112832-P1
REV B, 5/96

MKS Type 358C
Masster-Flo™ Mass Flow Meter
and
MKS Type 1359C
Masster-Flo™ Mass Flow Controller

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Safety Procedures and Precautions

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.

USE PROPER PROCEDURES WHEN PURGING

This instrument must be purged under a ventilation hood, and gloves must be worn to protect personnel.

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.

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.

Chapter One: General Information

Introduction

Warning

Before performing mass flow controller valve adjustments, you MUST purge your process equipment and then 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.

The MKS Type 358C Mass Flow Meter (MFM) and Type 1359C Mass Flow Controller (MFC) accurately measures and/or controls the mass flow rate of gases. Based upon a patented measurement technique[1], the instrument provides fast response and maintains excellent long-term stability.

The mechanical design reflects attention to field serviceability in that the instrument may be easily disassembled and reassembled without significant calibration shift. Furthermore, the design incorporates a Card Edge Type "D" shielded connector, metal cover, RF bypass capacitors, and proper layout to virtually eliminate RFI and EMI interference. A feature added to the controller is its ability to accept TTL level commands that remotely open or close the control valve.

The Flow Controller Instrument family may be powered, set point commanded, and displayed by compatible MKS equipment (Types 167, 246, 247, 660, and 647; refer to *Companion Products*, page 6) or by user supplied devices. Refer to their respective manuals for the appropriate information.

[1] U.S. Patent No. 4,464,932

How This Manual is Organized

This manual is designed to provide instructions on how to set up, install, and operate a Type 358/1359 unit.

Before installing your Type 358/1359 **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 describes how to mount the instrument in your system.

Chapter Three: Overview, gives a brief description of the instrument and its functionality.

Chapter Four: Operation, describes how to operate the instrument.

Chapter Five: Maintenance and Troubleshooting, describes maintenance procedures and how to troubleshoot a problem should the unit malfunction.

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

Appendix B: Gas Correction Factors, lists gas correction factors for many gases.

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 358/1359 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.

Chapter Two: Installation

How To Unpack the Type 358/1359 Unit

MKS has carefully packed the Type 358/1359 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 358/1358 Unit
- Type 358/1359 Instruction Manual (this book)

Optional Equipment:

- Electrical Connector Accessories Kit:
  0358C-K1 (358 MFM only):
- Interface Cables:

CB259-5-10:	Connects the 358 MFM to a 246, 247, or 660 unit Connects the 1359 MFC to a 246 or 247 unit
CB147-1-10:	Connects the 358 MFM to a 167 or 647 unit Connects the 1359 MFC to a 167 or 647 unit

Note

1. Braided, shielded cables are required to meet CE Mark certification.
2. To order braided, shielded cables, add an “S” after the cable type designation. For example to order a standard cable to connect the 358 MFM to a 246 controller, use part number CB259-5-10; for a shielded cable, use part number CB259S-5-10.

Companion Products

The 358 MFM is compatible with the following MKS instruments:

- Type 167 Single-Channel Readout/Set Point Module
- Type 647 Four/Eight-Channel Mass Flow and Pressure Programmer/Display
- Type 246 Single-Channel Mass Flow Meter Power Supply/Readout
- Type 247 Four-Channel Mass Flow Meter Power Supply/Readout
- Type 660 Single-Channel Power Supply/Digital Readout

The 1359 MFC is compatible with the following MKS instruments:

- Type 167 Single-Channel Readout/Set Point Module
- Type 647 Four/Eight-Channel Mass Flow and Pressure Programmer/Display
- Type 246 Single-Channel Mass Flow Meter Power Supply/Readout
- Type 247 Four-Channel Mass Flow Meter Power Supply/Readout

Dimensions

A dimensional drawing of the 358 MFM is shown in Figure 1, page 7. A dimensional drawing of the 1359 MFC is shown in Figure 2, page 9.

Note All dimensions are listed in inches with millimeters referenced in parentheses.

Figure 1: Dimensions of a Type 358 Mass Flow Meter

Figure 2: Dimensions of a Type 1359 Mass Flow Controller
(Sheet 1 of 2)

Figure 2: Dimensions of a Type 1359 Mass Flow Controller
(Sheet 2 of 2)

Setup

Mounting Instructions

1. Mount the flow components in a horizontal position.

   Mounting the flow components in other than a horizontal position will cause a small zero shift (refer to *Chapter Four: Operation*, beginning on page 19).

2. Install the instrument in the gas stream such that the flow will be in the direction of the arrow on the side of the base.

3. Ensure that you allow for connector clearance, access to the zero potentiometer, and access to the seat adjustment in the base of the 248A/B Control Valve.

Note Be sure to provide adequate clearance for Type “D” cable assemblies. Straight shielded connectors require approximately 3" height. Right Angle connectors require approximately 2" height.

Fittings

Swagelok® compression fittings (¼ inch) are standard for making the gas line connection. Cajon® male 4-VCR® or 4-VCO® fittings are available as standard options, when specified. All tubing should be clean and free of axial scratches. The tubing should be inserted through the compression nut and ferrules all the way to the shoulder as shown in Figure 3.

Figure 3: Gas Line Connection

Caution **Tighten the nut only 1 ¼ turns past finger tight. When remaking, tighten the nut 1/6 turn only. Overtightening will damage the tubing and fitting, and destroy a normally leak-tight fitting.**

Electrical Installation

To use the 358/1359 with any equipment other than complimenting MKS modules, the manufacturers' specifications should be consulted for connection, and proper electrical and power characteristics. Refer to *Appendix A: Product Specifications*, beginning on page 29, for the unit's electrical requirements.

15-Pin Type "D" Connector Pinout	
Pin Number	**Assignment**
1	Valve Test Point*
2	Flow Signal Output
3	Valve Close*
4	Valve Open*
5	Power Common
6	-15 VDC
7	+15 VDC
8	Set Point Input*
9	No Connection
10	Optional Input*
11	Signal Common
12	Signal Common
13	No Connection
14	No Connection
15	Chassis Ground
* *Type 1359 MFC only.*	

Table 1: 15-Pin Type "D" Connector Pinout

Note The "No Connection" pin assignment refers to a pin with no internal connection.

Cables

Certain interface cables can be supplied by MKS, or you may choose to make your own, provided the appropriate specifications contained herein are maintained.

Complete MKS Flow System (Flow Meters/Controllers/Power Supply/Readouts)

For convenience, when you purchase a complete mass flow meter/control system, specifying all companion MKS equipment at time of purchase, MKS will supply the appropriate cable(s) with connectors, in standard lengths at a nominal cost.

Interface Cables for Non-MKS Power Supplies/Readouts

Shielded cable assemblies, in a nominal 10' (3M) length, with a Type “D" connector on one end and terminated in “flying leads” (pigtail) fashion on the other end are available at nominal cost. Shielded cable assemblies are recommended, especially if environment contains high EMI/RFI noise.

Note

1. Braided, shielded cables are required to meet CE Mark certification.
2. To order braided, shielded cables, add an “S” after the cable type designation. For example to order a standard cable to connect the 358 MFC to 246 controller, use part number CB259-5-10; for a shielded cable, use part number CB259S-5-10.
3. Be sure to provide adequate clearance for Type “D” cable assemblies. Straight shielded connectors require approximately 3" height. Right Angle connectors require approximately 2" height.

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Chapter Three: Overview

Flow Path

The 358 MFM and 1359 MFC are laminar flow devices whose precise indication of mass flow is achieved through the use of a range controlling changeable bypass and a paralleling sensor tube. Upon entering the 358/1359 unit, the gas stream is divided into two parallel paths; the first is directed through the sensor tube, the second through the changeable bypass. The two paths are then rejoined to 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 MKS mass flow meter, 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 are observed because the output need not wait for a new temperature equilibrium to be established along the flow tube. A patent has been issued to MKS on this technique.

Tailored Control Circuitry

The flow controller uses the above measurement technique and includes control circuitry which provides drive current for the proportioning control valve. The flow controller accepts a 0 to 5 VDC set point signal, compares it to its own flow signal, and generates an error voltage. This error signal is then conditioned (derivative, proportional, and integral gain) and that it may reposition the controlling valve, thus reducing this error to within the accuracy specification of the instrument. This error will normally be less than 0.05% of full scale flow.[2] However, this error is a function of process dynamics; meaning, the noisier the process, the greater the average error (deviation of flow signal and set point). The compatible MKS power supply/readouts are designed to power, provide set point, and display the output of the flow controller.

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[2]This is the controller error and must not be confused with the instrument's measurement error (refer to *Appendix A: Product Specifications*, page 29).

Control Valve

The Control Valve is a specially constructed solenoid valve wherein the armature (moving valving mechanism) is suspended with two springs. This location mechanism assures that no friction is present thus making precise control possible. A control current is used to lift the armature from the seat thus allowing the controlled flow of gas.

Note

This is not an on/off valve. Variations of less than one micro-amp are necessary to give the control resolution obtainable with an MKS system.

An adjustable control orifice located on the bottom of the valve varies the closing force which allows for any small adjustments that may be necessitated by swelling or aging of the elastomeric seating material.

Caution

This adjustment is delicate and any more than ± 1/8 turn from nominal (factory setting) will be excessive.

Warning

Before performing mass flow controller valve adjustments, you MUST purge your process equipment and then 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.

The Gas Correction Factor (GCF)

A Gas Correction Factor (GCF) is used to indicate the ratio of flow rates of different gases which will produce the same output voltage from a mass flow controller. The GCF is a function of specific heat, density, and the molecular structure of the gases. Since flow controllers are usually calibrated with nitrogen, nitrogen is used as the baseline gas (GCF = 1). *Appendix B: Gas Correction Factors*, beginning on page 31, lists the gas correction factors for the most commonly used gases. If the gas you are using is not listed in the appendix, you must calculate its GCF 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 = (Standard 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

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.

Example:

Flowmeters calibrated with N_2 are available in ranges of 10 to 50,000 sccm. It is desired to flow 100 sccm of CCl_4; which meter should be chosen?

1. Look up the GFC for CCl_4.

   The GCF for CCl_4 is 0.31.

2. Apply the ratio of GCF's to determine the equivalent of N_2 (X).

   $$\frac{1.00}{0.31} = \frac{X}{100}$$

   $$X = 323 \text{ sccm}$$

3. 100 sccm of CCl_4 will look like 323 sccm of N_2. This falls within the range of a 500 sccm unit; therefore, it should be selected.

Chapter Four: Operation

General Information

After proper gas and electrical connections have been made, the following procedure should be used to put the 1359 mass flow controller into operation.

Warm-Up

When power is first applied to the MFC, the output will be +7.5 VDC. After being powered for a minute or so, the output will start dropping rapidly as the tube heaters reach control temperature. The instrument reading with no flow approaches zero output as the heaters stabilize. Measurements can be made within 10 minutes of turn-on. After 30 minutes from start, the instrument may be re-zeroed and the span will read correctly. Check the zero periodically to establish its reliability.

How To Adjust the Zero

1. With no gas flow assured, zero the output of the MFC using the zero pot as marked on the input side.

Note Set the zero with the unit in the same plane of orientation that it will be mounted in the system.

2. When used with a compatible MKS readout unit, it is only necessary to zero at the indicator, as this zeroed signal is sent to the controller section of the MFC.

   If you run out of adjustment in the readout, use the zero pot located on the upstream side of the MFM or MFC.

How To Use the Gas Correction Factor (GCF)

1. After zeroing, the MFC will provide a 0 to 5 VDC output corresponding to 0 to 100 percent nitrogen flow of meter rating, unless a special calibration has been called out at the time of ordering.

Caution **The system should be properly leak checked before operation.**

2. The 0 to 5 VDC output should be interpreted for other gases, as follows (refer to *Appendix B: Gas Correction Factors*, page 31, for a complete listing of correction factors for commonly used gases):

$$\frac{\textbf{Output}}{\textbf{5.000 F.S.}} \times \textbf{Range of Instrument} \times \textbf{Gas Correction Factor} = \textbf{Flow of Gas Used}$$

Example:

Output	=	3.22 VDC
Range	=	500 sccm N_2
Gas Correction Factor (CCl_4)	=	0.31
Flow	=	$\frac{3.22\ V}{5.000} \times 500 \times 0.31$
	=	100 sccm CCl_4

If interpretation of the output is undesirable and the readout equipment has no GCF potentiometer, a proper input divider can be constructed.

Note The MKS companion products (Type 167, 246, 247 , 660, and 647 units) provide gas correction factor adjustments.

The 0 to 5 VDC flow signal output comes from pin 2 and is referenced to Pin 12 which is signal common. Any appropriate 0 to 5 VDC input signal of less than 20K Ω source impedance referenced to Pin 12 can be used to supply a set point signal to Pin 8.

The 1359 MFC has been equipped with a circuit that makes response to a small set point command very rapid (< 2 seconds). At set points of less than 10%, there is some overshoot. The integrated flow for this period of time divided by the elapsed time (1.5 seconds) will be less than the set point flow rate. If this overshoot is harmful to the process, consult the factory for disabling instructions.

Use of the MFC is now routine except that if power to it is interrupted, the warming period should be observed.

How To Use the Valve Override

Note The valve override instructions only apply to the 1359 MFC.

The valve override permits you to fully open (purge) or close the control valve independent of the set point command signal.

- To OPEN valve, apply a TTL low to Pin 4, or connect Pin 4 to Pin 11 (signal common)
- To CLOSE valve, apply a TTL low to Pin 3, or connect Pin 3 to Pin 11

When both Valve Close and Valve Open are pulled down, the valve will be open at a setting of flow that is somewhat less than the full scale range of that controller.

How To Use the Valve Test Point

Note The valve test point instructions only apply to the 1359 MFC (Pin #1).

A valve test point is available to verify proper operation of the valve. When this test point is +12 VDC, the valve should be fully closed. When this test point is -12 VDC, the valve should be fully open. When controlling to a designated set point, the test point should be between +6 VDC and -8 VDC verifying proper operation.

If the valve test point voltages are incorrect for above designated conditions, refer to *Troubleshooting*, page 27.

How To Use the Analog Interface Signals

The accompanying MFC uses the analog set point input to provide “smart” features that otherwise would require separate signal lines and associated output control devices.

When the set point input is less than the +10 mV the valve will be driven fully closed. This condition is similar to pulling the “CLOSE” line to ground which will also close the valve. Note that the 10 mV threshold is determined at the MFC. If there are voltage errors caused by ground currents or improper grounding between the MFC and the device generating the set point input, these will add (or subtract) from the threshold to establish the “close” condition.

Standard MFCs from MKS Instruments have a “fast wake-up” feature that allows the flow rate to quickly rise to the set point value. This feature is most noticeable when a low percentage set point is commanded. With such a low drive signal most competitive MFCs will require several seconds (up to 30) to turn on the control valve. At set point initiation (when the set point exceeds 10 mV) the MKS MFC will quickly increase the drive current to the control valve. The current will continue to increase until the flow reading exceeds 50 mV. Exceeding the threshold turns the “fast wake-up” feature off and the normal control parameters are used to maintain the current flow rate.

The fast wake-up will remain off until the set point signal drops below 10 mV and the flow signal drops below 50 mV.

All MFCs from MKS Instruments have R.F. bypass capacitors on the incoming lines to reduce the susceptibility to stray high frequency signals. The capacitor on the set point input line may cause oscillations in the amplifier used to generate the set point voltage. These oscillations will occur if the amplifier is not designed to operate with capacitative loads. They can be prevented by installing a resistor of 150 to 1000 ohms in series with the set point input line.

Oscillation should be suspected if the flow rate does not follow the set point. Improper grounding can also cause discrepancies between flow rate and the set point.

Cautionary Notes

Note 1: MKS Supplied Power Supply / Display Equipment

When the 1359 MFC is used with an MKS 167, 246 or 247, Note 2 does not apply. The 167, 246 or 247 takes the flow signal from the 1359 unit, zeroes it with the front panel zero pot, and sends the signal back to the controller section of the 1359 unit on Pin 10.

Note 2: User Supplied Display Equipment

It is important to note that the controller section of the 1359 unit compares its own flow signal with the set point signal, and positions the valve to reduce this error to zero. Therefore, it is necessary to zero the flow transducer's output, using its zero potentiometer, rather than offsetting a non-zero signal with an equal and opposite signal in the readout equipment, if it is so equipped. Failure to properly zero the transducer will result in a disparity of set point and flow signals equal to the zero offset.

Note 3: Set Point Command

The use of a set point voltage source of low impedance (< 20K Ω) is necessary for concurrence between set point and flow signal output.

Note 4: General

A controller is a device that acts upon the value of an error signal (that of set point vs. actual flow). If the set point is above the flow signal (positive in relation to the set point) then the valve will be opened. If both signals are more negative than -0.5 VDC, but S.P. is more positive than the F.S, then the valve will be opened. And as most controllers use an integral mode, the longer the error endures, the more the valve will be opened.

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Chapter Five: Maintenance and Troubleshooting

General Information

If the 358/1359 unit fails to operate properly upon receipt, check for shipping damage, and check the cables for proper continuity. Any damage should be reported to the carrier and MKS Instruments immediately. If it is necessary to return the unit to MKS, obtain an ERA number (Equipment Return Authorization Number) from a MKS Service Center before shipping. Please refer to the inside 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.**

Maintenance

Valve Orifice Adjustment

Note This adjustment applies to the 1359 MFC only.

With no power applied, the valve should have no measurable leakage or flow when the valve is positioned vertically, base down, and 1 atmosphere differential pressure greater than the specification is applied.

If unacceptable leakage exists because of different operating conditions or normal wear, adjust the orifice assembly adjustment screw in the base by turning it clockwise:

1. Turn the orifice 5° to 10° clockwise at a time, each time observing a change in leakage.

2. Turn the orifice an additional 10° to 15° beyond the threshold of acceptable leakage.

   Excessive clockwise adjustment may reduce maximum flow control or impair control response.

If the leakage cannot be corrected by adjusting the orifice assembly, the problem is one of the following:

- Leaky seat - replace the Armature/Plug Assembly
- Leaky Orifice Assembly Seal - replace seals or assembly
- Scored, pitted body - inspect, replace as required

Never screw the Orifice Assembly hard up to the Armature/Plug Assembly. Damage requiring replacement of either or both assemblies will result.

Always disconnect the valve from its controller when adjusting for orifice leakage as valve bias misadjustment may hold the valve partially open.

Troubleshooting

Troubleshooting Chart		
Symptom	**Possible Cause**	**Remedy**
No output or overrange at zero (after warm-up)	Flow is on and above meter range	Isolate MFC from flow channel
	Improper cable	Check cable for type and damage
	Electronics	Return to MKS for service
Unit indicates approximately twice the known flow and is unstable	Unit installed in gas stream backwards	Reinstall unit in proper flow direction
Controller does not track	Improper zero adjustment	Zero the meter output (refer to *How To Adjust the Zero*, page 19)
Controller does not function	Valve misadjusted	Readjust the valve
	Valve override function applied	Disconnect he valve override function
Gas flow present with a zero set point applied	Purge command signal applied	Remove the purge command signal
Valve test point indicates +12 VDC	Leakage across valve	Adjust the valve
Valve test point indicates <+10 VDC	Electronics	Return to MKS for service
No gas flow with set point applied		
Valve test point indicates +12 VDC	Valve off command applied	Remove the valve off command
Valve test point indicates -12 VDC	Inadequate supply pressure	Adjust supply pressure
Unit produces large pressure drop or will not pass full flow	Clogged sensor tube and/or bypass	Return to MKS for service
Unit exhibits large temperature coefficient	Electronics	Return to MKS for service
		Check placement of MFC in hot system

Table 2: Troubleshooting Chart
(Continued on next page)

Troubleshooting Chart *(Continued)*		
Symptom	**Possible Cause**	**Remedy**
Unit is non-linear or exhibits erratic operation	Electronics	Return to MKS for service
Oscillation	Controller gain setting is too high	Reduce the controller gain setting (turn counter-clockwise)
	Incorrect upstream pressure regulator	Check manufacturer's specifications

Table 2: Troubleshooting Chart

Appendix A: Product Specifications

Performance Specifications

Accuracy[3]	± 0.5% F.S.
CE Mark Compliance	EMC Directive 89/336/EEC
Control range (controller only)	1 to 100% F.S.
Controller settling time (controller only)	≤ 2 seconds to within 2% of set point
Full scale ranges (nitrogen equivalent)	10; 20; 50; 100; 200; 500; 1,000; 2,000; 5,000; 10,000; 20,000; 50,000 sccm
Maximum inlet pressure	150 psig
Minimum pressure drop (meter only)	5 Torr at atmosphere
Operating temperature range	15° to 40° C (59° to 104° F)
Pressure coefficient	0.005% Rdg./psi
Resolution (measurement)	0.1% F.S.
Temperature coefficients Zero Span	 < 0.02% F.S./° C (200 ppm)[4] <0.10% of Rdg/° C
Warm-up time[5]	30 minutes

[3]Calibration referenced to 760 Torr/0° C (Semi Standard).

[4]Zero temperature coefficients for 10 and 20 sccm units is 0.5% of F.S./ ° C

[5]Consult factory for 10 sccm units

Electrical Specifications

Connector type	RF shielded Type "D"
Input/Command signal[6]	0 to 5 VDC from < 20K ohm source
Input voltage/Current required Max. at start up Typical at steady state	 ±15 VDC @ 250 mA ±15 VDC @ 160 mA
Output impedance	< 1 ohm
Output signal/Minimum load	0 to 5 VDC into > 10K ohm source

Mechanical Specifications

Fittings Standard Optional	 ¼" Swagelok® Cajon® 4-VCR® (male), Cajon 4-VCO® (male)
Leak integrity External (scc/sec He) Through closed valve[7]	 < 10^{-9} scc/sec. He < 10^{-7} scc/sec. He
Materials wetted Standard Optional	 316SS, Nickel, Viton® Buna-N, Neoprene®, or Kalrez®

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

[6]Controller only

[7]Type 1359 MFC only

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 Tetraflouride (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)

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)

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)

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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