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111758-P1
Rev B, 1/95
Instruction Manual

MKS Type 1449A
All-Metal
Mass Flow Controller

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MKS INSTRUMENTS

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for Type 1449A
Equipment

MKS Instruments, Inc. (**MKS**) warrants that the equipment described in the face of this warranty (the "equipment") manufactured by **MKS** shall be free from defects in materials and workmanship for a period of one year from date of shipment. For the period commencing with the date of shipment of this equipment and ending one year later, **MKS** will, at its option, either repair or replace any part which is defective in materials or workmanship without charge to the purchaser. The foregoing shall constitute the exclusive and sole remedy of the purchaser for any breach of **MKS** of this warranty.

The purchaser, before returning any equipment covered by this warranty, which is asserted to be defective by the purchaser, shall make specific written arrangements with respect to the responsibility for shipping the equipment and handling any other incidental charges with the **MKS** sales representative or distributor from which the equipment was purchased or, in the case of a direct purchase from **MKS**, with the **MKS** home office in Andover, Massachusetts, U.S.A.

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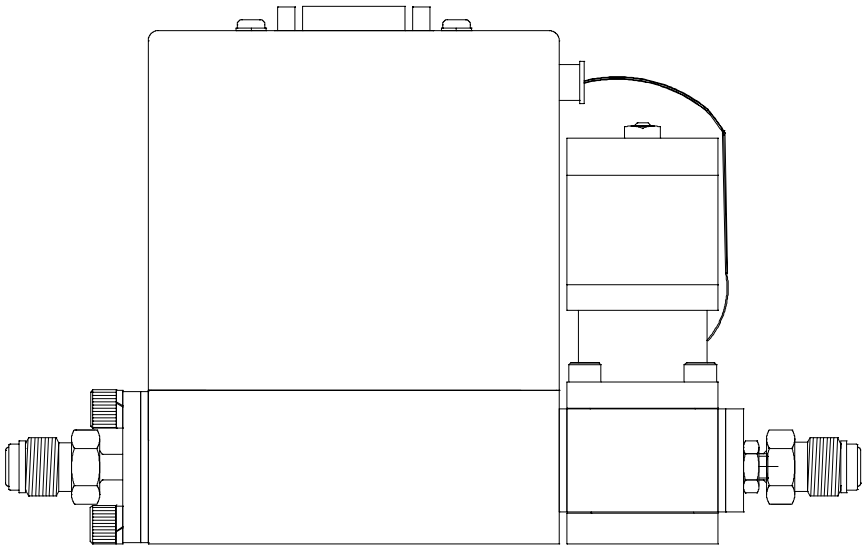
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111758-P1
REV B, 1/95

Type 1449A

All-Metal

Mass Flow Controller



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Safety Procedures

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of intended use of the instrument. MKS Instruments, Inc. assumes no liability for the customer's failure to comply with these requirements.

General Safety Procedures

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 insure 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.

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

All instrument fittings must be consistent with instrument specifications, and compatible with the intended use of the instrument.

CHECK FOR LEAK-TIGHT FITTINGS

Before proceeding to instrument set up, carefully check all plumbing connections to the instrument to insure leak-tight installation.

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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).

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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Chapter One
General Information

Introduction

The MKS Type 1449 Mass Flow Controller (MFC) accurately measures and controls the mass flow of gases, independent of gas pressure or temperature. The Type 1449 uses the MKS patented mass flow sensing technique for fast response, high accuracy, and stable zero and span calibration. It is designed to work in a system which includes a ± 15 VDC power supply, a readout instrument (an MKS readout/power supply, computer, or non-MKS readout), a regulated gas supply, and a processing chamber into which the gas flows. Figure 1 below shows a generic mass gas flow system.

Figure 1 : A Generic Mass Gas Flow System

The Type 1449 Mass Flow Controller utilizes an all metal, dual purpose valve (MKS Type 149), for mass flow rate control and leak-tight shut off ($< 5 \times 10^{-10}$ sccs He). The mass flow controller also incorporates a Type D shielded connector, metal cover, RF bypass capacitors, and proper layout to effectively minimize RFI and EMI interference. It is assembled in a class 100 environment and bag tested with helium. The outside to inside leak rate is less than 1×10^{-10} scc/sec. helium.

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How this Manual is Organized

This manual is designed to provide clear instructions on how to install, set up, and operate a Type 1449 Mass Flow Controller in a gas flow system. Please be sure to read the *Safety Procedures* section at the beginning of this manual before unpacking or using the Type 1449 Controller.

Chapter Two, *Installation*, explains environmental requirements and practical considerations to take into account when selecting the proper setting for the mass flow controller. Specific instructions are given in the *How to Unpack* section to insure that the integrity of the semiconductor clean Type 1449 Controller is maintained during unpacking. Once the mass flow controller is placed in its appropriate environment, follow the instructions in the *Set Up* section on mechanical and electrical connections.

The next chapter, *Operation*, provides the day to day operation procedures needed to use the Type 1449 MFC. The operating instructions are simple and straightforward, but should be adhered to so that the Type 1449 Controller can perform within the 0.5 % accuracy range it is designed to provide.

Chapter Four, *Theory of Operation*, explains in a general way how the Type 1449 Mass Flow Controller operates in a gas flow system. The *Maintenance* chapter mentions the few procedures necessary to keep the Type 1449 controller working well.

Appendix A lists product specifications for the Type 1449 Controller. Appendix B furnishes a list of companion products and supplies offered by MKS, and appropriate specifications for supplies the user may obtain from a non-MKS source. Appendix C lists the Gas Correction Factors for the most commonly used gases.

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Customer Support

Standard maintenance services are available at all of our regional MKS Calibration and Service Centers in North America, Europe, U.K., Japan, and Korea. MFC's can receive new seals, a range change (if needed), and re-calibration. As an extended courtesy, 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 1449 instrument, or to obtain information about companion products MKS offers, contact any authorized MKS Service Center. If it is necessary to return the instrument to MKS, please obtain an ERA Number (Equipment Return Authorization Number) from the MKS Service Center before shipping. The ERA Number expedites handling and assures 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.

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Chapter Two
Installation

The environment in which an instrument is placed will generally effect its performance. Since the 1449 is a premium MFC, attention to installation details is important.

Environmental Requirements

1. The ambient temperature must remain between 15 to 40°C.

   If the ambient temperature goes outside of these limits while the Type 1449 Controller is operating, control of the sensor will be compromised, and the zero and span coefficients will increase by 1 to 2 orders of magnitude.

2. The ambient air pressure must remain at atmosphere.

   A minimum inlet pressure of 20 psig is required to insure proper gas flow through the controller.

3. The maximum gas inlet pressure is 150 psig.

4. The power input required is ± 15 VDC.

   A. The maximum voltage/current at startup is ± 15 VDC @ 300 mA.

   B. The typical steady state voltage/current should be ± 15 VDC @ 160 mA.

5. The air pressure required to remove the shut-off is 60 - 100 psi.

How to Unpack the Type 1449 Controller

The Type 1449 Controller is assembled, leak tested with helium, and calibrated in a class 100 clean room environment. The instrument is double bagged in this environment to insure maintenance of its particle free condition during shipment. It is very important to remove the bags according to clean room etiquette. Use these instructions as a minimum level for clean room standard procedures.

1. Remove the outer bag in an ante room (garmenting room), or transfer box.

   Do not allow this outer bag to enter the clean room.

2. Remove the inner bag in the clean room.

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Set Up

For use of the Flow Controller Series instruments with any equipment other than complimenting MKS modules, the manufacturers' specifications should be consulted for connection, and proper electrical and power characteristics.

CAUTION

The shut-off valve in the Type 1449 unit is internally operated with a high vacuum oil (DC 704). It is possible that after prolonged exposure to corrosive gases or many hundreds of thousands of on-off cycles, the valve's isolation diaphragm could fracture, thus releasing the inert silicone oil into the gas stream. The quantity released could be up to 5cc. Thus, the downstream manifold should be provided with a low point trap capable of collecting this oil if a leak should occur. Tests have shown that because of the extremely low vapor pressure (10^{-11} at room temperature), all the oil will be collected in the trap and will not show up in the processing chamber.

If a leak should occurr, the leak rate when the shut-off valve is on (conducting), and the control valve is off, will increase.

1. Place the Type 1449 Controller where it will be connected to a gas supply and process chamber.

   The controller may be placed in any orientation, but a horizontal position with the controller flat on its base plate is recommended.

   A. Be sure to allow for access to the trim pots (zero, full scale, and controller gain potentiometers).

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

      a. Straight Shielded connectors require approximately 3 inches in height.

      b. Right Angle connectors require approximately 2 inches in height.

2. Install the instrument in the gas stream such that the flow is in the direction of the arrow on the side of the Type 1449 Controller's base.

3. Make the pneumatic connection for the shut off valve to the 1/8 inch NPT fitting with a 1/8 inch NPT male-to-1/4 inch tube fitting. (Refer to Figure 3, page 10).

4. Connect the gas line from the gas supply to the 4VCR fitting for gas input on the Type 1449 instrument. (Refer to Figure 2, page 10).

   A. Be sure to connect the gas line to the 4VCR fitting such that the gas flow from the gas supply is in the direction of the arrow on the 1449 controller.

   B. When tightening the VCR Hex nuts, use two wrenches - one to keep the male from rotating and the other to tighten the female. If any of the flange joints rotate, a leak may develop.

5. Connect the gas line going to the process chamber to the 4VCR fitting for gas output on the Type 1449 instrument.

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A. Be sure to connect the gas line to the 4VCR fitting such that the gas flow to the process chamber is in the direction of the arrow on the 1449 controller.

B. When tightening the VCR Hex nuts, use two wrenches - one to keep the male from rotating and the other to tighten the female. If any of the flange joints on the MFC rotates, a leak may develop.

6. Make the electrical connection to the Type D connector on the top of the MFC. (Refer to Table 1, page 11 for Signal-Pin correspondence.)

   For use of the Type 1449 Controller 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*, for electrical requirements of the Type 1449 Controller.

7. Leak test the fittings. Do not proceed to the next step until no gas flow is assured.

Warm Up and Start Up

1. Apply power to the Type 1449 Controller

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

   After about one minute the output signal starts to drop rapidly. After about ten minutes the signal is less than +1% high, and after thirty minutes it is less than 0.2% high.

2. For optimum results, wait a minimum of 30 minutes for the MFC to warm up and stabilize.

CAUTION

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.

3. Check to make sure no gas flow is entering the MFC, and that the Type 149 controller valve is positively off (no air pressure).

4. Zero the controller by turning the zero pot. screw until the readout displays zero.

5. Apply gas to the controller and watch the readout.

   When gas is first applied to the MFC, a positive readout momentarily appears due to the gas flow into the instrument. Once the gas reaches the Type 149 controller valve, however, the flow is stopped and the readout should drop back to zero.

   A. If the output reading does NOT return to zero within a minute or so, a leak is indicated.

      Check all connections. If the leak is in the 1449 unit, contact MKS for service.

   B. If the output reading DOES return to zero, the system is tight.

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Figure 2: The 1449 Mass Flow Controller

Figure 3: View of the Valve on the 1449 MFC

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Pinout of the 1449

Pin Number	Signal
1	Valve Test Point
2	Flow Signal Output
3	Valve Close
4	Valve Open
5	Power Common
6	- 15 VDC
7	+ 15 VDC
8	Setpoint Input
9	No Connection
10	Optional Input
11	Signal Common
12	Signal Common
13	No Connection
14	No Connection
15	Chassis Ground

Table 1: 1449 Controller Pinout

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Figure 4: Functional Flow Chart for the 1449 MFC

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Chapter Three
Operation

Operating Instructions

To create a controlled flow within the MFC, two inputs are required. Air pressure of 60-100 psi must be supplied through the 1/8 inch NPT fitting on the valve. A setpoint signal of 0-5 VDC must be supplied through the Type D electrical connector.

NOTE: A *valve close* or *valve open* signal sent through the Type D connector overrides the setpoint command, and closes or opens the control portion of the valve. It does not, however, directly activate the shutoff valve.

Good flow is initiated by following either of the two methods described below.

1. To initiate flow immediately:
   A. At the same time, supply air pressure (60-100 psi) through the 1/8 inch NPT fitting on the valve, and a setpoint (0-5 VDC) through the Type D connector.

      Assuming a fast acting air signal (less than 0.5 seconds to open the valve), flow will be stable to 2% of setpoint within 3 seconds.

2. To set up the MFC for proper flow, but delay the flow initiation:
   A. At the same time, send a setpoint (0-5 VDC), and a *valve close* command through the Type D connector.
   B. When flow is desired, supply air pressure (60-100 psi) to the 1/8 inch NPT fitting on the valve, and remove the *valve close* command.

To increase the speed at which the MFC reaches setpoint:

In special applications where speed to setpoint is of paramount concern, it is possible to apply the setpoint, or remove the *valve close* signal slightly before air pressure is supplied to the 1/8 inch NPT fitting. The lead of the setpoint command (or removal of the *valve close* signal) may be in the order of 100 to 1000 milliseconds. The correct lead must be determined experimentally, and will be highly application dependent.

***A soft close* condition:**

"Soft close" is that condition where air pressure is supplied to the valve thereby lifting the "hard close" actuator and where there is no driving current to the valve coil. In this state the MFC will flow typically <0.2 sccm, but is guaranteed to flow less than 1% of F.S. or 1 sccm, whichever is larger. There will be no valve drive current when there is a "valve closed" signal and/or no set point signal.

A *hard close* condition:

A "hard closed" condition is present whenever there is no air pressure to the shut-off valve. This condition overrides all other commands.

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Using the Meter and the Gas Correction Factor

After zeroing, the 1449 MFC provides a 0-5 VDC output corresponding to 0-100 percent of flow calibration. The 1449 controller is calibrated at the factory with nitrogen., unless a special calibration has been called out at the time of ordering.

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. Appendix C lists the Gas Correction Factors for commonly used gases. Refer to Appendix C for the correct Gas Correction Factor, and use it in the following formula.

Formula for interpreting Output Signal for Non-Nitrogen Gas

EXAMPLE 1:

Output	=	3.22V
Range	=	500 sccm N_2
GCF (CCl_4)	=	0.31

NOTE: When using the GCF, the accuracy of the flow reading may vary by ±5 %.

NOTE: All MKS readouts have Gas Correction Controls to provide direct readout.

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If a direct reading of output is desirable, and the readout equipment has no GCF potentiometer, a proper input divider may be constructed.

EXAMPLE 2:

Using the values from Example 1, and assuming a 1 volt F.S. readout, the flow signal must be divided 3.22 to 1.00 volts

.

NOTE: Use 1% RN60C resistors, or better.

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Chapter Four
Theory of Operation

General Theory

A gas stream entering the Type 1449 MFC is divided into two parallel paths. One path directs the gas upward into a sensor tube, and the other path sends the gas through a range controlling changeable bypass. Gas leaving the sensor tube is directed downward and rejoins the stream from the changeable bypass. The combined gas stream then passes through the control valve and exits the instrument. The two paths possess an L/D ratio of greater then 100:1, insuring laminar flow.

The mass flow measurement is accomplished as a stream of gas is passed through the sensor tube. A fixed temperature profile is maintained within the sensor tube. As laminar flow occurs, energy is required to maintain the fixed temperature. The greater the mass of the flow, the greater the energy (voltage) required to maintain a fixed temperature. Thus, the change in voltage is a linear function of mass flow rate. This change in voltage signal is then amplified to provide a 0-5 VDC output (the flow signal).

The flow signal is sent to a readout device. In some systems the flow signal is also simultaneously sent to the flow controller (refer to Figure 4, page 11) and in other systems the signal is only sent to the readout device, which in turn passes the signal to the flow controller. In either case, the flow controller compares the flow signal with a 0-5 VDC setpoint and generates an error voltage. This error signal is then conditioned (derivative, proportional, and integral gain), amplified, and sent to the valve drive. The valve drive causes the MKS Type 149 controlling valve to increase or decrease the mass flow.

The controller error is a function of process dynamics, which means that the noisier the process the greater the average error (deviation of flow signal to the setpoint). However, the above measurement and controlling technique reduces the error of the controller to less than 0.05% of full scale flow under normal conditions.

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Analog Interface Signals

The accompanying Mass Flow Controller (MFC) uses the analog set point input to provide ‘‘smart’’ features that otherwise would require separate signal lines and associated output control devices.

1. When the set point input is less than +10mV 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 10mV 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.

2. 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 set point exceeds 10mV) the MKS MFC will quickly increase until the flow reading exceeds 50mV. Exceeding this 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 10mV *and* the flow signal drops below 50mV.

3. 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 capacitive 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. (Note: improper grounding can also cause discrepancies between flow rate and the set point.)

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Chapter Five
Maintenance

General

1. Keep the 1449 Mass Flow Controller powered at all times.

2. Periodically check the zero to establish its reliability.

NOTE: If power to the 1449 MFC is interrupted, the warm up period (30 minutes) should be observed.

CAUTION

The oil filling screw on the base of the valve, and the piston stop set screw at the top of the valve must NEVER be touched, as valve damage and subsequent voiding of the warranty will result.

Should any difficulties be encountered in the use of your instrument, it is recommended that you contact any authorized MKS Calibration and Service Center for repair instructions.

IF IT IS NECESSARY TO RETURN THE INSTRUMENT TO MKS FOR REPAIR, PLEASE CONTACT THE NEAREST MKS CALIBRATION AND SERVICE CENTER FOR AN ERA NUMBER (EQUIPMENT RETURN AUTHORIZATION NUMBER) TO EXPEDITE HANDLING AND ASSURE PROPER SERVICING OF YOUR INSTRUMENT. REFER TO THE LIST OF SERVICE CENTERS INSIDE THE BACK COVER OF THIS MANUAL.

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Appendix A
Product Specifications

Full Scale Ranges	100,200,500,1000,2000,5000,10,000 sccm
Accuracy	±0.5% Full Scale
Repeatability	±0.2% Full Scale
Resolution	0.05% of Full Scale
Zero Temperature Coefficient	<0.02% of F.S./^{O}C (200 ppm/^{O}C)
Span Temperature Coefficient	<0.10% of F.S./°C (1000 ppm/^{O}C)
Control Range	1% to 100% of F.S. (1 sccm minimum)
Response Time	3 sec. from 0 to within 2% of setpoint (<1 sec. point to point response time)
Max. Inlet Pressure	150 psig
Ambient Temperature	15 to 40^{O} C
Minimum Pressure Drop Required	15 PSID at 30 PSIA inlet pressure
Warm-Up Time (Zero)	<10 min. to 1.0% F.S. (30 min. to 0.2% F.S.)
Max. Flow Through Valve When Hard Closed	_10^{-10} scc/sec He
Air Pressure required to remove Hard Closure	60-100 psi
Leak Integrity	External <1x10^{-10} scc/sec He
Power Input Required	±15 VDC @ 160mA continuous 300 MA at start-up (about 15 min.)
Output Signal	0-5 VDC into >10K ohm_ load
Output Impedance	<1_ohm
Minimum Load Resistance	Less than 10K_ Setpoint Source
Command Signal [1]	0-5 VDC FOR 0-F.S.
Materials (wetted) Standard	316SS, Nickel, Inconel and Gold, 440 SST (optional: Tungsten Carbide ball replacing 440 SST ball)
Fittings Standard	Cajon ® 4 VCR ® (male)[2]

[1] Although the input impedance of the setpoint circuit is high, we recommend a low setpoint drive signal impedance for good noise immunity when the equipment is used in a high RFI or EMI environment.

[2] Cajon ®, VCR ® are registered trademarks of Cajon Company, Macedonia, OH.

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

Table 2: Product Specifications

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Appendix B
Companion Products and Cables

Companion Products

Type 246 Power Supply/Display

Type 247 Power Supply/Readout Unit

Type 147 Mass Flow Programmer/Display

Microcal-F Flow Controller Calibration System

Califlow A-150 Primary Standard

Types 1159/1161 Mass Flow Controllers (in standard 3" lengths)

Type 1259 Mass Flow Controller (for general purpose applications)

Interface Cables

Certain interface cables can be supplied by MKS, or the customer may choose to make up their own according to individual needs, provided the appropriate specifications contained herein are maintained.

Interface Cables for Non-MKS Power Supplies/Readouts

Shielded cable assemblies, in a nominal 10' (3M) length, with one end terminated in "flying leads" (pigtail) fashion are also available.

Ribbon cable assemblies in a nominal 10' (3m) length, with one end terminated with a right angle mating female "D" connector, are also available.

NOTE: 1) Shielded cable assemblies are recommended, especially if the environment contains high RFI noise.

NOTE: 2) Be sure to provide adequate clearance for cable assemblies:

Straight shielded connectors require approximately 3" height.

Right Angle connectors require approximately 2" height.

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Appendix C
Gas Correction Factors

GAS	SYMBOL	SPECIFIC HEAT,Cp cal/g°C	DENSITY g/l @ 0°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
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

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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
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

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GAS	SYMBOL	SPECIFIC HEAT,Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
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	0.74
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
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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