114173-P1
Rev D, 9/96
Instruction Manual

# MKS Type 1500 Series
# Mass-Flo® Controller

Six Shattuck Road
Andover, MA 01810-2449
(800) 227-8766 or (978) 975-2350

Fax: (978) 975-0093
E-mail: mks@mksinst.com
Web site: http://www.mksinst.com

# WARRANTY

Type 1500 Series 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.

For the period commencing with the date of shipment of this equipment and ending one year later in the case of defects in materials and workmanship, but two years later in the case of failure to comply with the date-related operations warranty, **MKS** will, at its option, either repair or replace any part which is defective in materials or workmanship or with respect to the date-related operations warranty without charge to the purchaser. The foregoing shall constitute the exclusive and sole remedy of the purchaser for any breach by **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, USA.

This warranty does not apply to any equipment which has not been installed and used in accordance with the specifications recommended by **MKS** for the proper and normal use of the equipment. **MKS** shall not be liable under any circumstances for indirect, special, consequential, or incidental damages in connection with, or arising out of, the sale, performance, or use of the equipment covered by this warranty.

**MKS** recommends that all **MKS** pressure and flow products be calibrated periodically (typically every 6 to 12 months) to ensure accurate readings. When a product is returned to **MKS** for this periodic re-calibration it is considered normal preventative maintenance not covered by any warranty.

THIS WARRANTY IS IN LIEU OF ALL OTHER RELEVANT WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING THE IMPLIED WARRANTY OF MERCHANTABILITY AND THE IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, AND ANY WARRANTY AGAINST INFRINGEMENT OF ANY PATENT.

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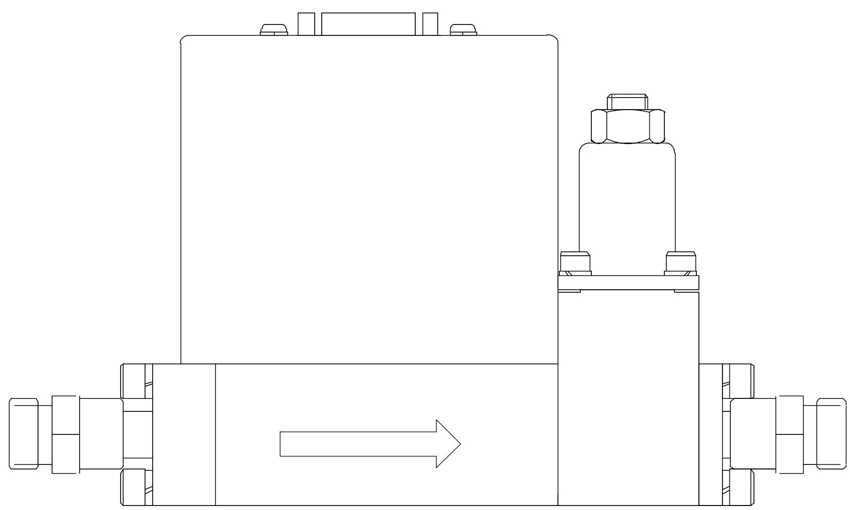
# Mass-Flo® Controller



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# Safety Procedures and Precautions

**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.**

**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 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 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 direction.

**CHECK FOR LEAK-TIGHT FITTINGS**

Before proceeding to instrument set up, carefully check all plumbing connections to the instrument to insure 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.

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# Chapter One: General Information

## Introduction

The MKS Mass-Flo® Meter and Controller 1500 Series of instruments accurately measure and control the mass flow rate of gases. Based on a patented flow sensing technique (U.S. Patent Nos. 4464932, 4679585; Foreign Patents - Patents Pending), the flow controllers provide continuous monitoring and closed-loop control of gas flows. Because it is *mass* flow that is being measured, it is not necessary to correct for variations in gas temperature and pressure. The instruments also utilize a patented *balanced forces* control valve to provide fast response and to eliminate oscillation.

The MKS 1500 Series Flow Meter/Controllers are designed for general, industrial, and process applications within a range of 20 to 200 slm (400 scfh). The flow meter/controllers offer excellent RFI protection, digital open/close valve commands, and a safety shutoff feature for set points under 0.2% of Full Scale. Accuracy is better than 1.0% of Full Scale in most ranges and the settling time is less than 2 seconds (to within 2% of set point).

The 1500 Series includes the following types:

- Type 1559A Mass Flow Controller (valve normally *closed*)
- Type 1562A Mass Flow Controller (valve normally *open*)
- Type 558C Mass Flow Meter configured in Types 1559A and 1562A

## How This Manual is Organized

This manual is designed to provide instructions on how to set up and install 1500 Series Flow Meter/Controller instrument.

**Before installing your 1500 Series Flow Meter/Controller 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 environmental requirements and practical considerations to take into account when determining the location for the flow instrument. Once the mass flow controller is placed in an appropriate environment, refer to the mechanical dimensions in the *Set Up* section and follow the instructions for gas line connections.

Chapter Three gives an *Overview* of the 1500 Series Flow Meter/Controller instruments. It describes the components of the instruments and lists the electrical pinouts of their Type "D" connectors.

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

Chapter Five, *Theory of Operation*, describes in a general way how the Flow Meter/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 adjust the control valves in the 1559/1562 units.

Chapter Seven, *Troubleshooting,* contains a checklist for reference in the event that your unit does not produce consistently good results.

Appendix A lists *Product Specifications* for the Flow Meter/Controller instruments.

Appendix B shows *Type 558 Meter Dimensions and Mounting Holes.*

Appendix C provides *Gas Correction Factors* for the most commonly used gases.

## Customer Support

Standard maintenance 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 1500 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 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.

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

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# Chapter Two: Installation

## How To Unpack the 1500 Series Unit

MKS has carefully packed the Series 1500 Flow Meter/Controller 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.

## Environmental Requirements

Install and operate a 1500 Series Flow Meter/Controller according to the following requirements.

1. The normal ambient operating temperature should remain between 15° C and 40° C (59 to 104° F).

2. The maximum gas inlet pressure is 150 psig.

3. Maximum voltage/current at startup is:
   A. ± 15 VDC (± 5%) @ 300 mA for the meter (Type 558).
   B. ± 15 VDC (± 5%) @ 450 mA for the controllers (Types 1559/1562).

4. Typical steady state voltage/current should be:
   A. ± 15 VDC @ 200 mA for the meter (Type 558).
   B. ± 15 VDC @ 350 mA for the controllers (Types 1559/1562).

5. The warm-up time is 30 minutes.

6. For optimal performance, the instrument should remain powered at all times.

For additional 1500 Series Flow instrument requirements refer to Appendix A, *Product Specifications,* page 35.

# Setup

Follow these guidelines when setting up a 1500 Series Flow instrument.

1. Place the Flow Meter/Controller where it will be connected to a gas supply and process chamber.

2. Mount the flow component 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 adjusted according to the instructions in *Warm Up and Start Up,* page 19.

3. Install the instrument 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.

   A. Straight Shielded connectors require approximately 3” height.

   B. Right Angle connectors require approximately 2” height.

5. Be sure to allow access to the zero potentiometer and to the coil nut at the top of the control valve.

Refer to Figures 1 and 2, page 11, for the location of the mounting holes and the overall dimensions.

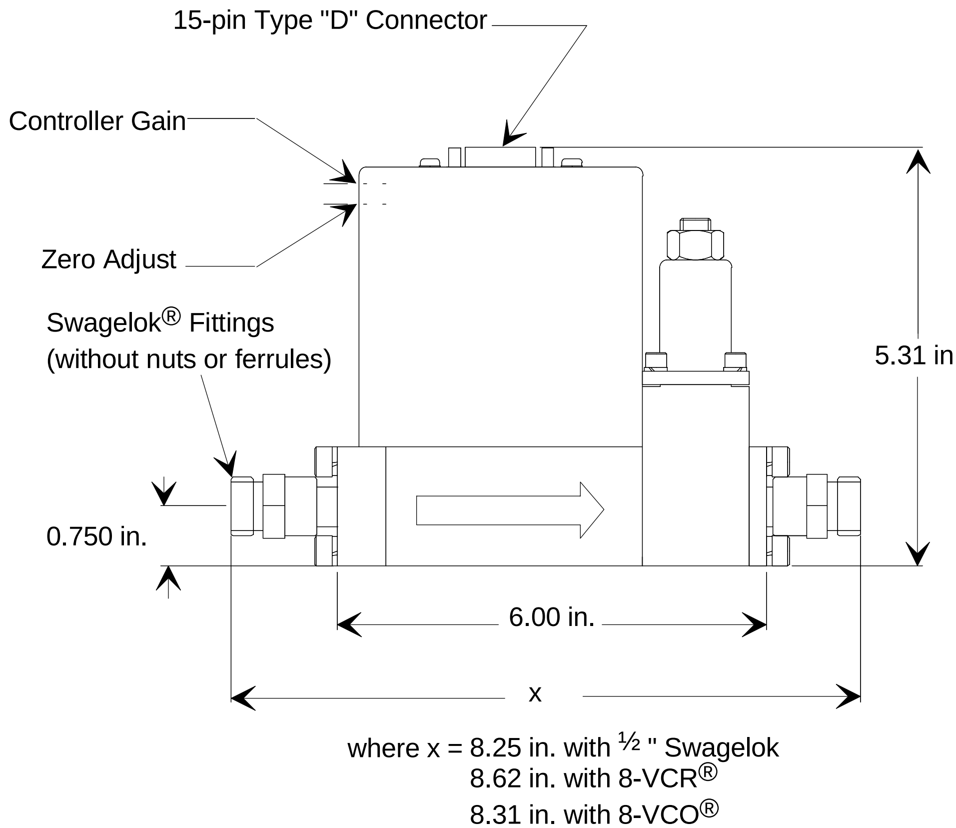


Figure 1: 1500 Series Flow Controller Dimensions

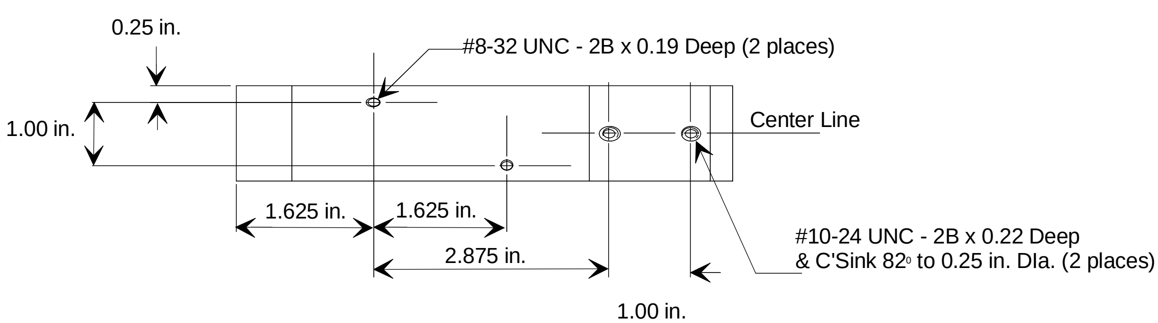


Figure 2: 1500 Series Flow Controller Mounting Holes

**Note**

Refer to *Appendix B: Type 558 Dimensions*, page 37, for mechanical dimensions of the meter only.

# Gas Line Connections

### Standard Fittings

Swagelok® compression fittings (½ inch) are standard. To connect the 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. Refer to Figure 3.

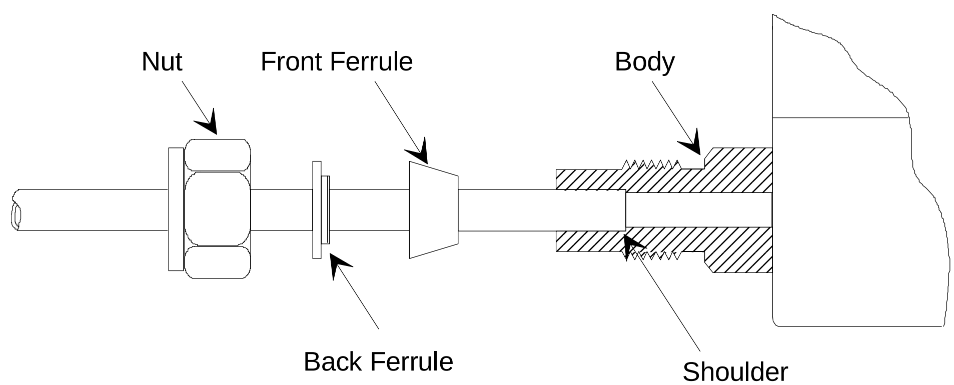


Figure 3: Standard Compression Fittings

**Caution**

**Tighten the nut only 1¼ turns past finger tight. When remaking, tighten the nut only ⅙ turn. Overtightening may damage the tubing and fitting, and destroy a normally leak-tight fitting.**

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

### Optional Fittings

Cajon® 8-VCR® (male) and Cajon 8-VCO® (male) fittings are available as options, when specified. Refer to the manufacturers' specifications for installation information.

### Standard Materials

Standard wetted materials are 316L SST and nickel with Viton® seals.

### Optional Seals

Buna-N, Kalrez®, and Neoprene® seals are available as options, when specified.

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# Chapter Three: Overview

## 1500 Series Mass-Flo Meter/Controllers

The Mass-Flo Meter and Controller 1500 Series of instruments are designed to provide accurate and repeatable control of gas flow. These Flow Meters and Controllers measure flow by measuring the power required to maintain a pre-established temperature profile along a laminar flow sensor tube. In the flow controllers, the metered flow rate signal is then compared to the set point signal by internal PID (Proportional, Integral, Derivative) control electronics. The control electronics generate the appropriate current to drive the control valve to meet the desired flow rate.

The control valves used with the 1500 Series Flow Controllers are magnetically actuated proportioning control valves. These valves are capable of providing very precise control of gaseous flow with excellent control resolution. These high flow rate controllers use a patented balanced-forces control valve. Unlike pilot valves and other magnetically actuated solenoid valves, this valve enables fast response to set point changes, without oscillation, over a wide range of inlet pressures.

### 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 ensures that no friction is present and makes precise control possible. In the Type 1559 controller (valve *normally closed*), the control current is used to *lift* the armature *from* the seat allowing a controlled flow of gas. In the Type 1562 controller (valve *normally open*), 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 seating material. Refer to *Valve Adjustment,* page 27, for instructions on how to adjust the control valve.

## Electrical Connections

For use of the Flow Meter/Controller Series instruments with other equipment (for example, a power supply/readout unit), consult the manufacturers' specifications for connection, and for proper electrical and power characteristics. Refer to *Appendix A: Product Specifications*, page 35, for electrical requirements of the 1500 Series Flow instruments. Table 1 lists the pin assignments for the Type “D” connector.

| **Type “D” Connector Pinout** | |
|---|---|
| **Pin Number** | **Assignment** |
| 1* | Valve Drive/Test Point |
| 2 | Flow Signal Output (+) |
| 3* | Valve Close Input |
| 4* | Valve Open Input |
| 5 | Input Power Common |
| 6 | -15 VDC Power Input |
| 7 | +15 VDC Power Input |
| 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 |
| ***Pin Numbers. 1, 3, 4, 8, and 10 apply to the controllers only.** | |

Table 1: Type “D” Connector Pinout

**Note**

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 ohm source impedance referenced to pin 12 can be used to supply a set point signal to pin 8.

A “No Connection” pin assignment refers to a pin with no internal connection.

### Valve Drive/Test Point

The Valve Drive/Test Point signal (pin 1) monitors the voltage sent from the controller to the control valve. A fully open valve is indicated by a -12 VDC signal, and a fully closed valve is indicated by a +12 VDC signal. Typical control voltages are between -5 VDC and +5 VDC.

### Optional Input

The Optional Input signal (pin 10), can either read or override the flow signal to the valve control circuit. A 0 to 5 VDC set point signal sent to pin 10, enables the control valve in the 1559 or 1562 instruments to control another parameter, for example, pressure. Using this example, the set point signal to the flow instrument becomes a pressure set point. The metered flow output is still available on pin 2, but it is not used to control the flow rate.

## Interface Cables

To meet the electromagnetic compatibility requirements of the CE Mark specification, a metal braided, shielded cable must be used (CB1559S-2). The “S” after the cable type designation indicates a metal braided shielded cable.

**Note**

1. Metal, braided shielded cables are required to meet CE Mark specifications.
2. To order a metal, braided, shielded cable, add an “S” after the cable type designation. For example, to order a standard connection cable, for a Type 247 unit, use part number CB1559-2; for a metal, braided, shielded cable use part number CB1559S-2.

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# Chapter Four: Operation

## Warm Up and Start Up

To put the Flow Controller Series instrument into operation, follow the steps below.

1. Leak test the fittings on the Flow Meter/Controller instrument using standard leak test procedures. Do not proceed to the next step until no gas flow is verified.

2. Plug the Type “D” connector into a power supply/display.

3. Apply power to the system.

   When power is first applied, the output signal jumps to +7.5 VDC. After being powered for a minute or so, the output signal starts to drop rapidly as the sensor tube heaters reach control temperature. Measurements can be taken (within 10 minutes of turn-on) as the heaters stabilize and the output approaches zero. After thirty minutes from power-up, the instrument is ready to be zeroed.

**Warning** **If the instrument is being used to control dangerous gases, it should be fully warmed up before applying the gases to the system. If necessary, a positive shutoff valve can be employed to ensure that no erroneous flow occurs during the warm up period.**

4. Ensure that no gas flow is entering the Flow Meter/Controller.

5. Be sure the instrument is in the same plane of orientation as it will be when mounted in the system (if it is not already mounted into position).

6. Zero the output of the instrument by turning the zero pot screw (located on the input side of the controller) until the readout displays zero.

***MKS Supplied Display Equipment***

When used with MKS supplied display equipment, it is necessary to zero only at the indicator, as this zeroed signal is sent to the controller section of the 1500 Series flow instrument.

***Customer Supplied Display Equipment***

As noted above, the controller section of the 1500 Series instrument compares its own flow signal with the set point signal. The difference between these signals is the error, or zero offset. The controller then sends an output signal to position the valve to reduce this error to zero. Therefore, if using non-MKS readout equipment, it is necessary to zero the flow controller's output using the flow controller's zero potentiometer. Failure to properly zero the instrument results in a disparity between the set point and flow signals, which is equal to the zero offset.

7. Apply gas to the controller.

   When gas is first applied to the controller, a positive readout momentarily appears due to the gas flow into the instrument. Once the gas reaches the user shutoff 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 Flow Meter/Controller instrument, contact MKS for service. Refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

   B. If the output reading *does* return to zero, the system is tight and ready for normal operation.

## Set Point Command

The 1500 Series of Flow instruments use an analog set point input to provide *smart* features that otherwise would require separate signal lines and associated output control devices. A set point command signal greater than 10 mV is required for the flow controller to generate an output. Similarly, if the set point input is less than 10 mV, the control valve is driven fully closed.

### Adjusting Speed to Set Point

The 1559/1562 Flow Controllers have a *fast wake-up* feature that allows the flow rate to quickly rise to the set point value, providing a very rapid response (less than 2 seconds) to a small set point command. At set point initiation (when the set point exceeds 10 mV), the 1500 Series instruments quickly increase the drive current to the control valve until the flow reading exceeds 50 mV. 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* feature remains off until the set point signal drops below 10 mV *and* the flow signal drops below 50 mV.

## Valve Override

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

> 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.

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.

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# Chapter Five: Theory of Operation

## Flow Path

The MKS Flow Controller series of 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 Flow Meter, 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 MKS Flow Meter/Controller, 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 does not need to wait for a new temperature equilibrium to be established along the flow tube.

## Control Circuitry

The 1500 Series flow controllers use the above measurement technique and include a control circuit which provides a 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 typically 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 35, for more information.

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.

**Note**

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

## The Gas Correction Factor (GCF)

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 mass flow controller (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 = (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 |

Refer to *Appendix C: Gas Correction Factors,* page 39, for 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 Controls to provide direct readout.

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# Chapter Six: Maintenance

## Valve Adjustment

**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.**

All valves are 100% leak-checked at the factory prior to shipment. Should unacceptable leakage occur as a result of different operating conditions or normal wear, follow the instructions in the next two sections (depending on the controller type) to adjust the valve. Refer to Figure 4, page 28.

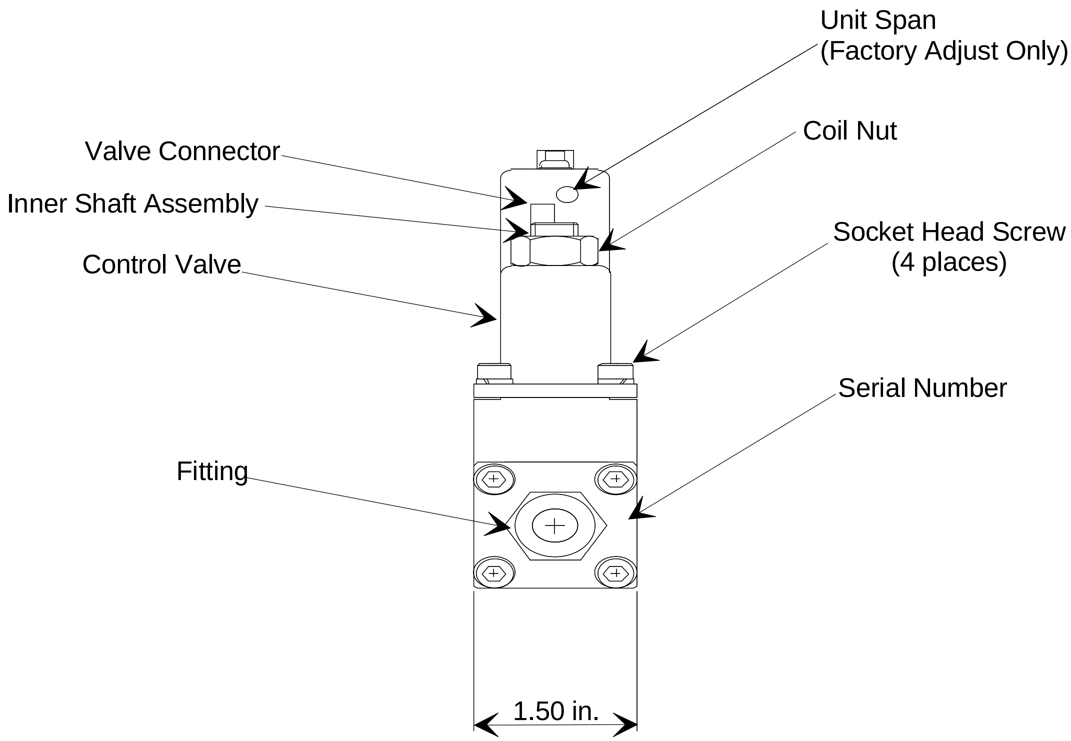


Figure 4: Side View of the 1500 Series Flow Controller

### 1559 Flow Controller

The valve used in the Type 1559 Flow Controller is 100% leak-checked at the factory prior to shipment. The valve is leak-checked to a specification of maximum closed conductance less than 0.1% of F.S. across the valve seat. This specification is based on the valve being positioned vertically, base down, and *no* power or set point command signal applied.

To detect leakage using a flow controller valve adjustment bench test, perform the following steps.

1. Disconnect the valve from its controller (valve bias misadjustment may hold the valve partially open).

2. Loosen the $^{11}/_{16}$ ” coil nut located just above the solenoid.

3. Use a $^{5}/_{32}$” allen wrench to loosen the four socket head screws on the body of the control valve.

4. Use a $^{3}/_{16}$ ” allen wrench to turn the inner shaft assembly, 5° to 10° at a time. Observe the change in leakage at each adjustment until there is no leakage present.

**Caution**

**This adjustment is delicate and any more than 45° turn from nominal (factory setting) will be excessive.**

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

5. Tighten the socket screws and coil nut.

6. Check the leak rate.
   - A. Repeat steps 1 through 5 if the leak is unacceptable.
   - B. The acceptable leak rate is $\leq$ 0.1% F.S.

7. Drive the control valve fully *open* for 15 minutes.

8. Following the warm up period, test the flow controller to ensure that full scale can be reached.
   - A. If full scale flow cannot be reached, repeat steps 1 through 7.
   - B. If leakage cannot be corrected with this adjustment procedure, return the unit to MKS for servicing.

## 1562 Flow Controller

The valve used in the Type 1562 Flow Controller is 100% leak-checked at the factory prior to shipment. The valve is leak-checked to a specification of maximum closed conductance less than 1.0% of F.S. across the valve seat. This specification is based on the valve being positioned vertically, base down, and *full* power applied.

To detect leakage using a flow controller valve adjustment bench test, perform the following steps.

1. Apply full power to the control valve (15 VDC @ 250 mA), by setting the controller to zero flow.

2. Loosen the $^{3}/_{16}$ ” coil nut located just above the solenoid.

3. Use a $^{5}/_{32}$ ” allen wrench to loosen the four socket head screws on the body of the control valve.

4. Use a $^{3}/_{16}$ ” allen wrench to turn the inner shaft assembly, 5° to 10° at a time. Observe the change in leakage at each adjustment until there is no leakage present.

**Caution**

**This adjustment is delicate and any more than 45° turn from nominal (factory setting) will be excessive.**

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

5. Tighten the socket screws and coil nut.

6. Check the leak rate.

   A. Repeat steps 1 through 5 if the leak is unacceptable.

   B. The acceptable leak rate is ≤ 1.0% F.S.

7. Drive the control valve fully *closed* for 15 minutes.

**Warning**

**Be careful not to touch the coil once the instrument is in operation, as the temperature of the coil can become very hot.**

8. Following the warm up period, test the Flow Controller to ensure that full scale can be reached.

   A. If full scale flow cannot be reached, repeat steps 1 through 7.

   B. If leakage cannot be corrected with this adjustment procedure, return the unit to MKS for servicing.

## Repair

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

**Note**

If it is necessary to return the instrument to MKS for repair, please contact any of the MKS international service/calibration centers listed on the inside of the back cover for an ERA (Equipment Return Authorization) number to expedite handling and ensure proper servicing of your instrument.

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# Chapter Seven: Troubleshooting

## Troubleshooting Chart

| Troubleshooting Chart | | |
|---|---|---|
| **Symptoms** | **Possible Cause** | **Remedy** |
| Over-range at zero (after warm-up) | Flow is on and above meter range<br>Electronics malfunctioning | Isolate Flow instrument<br>Return for service |
| No output, or over-range at zero (after warm-up) | Improper cable<br>Electronics malfunctioning | Check cable for type<br>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 in *Warm Up and Start Up*, page 19 |
| Controller does not function | Valve misadjusted<br>Valve override function applied<br>Electronics malfunctioning | Readjust valve<br>Disconnect valve override<br>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<br>Return for service |
| Unit is non-linear or has erratic operation | Heater winding out of regulation | Return for service |

*Table continued on next page*

| Troubleshooting Chart (Continued) | | |
|---|---|---|
| **Symptoms** | **Possible Cause** | **Remedy** |
| Oscillation | Too high a controller gain setting | Reduce (turn counter-clockwise) |
| | 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 |

# Appendix A: Product Specifications

## General Specifications

| | |
|---|---|
| CE Mark Compliance[1] | EMC Directive 89/336/EEC |
| Full Scale Ranges (nitrogen equivalent) | 20, 50, 100, 200 slm |
| Control Range (controllers only) | 1.0 to 100% of F.S. |
| Accuracy[2] | ±1.0% of F.S. |
| Repeatability | ±0.2% of Rdg. |
| Resolution (measurement) | 0.1% of F.S. |
| Temperature Coefficients<br>Zero<br>Span | <br><0.05% of F.S./° C<br><0.10% of Rdg./° C |
| Normal Operating Temperature Range | 15 to 40° C (59 to 104° F) |
| Warm-up Time | 30 minutes |
| Controller Settling Time (to within 2% of set point) | <2 sec.[3] |
| Meter Settling Time (to within 2% of set point) | <500 milliseconds |
| Maximum Inlet Pressure | 100 psig (250 psig optional) |
| Pressure Coefficient | 0.005% of Rdg./psi |
| Minimum Pressure Drop (at atmosphere) across Flow Meter | 0.15 to 1.25 psid (dependent upon range) |

[1] Requires a metal braided shielded cable

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

[3] Gain can be adjusted to increase settling time

## Electrical Specifications

| | |
|---|---|
| Input Voltage/Current Required | |
| Max. at start up (first 5 sec) | ±15 VDC (±5%) @ 300 mA (558 meter)<br>±15 VDC (±5%) @ 450 mA (1559/1562 controllers) |
| Typical at steady state | ±15 VDC @ 200 mA (558 meter)<br>±15 VDC @ 350 mA (1559/1562 controllers) |
| Set point Command Signal (controllers only) | 0 to 5 VDC from < 20K ohm |
| Output Signal/Minimum Load | 0 to 5 VDC into > 10K ohm |
| Output Impedance | <1 ohm |
| Connector Type | 15-pin Type “D” |

## Mechanical Specifications

| | |
|---|---|
| Materials Wetted - Body Seals | |
| Standard | 316L sst, nickel (controllers only), Viton® |
| Optional | Buna-N, Neoprene®, Kalrez® |
| Leak Integrity (scc/sec He) | |
| External | $\leq 10^{-9}$ |
| Through closed valve | ≤0.1% of F.S. (1559 controller)<br>≤1.0% of F.S. (1562 controller) |
| Fittings | |
| Standard | Cajon® 8-VCR® (male) |
| Optional | ½” Swagelok®<br>Cajon 8-VCO® (male) |

# Appendix B: Type 558 Dimensions

## Dimensions

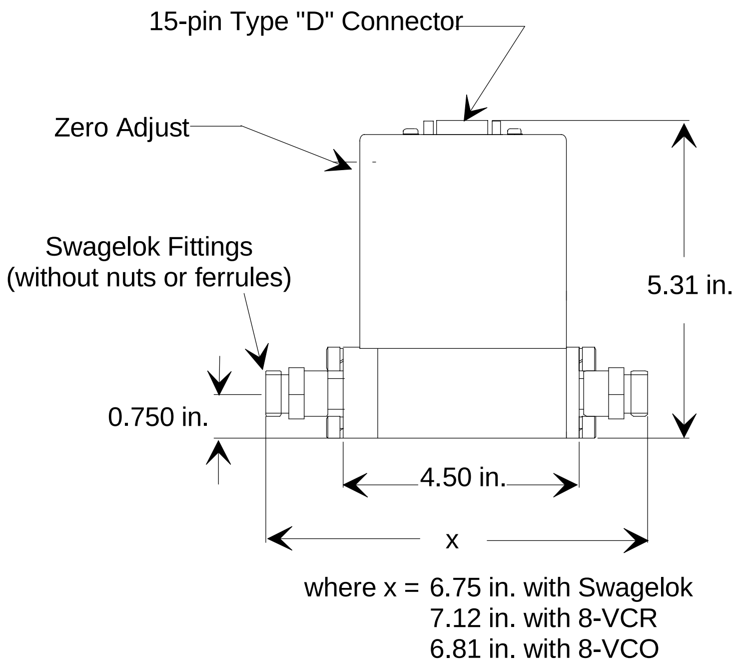


Figure 5: Type 558 Dimensions

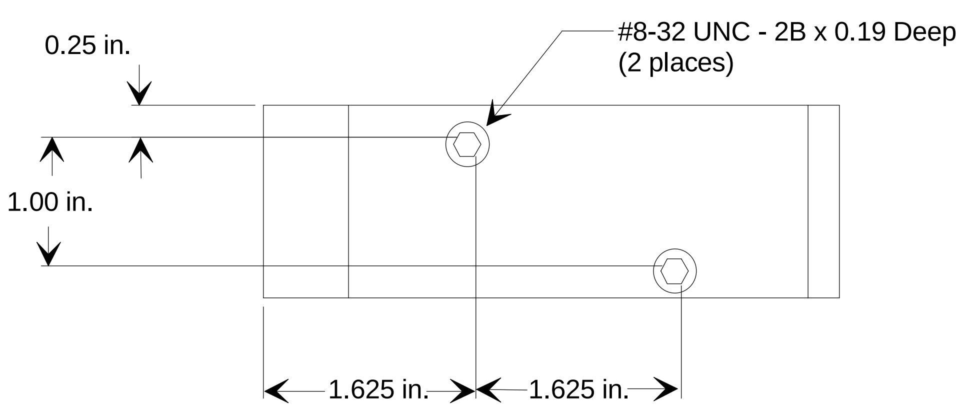


Figure 6: Type 558 Mounting Holes

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# Appendix C: Gas Correction Factors

## Gas Correction Factor Table

| 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[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°C | DENSITY g/l @ 0°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.

# Index