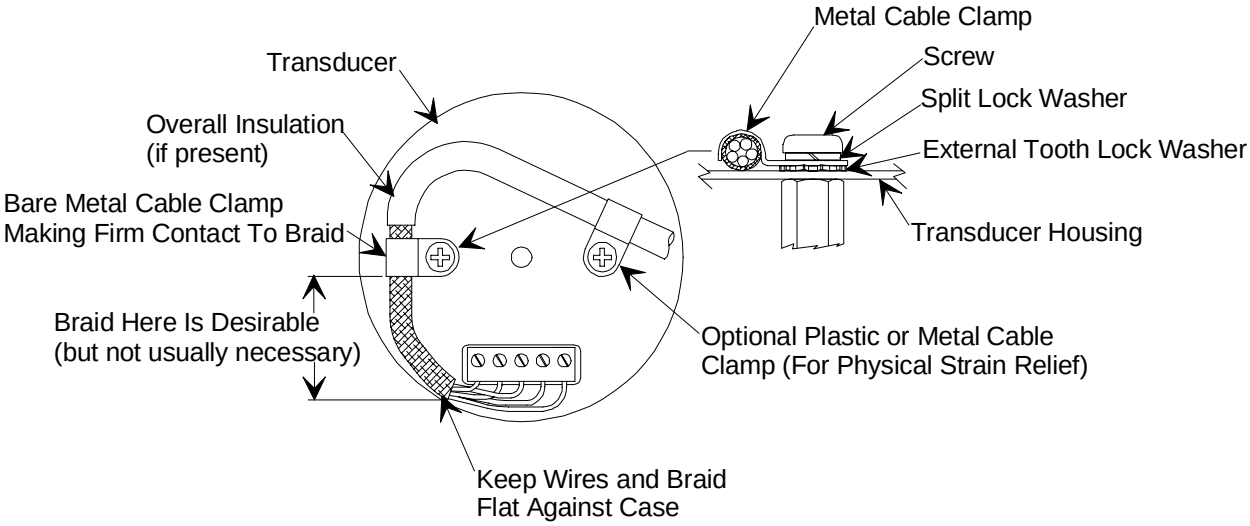


Figure 1: Preferred Method To Connect a Shielded Cable

Example 2: Alternate Method To Connect Cable

(shown on a transducer)

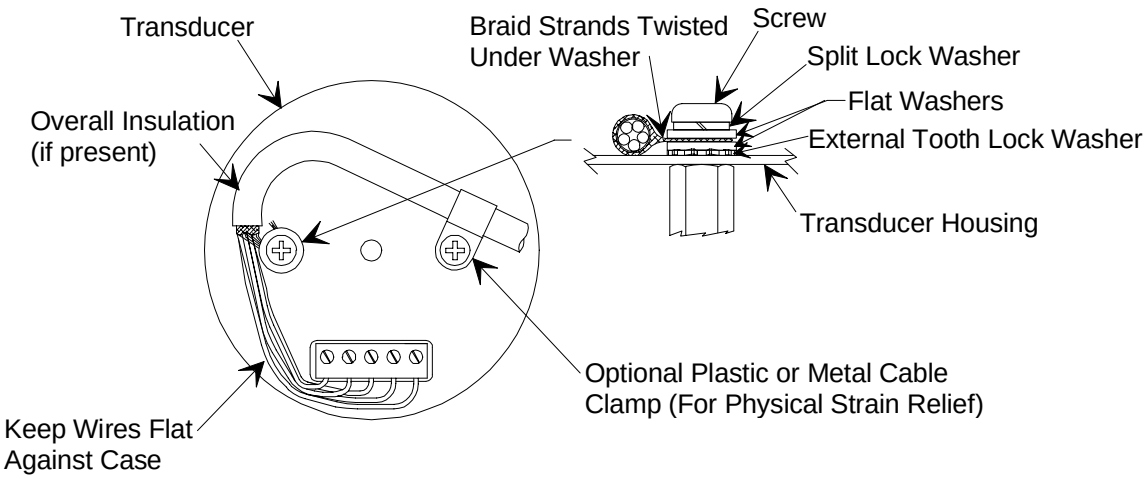


Figure 2: Alternate Method To Connect a Shielded Cable
(Use When Cable Clamp is Not Available)

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Setup

Follow the guidelines listed below when setting up an 1100 Series MFC:

1. Place the 1100 Series MFC where it will be connected to a gas supply and process chamber.

2. Mount the MFC into position.

   Mounting of flow components in other than the position in which they are calibrated (typically horizontal) will cause a small zero shift. The zero offset can be removed according to the instructions in *Warm Up and Start Up*, page 25.

3. Install the MFC in the gas stream such that the flow will be in the direction of the arrow on the side of the controller's base.

4. Be sure to allow clearance for the cable connector and tubing:

   Straight Shielded connectors require approximately 3” (76.2 mm) height.
   Right Angle connectors require approximately 2” (50.8 mm) height.

5. Be sure to allow access to the zero potentiometer.

   Refer to Figure 6, page 18, for the location of the zero potentiometer.

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Mounting an MFC

Tapped holes are provided in the base of each unit (Types 1159, 1160, 1162, and 1163) for mounting. Refer to Figure 3 for the location of the mounting holes.

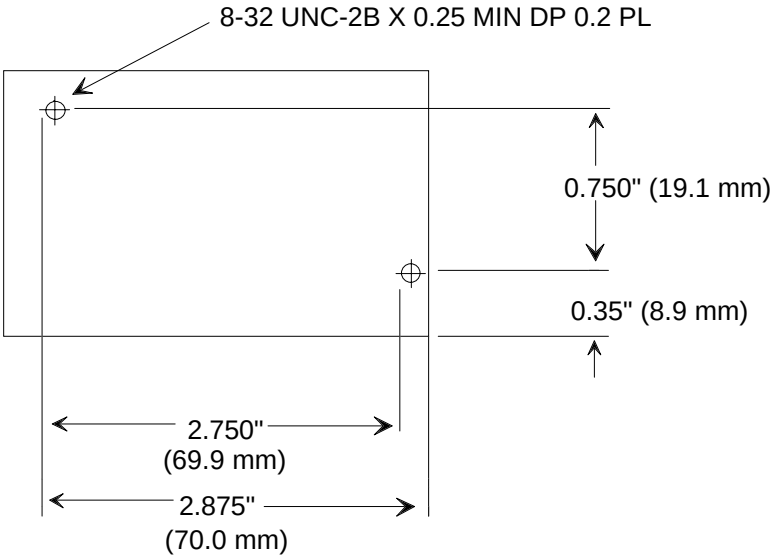


Figure 3: Location of the Mounting Holes

Mounting an MFC Configured with a NUPRO Valve

MFC Types 2159, 2160, 2162, and 2163 include a positive shut-off NUPRO 4BN Valve in their configurations. Each assembly is attached to an aluminum plate and is intended to be mounted horizontally. Vertical mounting is acceptable but a correctable zero offset of the MFC unit will result. The air operator port is a 1/8" NPT (National Pipe Thread) internal fitting. The aluminum plate can be mounted via four mounting holes.

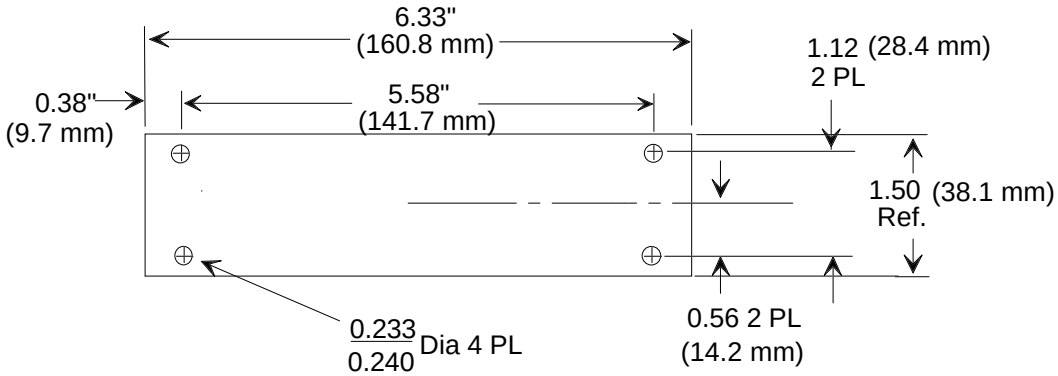


Figure 4: Aluminum Mounting Plate Holes

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Gas Line Connections

The 1100 Series is equipped with ¼ inch Swagelok® fittings. Cajon® 4-VCR® (male) compatible, and Cajon® 4-VCO® (male) compatible fittings are available as options. Refer to the manufacturers' specifications for installation information on VCR and VCO compatible fittings.

How To Install a Swagelok Fitting

To connect the ¼ inch Swagelok fittings, follow the steps below.

1. Be sure the tubing is clean and free of axial scratches.
2. Insert the tubing through the compression nut and ferrules all the way to the shoulder.

   Figure 5 shows the components in a standard compression fitting.

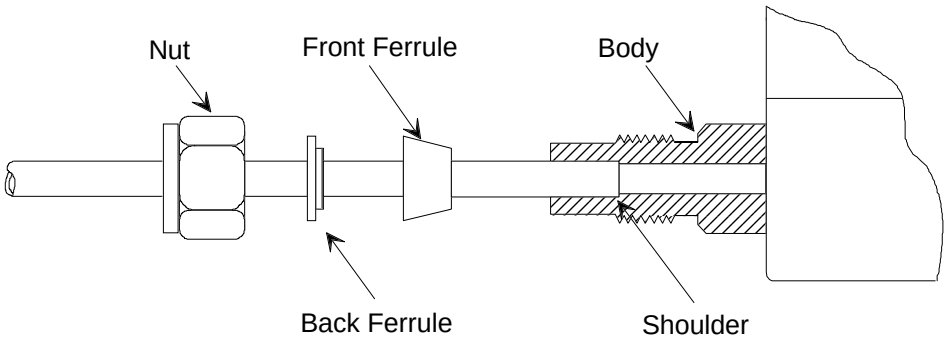


Figure 5: Standard Compression Fitting

Caution

Tighten the nut *only* 1¼ turns past finger-tight. When remaking, tighten the nut only 1/6 turn. Overtightening damages the tubing and fitting, and destroys a normally leak-tight fitting.

3. Connect the fitting on the other side of the MFC (one fitting is for gas input and the other fitting is for gas output).

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Chapter Three: Overview

General

An MFC 1100 Series instrument measures the mass flow rate of a gas and controls the flow rate according to a given set point. The control range can be from 1.0 to 100% of Full Scale (F.S.) with an accuracy rate of ± 1.0% of F.S. The F.S. Range (nitrogen equivalent) is from 10 to 30,000 sccm.

The standard MFC wetted materials are 316L SST and nickel with Viton® seals. Optional seals include Buna-N, Neoprene,® and Kalrez®. Standard fittings are ¼ " Swagelok. Optional fittings available are Cajon 4-VCR (male) compatible and Cajon 4-VCO (male) compatible.

The MFC 1100 Series instruments offer a choice of either normally *closed* or normally *open* versions, as well as a choice of either a Type "D" or a recessed P. C. card edge connection. The MFC 1100 Series instruments also offer MFC types that are configured with a NUPRO valve (refer to the next section for information about the NUPRO valve configurations). The following types are available:

- Type 1159 - An MFC with Type "D" connector/valve normally *closed*
- Type 1160 - An MFC with Recessed P. C. Edge Card connector/valve normally *closed*
- Type 1162 - An MFC with Type "D" connector/valve normally *open*
- Type 1163 - An MFC with Recessed P. C. Edge Card connector/valve normally *open*

Refer to Figure 6, page 18, for the dimensions of an MFC.

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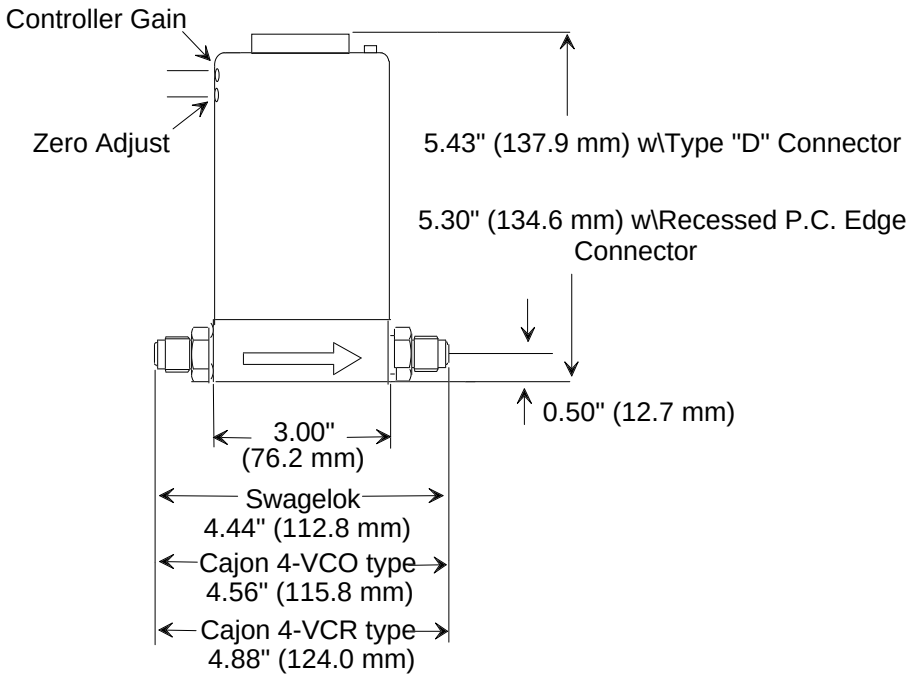


Figure 6: Dimensions

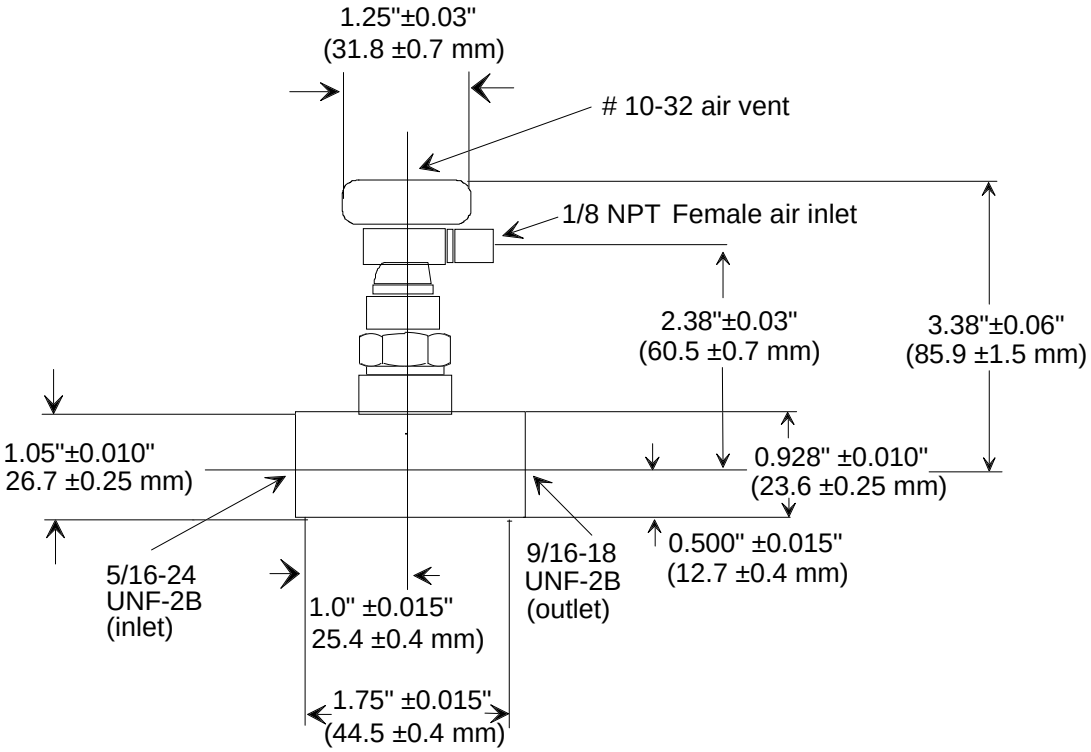


Figure 7: NUPRO Valve Dimensions

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NUPRO Positive Shut-off Valve

A NUPRO 4BN series pneumatically operated valve may be used in series with an MFC when a no-leakage condition is required. Since the spring force is very low in an MKS Mass-Flo controller, leak tightness cannot be guaranteed using this valve alone. The NUPRO valve is an all 316 SST bellows seal valve with a Kel-F® valve seat. It has a maximum leak rate across the ports of $3x10^{-8}$ sccm He and a leak rate of less than $1x10^{-9}$ sccm He to the outside. The following configurations are available:

- Type 2159 - An MFC Type 1159 configured with a NUPRO BN positive shut-off valve downstream
- Type 2160 - An MFC Type 1160 configured with a NUPRO BN positive shut-off valve downstream
- Type 2162 - An MFC Type 1162 configured with a NUPRO BN positive shut-off valve downstream
- Type 2163 - An MFC Type 1163 configured with a NUPRO BN positive shut-off valve downstream

Refer to Figure 7, page 18, for the dimensions of a NUPRO valve.

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Interface Connectors and Cables

MKS can supply interface cables, or you can make cables according to the following specifications:

A. Shielded cable assemblies, in a nominal 10’ (3 m) length, with Type “D” connector on one end and terminated in *flying leads* (pigtail) fashion on the other end.

B. Ribbon cable assemblies in a nominal 10’ (3 m) length, with properly keyed P. C. Edge Card connector on one end and non-terminated on the other end.

Note 

Units with Edge Card connectors or units that use flying leads are not CE Mark compliant.

Note 

1. Metal braided, shielded cables are required to meet CE Mark specifications.
2. To order metal braided, shielded cables, add an “S” after the cable type designation. For example, to order a standard cable to connect the 1159 unit to a 246 readout, use part number CB259-5-10; for a metal braided, shielded cable, use part number CB259S-5-10.

Note 

1. Use shielded cable assemblies, especially if the environment contains high EMI/RFI noise.
2. Be sure to provide adequate clearance for Type “D” cable assemblies:
   - Straight Shielded connectors require approximately 3” (76.2 mm) height.
   - Right Angle connectors require approximately 2” (50.8 mm) height.

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Electrical Connections

To use an MFC 1100 Series instrument with any equipment other than complimenting MKS modules, consult the manufacturers' specifications for connection, and for proper electrical and power characteristics. Refer to Appendix A, *Product Specifications*, beginning on page 39, for electrical requirements of the 1100 Series instruments.

Type "D" Connector

Table 1 shows the pinout of the 1100 Series instruments that have a Type "D" connector (Types 1159, 2159, 1162, 2162).

Type "D" Connector Pinout			
Pin	**Assignment**	**Pin**	**Assignment**
1	MKS Test Point	9	No Connection
2	Flow Signal Output	10	Optional Input
3	Valve Close	11	Signal Common
4	Valve Open	12	Signal Common
5	Power Common	13	No Connection
6	-15 VDC	14	No Connection
7	+15 VDC	15	Chassis Ground
8	Set Point Input		

Table 1: Type "D" Connector Pinout

Note

1. The 0 to 5 VDC flow signal output comes from pin 2 and is referenced to pin 12 (signal common).
2. Any appropriate 0 to 5 VDC input signal of less than 20K ohm source impedance referenced to pin 12 can be used to supply a set point signal to pin 8.
3. There is no internal connection on the pins assigned a "No Connection" function.

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P. C. Edge Card Connector

Table 2 shows the pinout of the MFC 1100 Series instruments that have a recessed P. C. Edge Card connector (Types 1160, 2160, 1163, 2163).

P. C. Edge Card Connector Pinout			
Assignment	**Pin**	**Pin**	**Assignment**
Chassis Ground	1	A	Set point 0 to 5.0 VDC
Power Common	2	B	Signal Common
Flow Signal Out 0 to 5.0 VDC	3	C	Signal Common
± 15 VDC	4	D	Valve Open
Optional Input	5	E	No Connection
No Connection	6	F	-15 VDC
KEY	7	H	KEY
No Connection	8	J	MKS Test Point
No Connection	9	K	No Connection
Signal Ground	10	L	Valve Close

Table 2: P. C. Edge Card Connector Pinout

Note

1. Pins 1 through 10 are located on one side of the gold finger connection and pins A through L are located on the opposite side of the gold finger connection.
2. The 0 to 5 VDC flow signal output comes from pin 3 and is referenced to pin B which is signal common.
3. Use any appropriate 0 to 5 VDC input signal of less than 20K ohm source impedance referenced to pin B to supply a set point signal to pin A.
4. There is no internal connection on the pins assigned a “No Connection” function.

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Control Valve

The Control Valve is a specially constructed solenoid valve in which the armature (moving valve mechanism) is suspended by two springs. This arrangement assures that no friction is present and makes precise control possible. In MFCs with normally *closed* valves (1159, 1160, 2159, and 2160), the control current is used to *lift* the armature *from* the seat allowing a controlled flow of gas. In MFCs with normally *open* valves (1162, 1163, 2162, and 2163), the control current is used to *pull* the armature *to* the seat allowing a controlled flow of gas.

It is possible to adjust the control valve to compensate for swelling or aging of the elastomeric sealing material. Refer to *Valve Adjustment*, page 35, for instructions on how to adjust the control valve.

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Chapter Four: Operation

Warm Up and Start Up

The section describes the procedure to start up and zero a flow controller.

How To Start Up the Flow Controller

1. Leak test the fittings on the MFC using standard leak test procedures.

   Do *not* proceed to the next step until you are certain that there is no gas flow.

2. Plug the power supply/readout cable (MKS or customer-supplied) into the connector (either a 15-pin Type "D" or a P. C. Edge Card connector) located at the top of the flow controller.

   Plug the other end of the cable into an MKS or MKS-compatible power supply/readout unit.

3. Apply power to the MFC instrument.

   When power is first applied, the output signal jumps to + 7.5 VDC.

   You can monitor the flow output signal as the heaters stabilize and the output approaches zero. After being powered for a minute or so, the output signal starts to drop rapidly as the sensor tube heaters reach control temperature. Approximately thirty minutes after power up, the output signal should be within 10 mV (0.2% F.S.) of the final zero and span voltages.

Warning 

If the instrument is being used to control dangerous gases, be sure that the system is *fully warmed up* before applying gases to the system. You may install a positive shut-off valve to prevent inadvertent gas flow during the warm-up period.

Once the flow controller is completely warmed up, you can proceed to zero the unit as required.

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How To Zero the Flow Controller

Ensure that no gas flow is entering the flow controller

1. Apply gas at a regulated pressure to the flow controller.
2. Close the positive shut-off valve downstream of the instrument.
3. Command the control valve open by either sending a full scale set point (5 VDC) or connecting the valve open pin to signal ground.

   A positive flow may occur momentarily while the gas pressure equalizes across the flow controller.

Note A set point command signal greater than 50 mV (1% of full scale) is required for the flow controller to generate an output.

Adjust the Zero Pot

1. Once flow through the controller has stopped (reached zero flow), remove the set point or valve open command.

   A positive flow may occur momentarily while the gas pressure equalizes across the flow controller.

2. Turn the Zero pot (located on the input side of the flow controller) until the readout displays zero.

   Refer to Figure 6, page 18, for the location of the Zero pot.

   If you are using an MKS power supply/readout unit, the flow controller can also be zeroed at the front panel of the readout unit.

3. Open the positive shut-off valve.

   The controller may indicate a small, positive flow (<0.5% F.S.) due to a leak through its control valve. However, do ***not*** "zero out" this flow since it represents an actual flow measurement inherent in the system.

Note If the flow signal oscillates, the valve controller gain may require adjustment. The controller gain is located on the upstream side of the controller. Rotate the pot counter-clockwise to reduce the controller gain; clockwise to increase the controller gain.

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Valve Override

Valve override enables the control valve to be fully opened (purged) or closed independent of the set point command signal.

For 1100 Series Controllers with a **Type "D" Connector**:

To *open* the valve, apply a TTL low to pin 4, or connect pin 4 to pin 11 (signal common).

To *close* the valve, apply a TTL low to pin 3, or connect pin 3 to pin 11.

For 1100 Series Controllers with a **P. C. Card Edge Connector**:

To *open* the valve, apply a TTL low to pin D, or connect pin D to pin 10 (signal common).

To *close* the valve, apply a TTL low to pin L, or connect pin L to pin 10.

When both Valve Close and Valve Open are pulled down, the meter purges at a rate of flow that is somewhat less than the full scale range of the controller.

Adjusting the Speed to Set Point

The 1100 Series MFC instruments are equipped with a circuit that provides a very rapid response (<2 seconds) to a small set point command. At set points of less than 10% of F.S., there is a slight overshoot. The integrated flow for this period of time divided by the elapsed time (1.5 seconds.) is less than the set point flow rate. If this overshoot is harmful to your process, consult the factory for disabling instructions or for modification.

NUPRO BN Shutoff Valve

It is only necessary to apply or remove air pressure to the air operator to ensure an open or closed condition. No attempt should be made to control flow rate using this valve.

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Chapter Five: Theory of Operation

Flow Path

The MKS MFC Series 1100 instruments are laminar flow devices whose precise indication of mass flow is achieved through the use of a range controlling changeable bypass and a parallel sensor tube. Upon entering the MFC, the gas stream is divided into two parallel paths; the first is directed through the sensor tube, the second goes through the changeable bypass. The two paths are then rejoined and pass through the control valve before exiting the instrument. The two paths possess an L/D ratio of greater than 100:1, assuring laminar flow. With proper flow calibration equipment available, field-range changing is possible.

Measurement Technique

The amount of energy required to maintain a fixed temperature profile along a tube through which laminar flow is occurring is a function of mass-flow rate. In the MFC, resistance heaters are wound on the sensor tube and form the active legs of bridge circuits. Their temperatures are established such that a voltage change on the sensor winding is a linear function of a flow change. This signal is then amplified to provide a 0 to 5 VDC output. Improved response times (compared to differential temperature based MFCs) are observed because the output does not need to wait for a new temperature equilibrium to be established along the flow tube.

Control Circuitry

The mass flow controllers use the above measurement technique and include a control circuit which provides drive current for the proportioning control valve. The flow controllers accept a 0 to 5 VDC set point signal, compare it to their own flow signal, and generate an error voltage. This error signal is then conditioned (derivative, proportional, and integral gain) and amplified so that it can reposition the controlling valve, thus reducing the controller error to within the accuracy specification of the instrument. This error is normally less than 0.05% of full scale flow.

Note 

The controller error must not be confused with the instrument's measurement error. Refer to *Appendix A, Product Specifications*, page 39, for more information.

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The controller error is a function of process dynamics, which means the noisier the process, the greater the average error (deviation of flow signal and set point). If the set point is above the flow signal (positive in relation to the flow signal), the valve opens. If the set point is below the flow signal (negative in relation to the flow signal), the valve closes. Most controllers use an integral mode which means that the longer the error endures, the more the valve opens. MKS Types 147/647, 246, and 247 are designed to power, provide set point, and display the output of the MFC 1100 Series instruments.

Note 

When the set point input is less than +10 mV, the control valve will be driven fully closed.

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Gas Correction Factor

To interpret the output signal for gases other than nitrogen, use the Gas Correction Factor (GCF). The GCF is a number used to indicate the ratio of flow rates of different gases which will produce the same output voltage from a MFC. The GCF is a function of specific heat, density, and the molecular structure of the gases. Since controllers are usually calibrated with nitrogen, nitrogen is used as the baseline gas (GCF = 1). The GCF of any other gas is determined by using the following equation:

$$GCF_x = \frac{(0.3106)\ (S)}{(d_x)\ (Cp_x)}$$

where:

GCF_x = Gas Correction Factor for gas X

d_x = Standard Density of gas X, g/l (at 0° C and 760 mmHg)

Cp_x = Specific Heat of gas X, cal/g ° C

0.3106 = (Density of nitrogen) (Specific Heat of nitrogen)

S = Molecular Structure correction factor where

S equals:

1.030	for Monatomic gases
1.000	for Diatomic gases
0.941	for Triatomic gases
0.880	for Polyatomic gases

Refer to *Appendix B, Gas Correction Factors,* page 41, for a list of the Gas Correction Factors for the most commonly used gases.

Note

1. When using the GCF, the accuracy of the flow reading may vary by ±5%, however, the repeatability will remain ±0.2% of F.S.
2. All MKS readouts have Gas Correction Adjustment controls to provide direct readout.

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How To Determine the Flow Controller Range

These MFCs are available in ranges from 10, to 30,000 sccm (N_2 equivalent). To select the appropriate range flow controller, the equivalent flow rate of nitrogen to the flow rate of the desired gas must be determined. Calculate the ratio of the GCF of nitrogen (1.00) to the GCF of the desired gas (refer to *Appendix B, Gas Correction Factors*, page 41) as shown in the following example.

Example:

You need a flow rate of 250 sccm of argon (Ar). What range flow controller should you use?

1. Find the Gas Correction Factor of Ar (refer to *Appendix B, Gas Correction Factors*, page 41).

   1.39 is the GCF for Ar.

2. Insert the GCF of Ar in the following formula:

$$\frac{(\text{GCF of } N_2)}{(\text{GCF of Ar})} = \frac{(x)}{(\text{Desired flow rate of Ar})}$$

where x is the flow rate of nitrogen (sccm).

$$\frac{(1.00)}{(1.39)} = \frac{(x)}{(250 \text{ sccm Ar})}$$

$$x = 180 \text{ sccm } N_2$$

A flow rate of 250 sccm of Ar will produce a flow rate equivalent to 180 sccm of N_2. This falls within the range of a 200 sccm flow controller.

When calculating equivalent N_2 flows using gas correction factors, be sure to use a flow controller with a sufficient flow rate range. For example, if the calculated equivalent N_2 flow in the example shown above is 205 sccm, use a 500 sccm flow controller. The 500 sccm instrument can then be calibrated such that 205 sccm N_2 = full scale.

Note 

When using a gas with a density *higher* than nitrogen, be sure that the control valve Full Scale range can accommodate the desired flow rate. Please call the MKS Applications group if you have any questions.

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How To Read the Flow Output Directly

If your readout equipment does not provide a GCF (gas correction factor) potentiometer, you must add a proper input divider to read the flow signal directly.

Using the values from the example above, and assuming a 1 Volt F. S. readout, the flow signal must be divided 2.44 to 1.00 Volts.

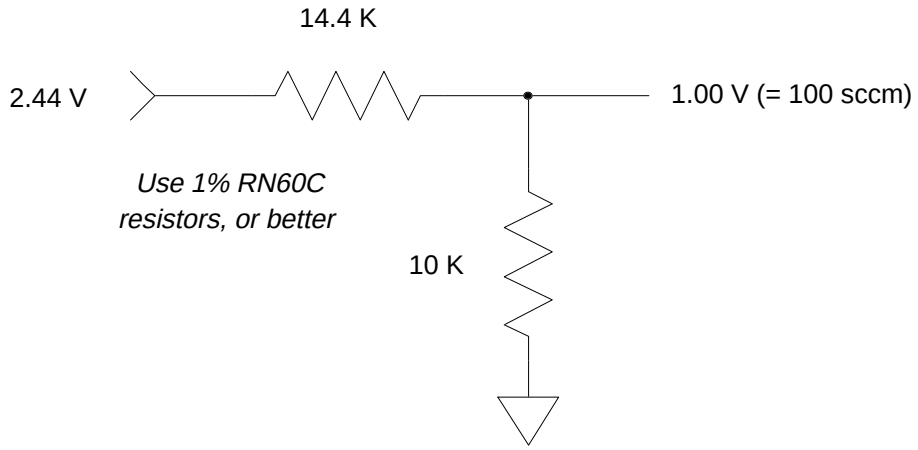


Figure 8: Wiring Diagram for an Input Divider

Note MKS Types 246, 247, and 260 provide gas correction factor adjustment.

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Chapter Six: Maintenance

Warning 

Before performing mass flow controller valve adjustments, you MUST purge your process equipment and the MFC with an inert gas, such as argon or nitrogen, and isolate the MFC from toxic and hazardous gases. Use an inert surrogate gas while adjusting the valve preload as a safeguard against inadvertent exposure to any toxic or hazardous gas. A release of hazardous or toxic gas could cause serious injury. If necessary, remove the MFC from the process equipment to adjust the valve.

Questions concerning the safe handling of toxic or hazardous gases may be answered by consulting your corporate policy, a government agency such as OSHA or NIOSH, or experts familiar with your process gas.

MKS assumes no liability for safe handling of toxic or hazardous gases.

Valve Adjustment

All valves are 100% leak-checked at the factory prior to shipment using a Helium Mass Spectrometer to assure a leak integrity of 10^{-5} scc/sec He. If leak-checked using a MFC valve adjustment bench test (as described below) with no set point command signal applied, the valve should have a leakage rate of less than 0.1% of full scale flow in the MFC's with the valve normally *closed* and 0.5% of full scale flow in the MFC's with the valve normally *open*. To detect leakage, perform the following steps.

1. Connect the MFC to the upstream side of a 15 psig gas source and monitor the flow signal generated by the MFC.

2. If using the MFC to monitor the leak rate, verify that the valve is not being commanded to open, that is, no set point has been established nor has the *valve open* function been employed.

3. Locate the valve adjustment screw (access the screw via the ¼" hole in the top of the cover). Turn the screw counter clockwise until it is fully backed out.

4. Slowly turn the screw clockwise (back in) until the leak is no longer detectable.

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5. Turn the screw counter clockwise again, 30° at a time, until a leak is *just* detectable.

6. Turn the screw back in, 1/3 of a turn, and verify that no leakage exists.

7. If a leak is still present, continue to turn the adjustment screw as described in the previous steps.

Caution  **This adjustment is delicate and any more than ±1½ turns from nominal (factory setting) will be excessive.**

8. As a final check, the voltage level at pin J (pin 1, Type "D" connector) can be used to indicate the proper working condition of the valve. Set a command signal of 5 VDC to give 100% of F. S. The voltage level at pin J (pin 1, Type "D" connector) should be between 0 and +5.0 VDC during control.

Repair

Contact any authorized MKS Sales Office or Calibration and Service Center should you encounter any difficulties or problems using your flow controller.

Note  If you must return the instrument to MKS for repair, please contact any of the MKS service and calibration centers listed on the inside back cover of this manual, for an ERA (Equipment Return Authorization) number to expedite handling and ensure proper servicing of your instrument.

Warning  **All returns to MKS Instruments must be free of harmful, corrosive, radioactive, or toxic materials.**

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Chapter Seven: Troubleshooting

Troubleshooting Chart		
Symptoms	**Possible Cause**	**Remedy**
Over-range at zero (after warm-up)	Flow is on and above meter range	Isolate MFC
	Sensor winding open	Return for service
No output or over-range at zero (after warm-up)	Improper cable	Check cable for type
	Electronics malfunctioning	Return for service
Unit indicates approx. twice known flow and is unstable	Unit installed in gas stream backwards	Reinstall unit in proper flow direction
Controller does not track set point	Improper zero adjustment	Zero meter output as described on page 26
Controller does not function	Valve override applied	Disconnect valve override
	Electronics malfunctioning	Return for service
	Valve incorrectly adjusted	Return for service
Unit produces large pressure drop or will not pass full flow	Clogged sensor tube and/or bypass	Return for service
Unit exhibits large zero temp. coefficient.	Ambient heater out of regulation	Check placement of flow meter in hot system
		Return for service
Unit is non-linear or has erratic operation	Winding out of regulation	Return for service
Oscillation	Too high a controller gain setting	Reduce (turn counterclockwise)
	Incorrect upstream pressure regulator	Check manufacturers' specifications
	Upstream pressure too high	Reduce upstream pressure
	Amplifier not handling capacitance loads	Install 150 to 1000 ohm resistor in series with set point input line

Table 3: Troubleshooting Chart

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Appendix A: Product Specifications

General Specifications

Accuracy[1]	± 1.0% of F.S.
CE Mark Compliance[2, 3]	EMC Directive 89/336/EEC
Control Range (controllers only)	1.0 to 100% of F. S.
Controller Settling Time (to within 2% of set point)	<2 sec.[4]
Full Scale Ranges (nitrogen equivalent)	10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10,000, 20,000, 30,000 sccm
Maximum Inlet Pressure	150 psig
Minimum Pressure Drop (at atmosphere) across Flow Meter	15 psid[5] at atmosphere
Normal Operating Temperature Range	15° to 40° C (59° to 104° F)
Pressure Coefficient	0.005% of Rdg./psi
Repeatability	± 0.2% Rdg.
Resolution (measurement)	0.1% of F.S.
Temperature Coefficients	
Zero	<0.05% of F.S./° C (500 ppm)[6]
Span	<0.10% of Rdg./° C (1000 ppm)
Warm-up Time	30 minutes[7]

Due to continuing research and development activities, these product specifications are subject to change without notice.

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[1]Includes non-linearity, hysteresis, and non-repeatability referenced to 760 mmHg/0° C

[2]Requires metal, braided, shielded cables, properly grounded at both ends.

[3]Units with Edge Card connectors or units that use flying leads are not CE Mark compliant.

[4]Settling time on 10, 20, and 50 sccm units is <3 sec. at 10% of F.S.

[5]25 psid for 30K sccm range

[6]Zero temperature coefficients for 10 and 20 sccm units is 0.2 of F.S./° C

[7]For warm-up time on 10 sccm units, consult factory

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Electrical Specifications

Connector Type	
1159/1162 1160/1163	15-pin Type "D" Recessed P. C. Edge Card
Input Voltage/Current Required	
Max. at start up	± 15 VDC (±5%) @ 300 mA
Typical at steady state	± 15 VDC @ 180 mA
Output Impedance	<1 ohm
Output Signal/Minimum Load	0 to 5 VDC into > 10K ohm
Set Point Command Signal (controllers only)	0 to 5 VDC from < 20K ohm

Mechanical Specifications

Dimensions	
Body length less fittings	5.30" H x 3.00" L x 1.45" W[8] (134.6 mm x 76.2 mm x 36.8 mm)
VCR mating face to face	5.30" H x 4.88" L x 1.45" W (134.6 mm x 76.2 mm x 36.8 mm)
Fittings	
Standard	¼ " Swagelok®
Optional	Cajon® 4-VCR® (male) compatible, Cajon 4-VCO (male) compatible
Leak Integrity (scc/sec He)	
External	$\leq 10^{-9}$
Through closed valve	
1159/1160 1162/1163	$\leq 10^{-5}$ ≤ 0.5% of F.S.

[8]Types 1159B/1162B - Body length - 5.43"H x 3.00"L x 1.45"W (137.9 mm x 76.2 mm x 36.8 mm), VCR mating - 5.43"H x 4.88"L x 1.45"W (137.9 mm x 124.0 mm x 36.8 mm)

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Appendix B: Gas Correction Factors

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Air	- - -	0.240	1.293	1.00
Ammonia	NH_3	0.492	0.760	0.73
Argon	Ar	0.1244	1.782	1.39[1]
Arsine	AsH_3	0.1167	3.478	0.67
Boron Trichloride	BCl_3	0.1279	5.227	0.41
Bromine	Br_2	0.0539	7.130	0.81
Carbon Dioxide	CO_2	0.2016	1.964	0.70[1]
Carbon Monoxide	CO	0.2488	1.250	1.00
Carbon Tetrachloride	CCl_4	0.1655	6.86	0.31
Carbon Tetrafluoride (Freon - 14)	CF_4	0.1654	3.926	0.42
Chlorine	Cl_2	0.1144	3.163	0.86
Chlorodifluoromethane (Freon - 22)	$CHClF_2$	0.1544	3.858	0.46
Chloropentafluoroethane (Freon - 115)	C_2ClF_5	0.164	6.892	0.24
Chlorotrifluoromethane (Freon - 13)	$CClF_3$	0.153	4.660	0.38
Cyanogen	C_2N_2	0.2613	2.322	0.61
Deuterium	D_2	1.722	0.1799	1.00
Diborane	B_2H_6	0.508	1.235	0.44
Dibromodifluoromethane	CBr_2F_2	0.15	9.362	0.19
Dichlorodifluoromethane (Freon - 12)	CCl_2F_2	0.1432	5.395	0.35
Dichlorofluoromethane (Freon - 21)	$CHCl_2F$	0.140	4.592	0.42
Dichloromethysilane	$(CH_3)_2SiCl_2$	0.1882	5.758	0.25

(Table continued on next page)

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GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Dichlorosilane	SiH_2Cl_2	0.150	4.506	0.40
1,2-Dichlorotetrafluoroethane (Freon - 114)	$C_2Cl_2F_4$	0.160	7.626	0.22
1,1-Difluoroethylene (Freon - 1132A)	$C_2H_2F_2$	0.224	2.857	0.43
2,2-Dimethylpropane	C_5H_{12}	0.3914	3.219	0.22
Ethane	C_2H_6	0.4097	1.342	0.50
Fluorine	F_2	0.1873	1.695	0.98
Fluoroform (Freon - 23)	CHF_3	0.176	3.127	0.50
Freon - 11	CCl_3F	0.1357	6.129	0.33
Freon - 12	CCl_2F_2	0.1432	5.395	0.35
Freon - 13	$CClF_3$	0.153	4.660	0.38
Freon - 13 B1	$CBrF_3$	0.1113	6.644	0.37
Freon - 14	CF_4	0.1654	3.926	0.42
Freon - 21	$CHCl_2F$	0.140	4.592	0.42
Freon - 22	$CHClF_2$	0.1544	3.858	0.46
Freon - 23	CHF_3	0.176	3.127	0.50
Freon - 113	$C_2Cl_3F_3$	0.161	8.360	0.20
Freon - 114	$C_2Cl_2F_4$	0.160	7.626	0.22
Freon - 115	C_2ClF_5	0.164	6.892	0.24
Freon - 116	C_2F_6	0.1843	6.157	0.24
Freon - C318	C_4F_8	0.185	8.397	0.17
Freon - 1132A	$C_2H_2F_2$	0.224	2.857	0.43
Helium	He	1.241	0.1786	.- - -2
Hexafluoroethane (Freon - 116)	C_2F_6	0.1843	6.157	0.24
Hydrogen	H_2	3.419	0.0899	.- - -2
Hydrogen Bromide	HBr	0.0861	3.610	1.00

(Table continued on next page)

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GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Hydrogen Chloride	HCl	0.1912	1.627	1.00
Hydrogen Fluoride	HF	0.3479	0.893	1.00
Isobutylene	C_4H_8	0.3701	2.503	0.29
Krypton	Kr	0.0593	3.739	1.543
Methane	CH_4	0.5328	0.715	0.72
Methyl Fluoride	CH_3F	0.3221	1.518	0.56
Molybdenum Hexafluoride	MoF_6	0.1373	9.366	0.21
Neon	Ne	0.246	0.900	1.46
Nitric Oxide	NO	0.2328	1.339	0.99
Nitrogen	N_2	0.2485	1.250	1.00
Nitrogen Dioxide	NO_2	0.1933	2.052	0.16
Nitrogen Trifluoride	NF_3	0.1797	3.168	0.48
Nitrous Oxide	N_2O	0.2088	1.964	0.71
Octafluorocyclobutane (Freon - C318)	C_4F_8	0.185	8.937	0.17
Oxygen	O_2	0.2193	1.427	1.00
Pentane	C_5H_{12}	0.398	3.219	0.21
Perfluoropropane	C_3F_8	0.194	8.388	0.17
Phosgene	$COCl_2$	0.1394	4.418	0.44
Phosphine	PH_3	0.2374	1.517	0.76
Propane	C_3H_8	0.3885	1.967	0.36
Propylene	C_3H_6	0.3541	1.877	0.41
Silane	SiH_4	0.3189	1.433	0.60
Silicon Tetrachloride	$SiCl_4$	0.1270	7.580	0.28
Silicon Tetrafluoride	SiF_4	0.1691	4.643	0.35
Sulfur Dioxide	SO_2	0.1488	2.858	0.69

(Table continued on next page)

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GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Sulfur Hexafluoride	SF_6	0.1592	6.516	0.26
Trichlorofluoromethane (Freon - 11)	CCl_3F	0.1357	6.129	0.33
Trichlorosilane	$SiHCl_3$	0.1380	6.043	0.33
1,1,2-Trichloro - 1,2,2-Trifluoroethane (Freon - 113)	CCl_2FCClF_2 or ($C_2Cl_3F_3$)	0.161	8.360	0.20
Tungsten Hexafluoride	WF_6	0.0810	13.28	0.25
Xenon	Xe	0.0378	5.858	1.32

[1]Empirically defined

[2]Consult MKS Instruments, Inc. for special applications.

NOTE: Standard Pressure is defined as 760 mmHg (14.7 psia). Standard Temperature is defined as 0^{o}C.

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