MKS

Instruction Manual

112488 - P1
REV A, 10/90

MKS Type 558A
Mass Flow Meter

MKS Type 1559A
Mass Flow Controller

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SECTION 1

USER RESPONSIBILITY

This equipment will perform in conformity with the description contained in this manual when operated, maintained, and repaired in accordance with the instructions provided. This equipment or any of its parts should not be altered without the prior written approval of MKS Instruments. The user of this equipment shall have the sole responsibility for any malfunction which results from improper use, faulty maintenance, damage, improper repair, or alteration by anyone other than MKS Instruments or a service facility designated by MKS Instruments.

Be sure that the equipment received conforms with your order specifications. The user is responsible for selecting equipment compatible with the gas in use, and conditions of pressure, temperature, flow, etc. Selection information can be found in MKS Instruments catalogs or technical data sheets. In addition, MKS Instruments sales representatives can aid in the selection process.

Carefully inspect the flow controller upon receipt to be sure that there is no damage or contamination. Pay particular attention to connection threads. While MKS Instruments assembles flow controller components to exacting leak-tight standards, you should also inspect for any loosening of parts which can occur in shipping. Loose parts may be dangerously propelled from a flow controller. If there are adverse signs, return to the supplier.

SECTION 2

SUMMARY OF WARNINGS AND CAUTIONS

The 558/1559 Mass Flow Meter/Controller is designed to measure/control gas flow rates to 200 SLM at pressures up to 150 psig. Accordingly, the instrument should be used with proper procedural and safety practices common to this type of equipment.

WARNING

Means there is a possibility of personal injury to the user.

CAUTION

Indicates there is a possibility of damage to the instrument or the system it is used in.

SUMMARY OF ALL WARNINGS AND CAUTIONS CONTAINED IN THIS MANUAL

WARNING

On initial turn on, the characteristics of the sensor are such that for about one minute the device will read a large error flow. If the meter is used to control dangerous gases they should not be applied before the meter has been fully warmed up. A positive shut-off valve can be employed to insure that no erroneous flow can occur during warm up.

CAUTION

Tighten nut only 1 1/4 turns past finger tight. When remaking, tighten nut 1/6 turn only. Over-tightening will damage tubing and fitting, and destroy a normally leak-tight fitting.

CAUTION

System should be properly leak checked before operation.

CAUTION

When using user supplied display equipment, it is important to note that the controller section of the 1559A 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.

SECTION 3

GENERAL DESCRIPTION AND SPECIFICATIONS

3.1 GENERAL

The MKS Flow Meter/Controller series of instruments accurately measures and controls the mass flow rate of gases. Based upon a patented measurement technique,* 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 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 complimentary MKS equipment (Models 112, 147, 247) or by user supplied devices. Refer to their respective manuals for the appropriate information.

* U.S. Patent No. 4,464,932

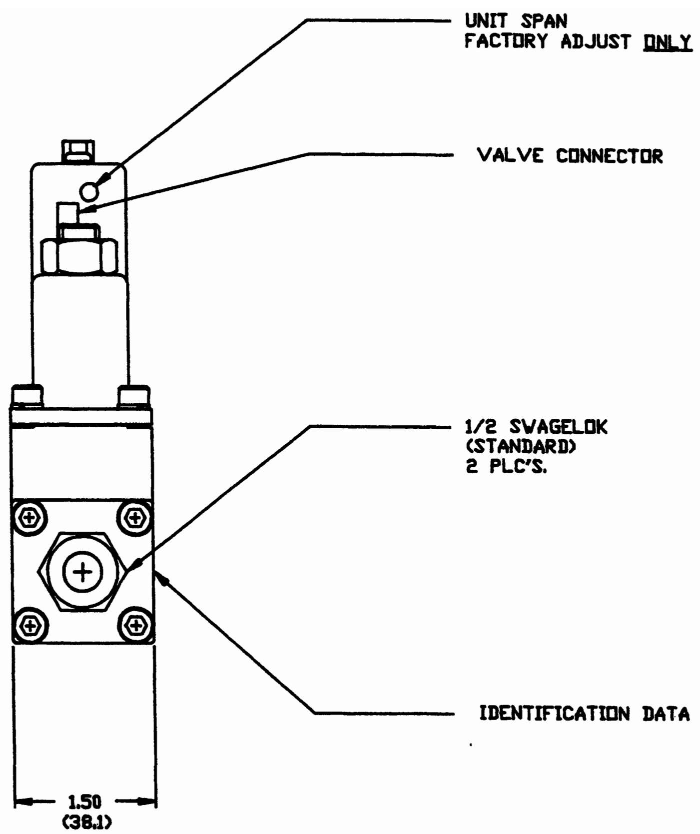


TABLE 1	
FITTING TYPE	DIM 'A'
SWAGELOK	8.25 (209.4)
8 VCR	8.62 (219.1)
8 VCO	8.31 (210.9)

(SEE NOTE 4.)

FIGURE 1
OUTLINE DWG
TYPE 1559A
(D111560-B)

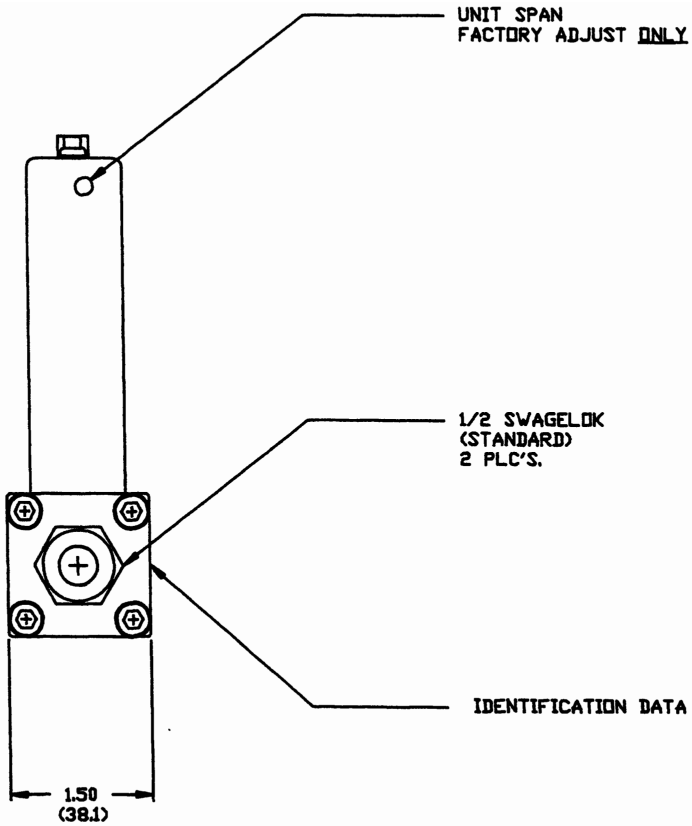
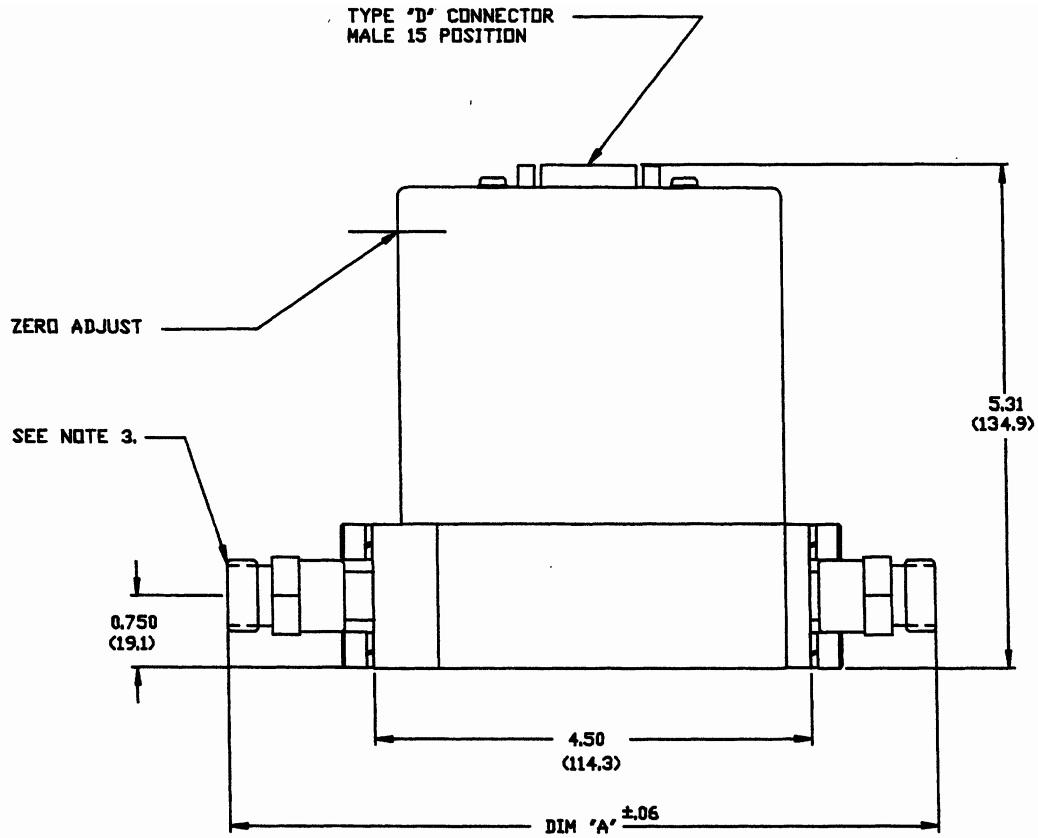
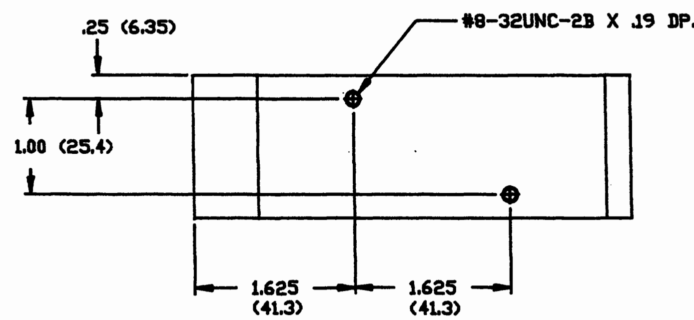


TABLE 1	
FITTING TYPE	DIM 'A'
SWAGELOK	6.75 (171.3)
8 VCR	7.12 (181.0)
8 VCO	6.81 (172.8)

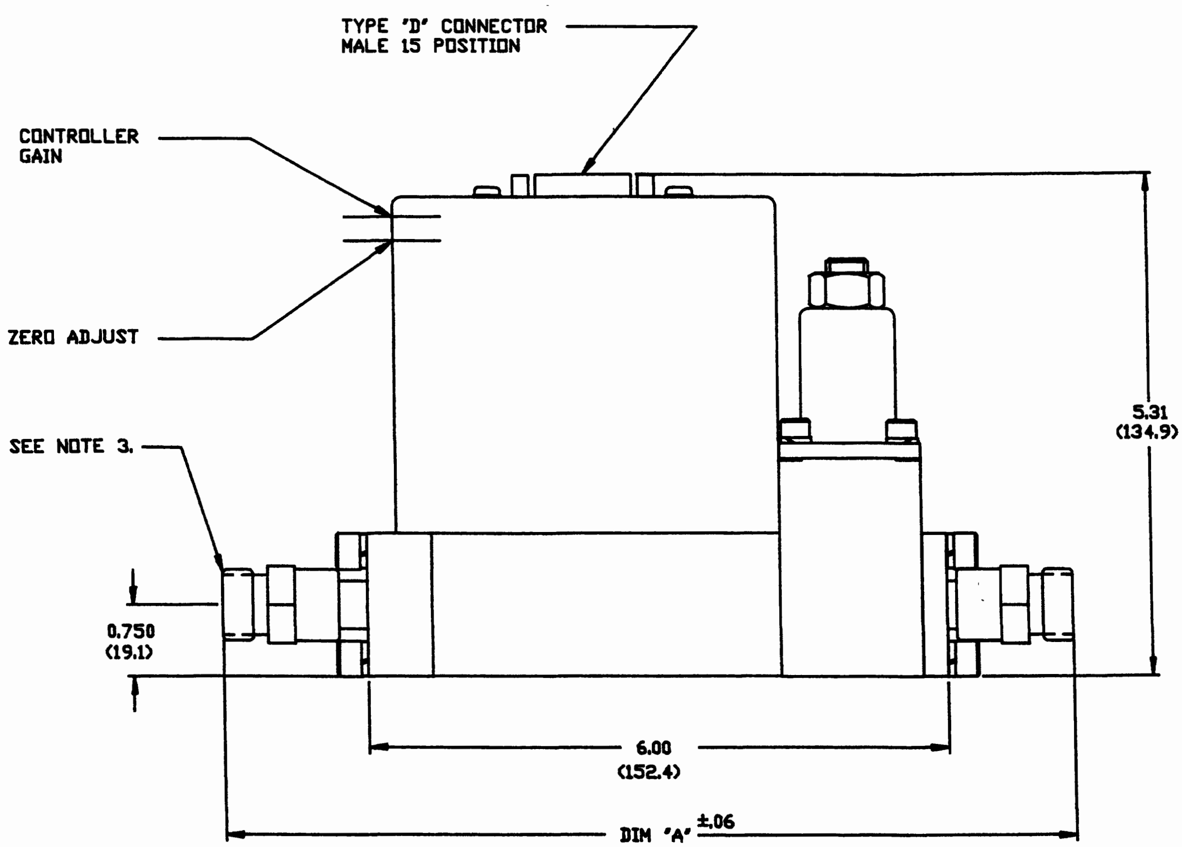
(SEE NOTE 4.)

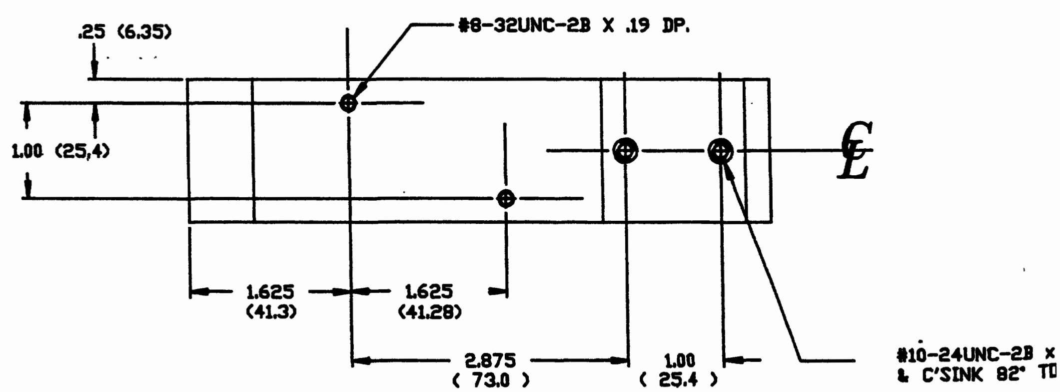
FIGURE 2
OUTLINE DWG
TYPE 558A
(D111600-B)





1 . UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE NOMINAL VALUES IN INCHES (MM REFERENCED).
2. 8 VCR FITTINGS: MALE ON BOTH ENDS, MATING GLANDS, GASKETS & NUTS ARE TO BE SUPPLIED BY CUSTOMI
3. SWAGELOK FITTINGS ARE SHOWN WITHOUT NUTS OR FERRULES.
4. DIM 'A': VCR DIMENSIONS ARE FROM MATING FACE TO MATING FACE.
SWAGELOK DIMENSIONS ARE FROM FITTING BODY END TO FITTING BODY END (LESS NUT).
EACH FITTING HAS A .50 MAX. TUBE INSERTION DEPTH.





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SWAGELOK DIMENSIONS ARE FROM FITTING BODY END TO FITTING BODY END (LESS NUTS).
EACH FITTING HAS A .50 MAX. TUBE INSERTION DEPTH.

3.2 SPECIFICATIONS

558A/1559A

Performance Specifications

Full Scale Ranges	20, 50, 100, 200, slm (nitrogen equivalent)
Control Range[1]	1.0 to 100% of F.S.
Accuracy (incl. non-linearity)[2]	±1.0% of F.S.
Resolution (measurement)	0.1% of F.S.
Temperature Coefficients	
Zero	<0.05% of F.S./°C (500 ppm)
Span	<0.10% of Reading/°C (1000ppm)
Operating Temperature Range	15° to 40°C
Warm-up Time	30 minutes
Settling Time[1]	<2 sec. to within 2% of set point (controller) gain can be adjusted to increase settling time
Maximum Inlet Pressure	150 psig.
Pressure Coefficient	0.005% of Reading/psi
Minimum Pressure Drop[3]	11 Torr at atmosphere (0.2 psi)

Electrical Specifications

Input Voltage/Current Required Max. at start up/typical at steady state	±15 VDC @ 500mA/250mA[1] ±15 VDC @ 150mA/100mA[3]
Input/Command Signal[1]	0-5 VDC from < 20K Ω source
Output Signal/Minimum Load	0-5 VDC into > 10K Ω source
Output Impedance	<1 Ω
Connector Type	15-pin, RF shielded Type "D"

Mechanical Specifications

Materials Wetted	
Standard	316SS, Nickel[1], Viton
Optional	Buna-N, Neoprene, or Kalrez
Leak Integrity	
External	≤ 10^{-9} scc/sec. He
Through closed valve[1]	≤ 0.1% of F.S.
Fittings	
Standard	½" Swagelok
Optional	Cajon 8 VCR (male), Cajon 8 VCO (male)

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1 Controller Only
2 Calibration Referenced to 760 Torr/0°C
3 Meter only

3.3 THEORY OF OPERATION

Flow Path

The MKS Flow Controller Instrument series 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 Flowmeter /Controller, 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 0-5 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 0-5 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 from 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 .05% of full scale flow.* 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 MKS Type 112, 147, and 247 are designed to power, provide set point, and display the output of the flow controller.

* This is the controller error and must not be confused with the instrument's measurement error (see specifications).

Control Valve

The control valve is a solenoid-activated, proportioning control valve. This valve eliminates oscillation and offers better time response as compared to other control valves through the use of a patented* "balanced-forces" design that automatically neutralizes pressure induced forces within the control valve.

An adjustable shaft assembly varies the closing force, thus allowing for small adjustments that may be necessitated because of swelling or aging of the elastomer seat. See Section 7.2 for additional details on orifice adjustment.

- CAUTION -

THIS ADJUSTMENT IS DELICATE AND MORE THAN ± 1/8 TURN FROM NOMINAL (FACTORY SETTING) WILL BE EXCESSIVE.

* U.S. Patent No. 4,796,854

SECTION 4

INSTALLATION

4.1 MECHANICAL INSTALLATION - MOUNTING

General

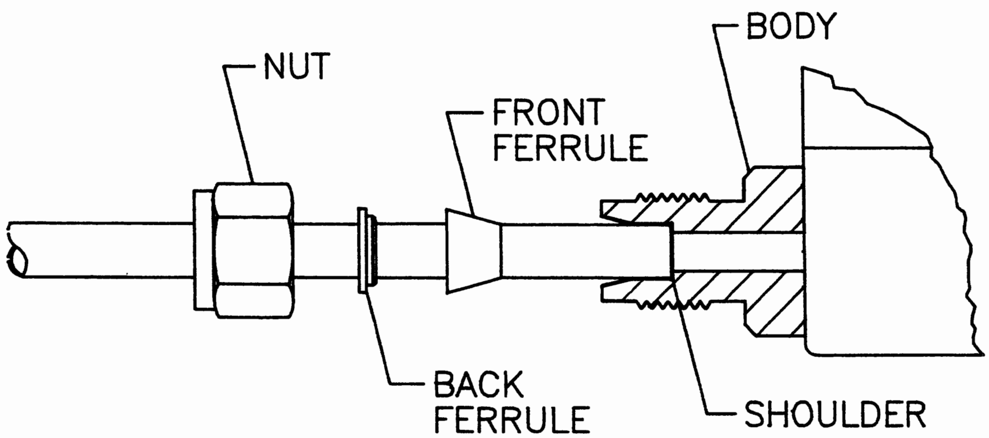
1) Horizontal mounting of flow components is preferred. Mounting of flow components in other than a horizontal position will cause a small zero shift, Section 5-1.

2) The instrument must be installed in the gas stream such that the flow will be in the direction of the arrow on the side of the base.

3) Be sure to allow for connector clearance, access to zero potentiometer, and access to the seat adjustment of the Control Valve.

4.2 Mechanical Installation - Gas Line Connection
Standard Fittings

Swagelok® compression fittings (½ inch) are standard. Tubing used 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 below.



- CAUTION -

Tighten nut only 1-1/4 turns past finger tight. When remaking, tighten nut 1/6 turn only. Over-tightening will damage tubing and fitting, and destroy a normally leak-tight fitting.

Optional Fittings

Cajon® male 8 VCR/8 VCO Fittings are available as a standard option.

Swagelok® is a registered product trademark of Crawford Fitting Company.

Cajon® is a registered product trademark of the Cajon Company.

4.3 Electrical Installation

For use of the Flow Meter/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. Refer to Section 3.2 for electrical requirements of MKS flow instruments.

Signal-Pin Correspondence of Type D connector.

Pin #	Signal
1	Valve Drive/Test Point * +
2	Flow Signal Output (0 to 5 VDC)
3	Valve Close Input *
4	Valve Open Input *
5	Power Common
6	-15 VDC Power Input
7	+15 VDC Power Input
8	Set Point Input (0 to 5 VDC) *
9	No Connection
10	Optional Input (0 to 5 VDC) * θ
11	Signal Common
12	Signal Common
13	No Connection
14	No Connection
15	Chassis Ground

* Controller only

\+ The Valve drive test point is used to monitor the voltage sent from the controller to the control valve. Values are -12 volts for fully open, +12 volts for fully closed. Typical control voltages are between -5 VDC and +5 VDC.

θ Optional Input - by sending a 0-5 VDC set point signal to the optional input pin, the control valve in the 1559 can be used to control another parameter (pressure, pH, etc.). The set point signal to the 1559 is then a pressure, pH, etc. set point. The metered flow output is still available on Pin #2, but is not used to control the flow rate.

Interface Cables

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

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

   For convenience, when a customer purchases 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.

2. Interface Cables for Non-MKS Power Supplies/Readouts

   - Shielded cable assemblies, in a nominal 10' (3M) length, with "D" Type connector on one end and terminated in "flying leads" (pigtail) fashion on the other end are available at nominal cost.

Note: 1) Shielded cable assemblies are recommended, especially if environment contains high EMI/RFI noise.

2) Be sure to provide adequate clearance for "D" Type cable assemblies:

- Straight Shielded connectors require approximately 3" height.

- Right Angle connectors require approximately 2" height.

SECTION 5

OPERATION

5.1 OPERATION OF MODEL 558A/1559A MASS FLOW CONTROLLER

After proper gas and electrical connections have been made, and proper gas correction factors have been applied (Section 6), the following procedure should be used to put the instrument into operation.

Warm-Up

When power is first applied, 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 zero periodically to establish its reliability.

WARNING

> On initial turn on, the characteristics of the sensor are such that for about one minute the device will read a large error flow. If the meter is used to control dangerous gases they should not be applied before the meter has been fully warmed up. A positive shut-off valve can be employed to insure that no erroneous flow can occur during warm up.

Zeroing

A. With no gas flow assured, zero the output of the MFC using the zero pot as marked on the input side. Note: Zero should be set with the flow instrument mounted in same plane of orientation that it will be mounted in system.

B. When used with an MKS 112, 147, or 247, it is only necessary to zero at the indicator, as this zeroed signal is sent to the controller section of the Flow Controller. If one runs out of adjustment in the readout, use the zero pot of meter/controller located on the upstream side.

MFC Use and Application of Gas Correction Factor (GCF)

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

CAUTION

System should be properly leak checked before operation.

B. This 0-5 VDC output should be interpreted for other gases as follows:

$$\frac{\text{Output}}{5.000\ \text{F.S.}} \times \text{Range of Instrument} \times \text{GCF*} = \text{Flow of Gas Used}$$

Example: Output = 3.22 VDC

Range = 500 sccm N_2

Gas Corr. Factor (CCL_4) = 0.31

Flow $= \frac{3.22V \times 500 \times .31}{5.000} = 100$ sccm CCL_4

C. If interpretation of the output is undesirable and the readout equipment has no GCF potentiometer, a proper input divider can be constructed. (Note: MKS Models 112, 147, 247 and instruments provide gas correction factor adjustment.)

D. The 0-5 VDC flow signal output comes from Pin 2 and is referenced to Pin 12 which is signal common.

E. Any appropriate 0-5 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.

F. The 1559A Controller has been equipped with a circuit that makes response to a small set point command very rapid (<2 secs.). At set points of less than 10%, there is overshoot. The integrated flow for this period of time divided by the elapsed time (1.5 secs.) will be less than the set point flow rate. If this overshoot is harmful to the process, consult the factory for disabling instructions.

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

Valve Override (Controller only)

Valve override permits the user 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.

NOTE: When using the 1559 with MKS supplied power supply/display equipment (an MKS 147 or 247), Note 2 does not apply. The 147 or 247B takes the flow signal from the 1559A, zeroes it with the front panel zero pot, and sends the signal back to the controller section of the 1559A on Pin 10.

CAUTION

When using user supplied display equipment, it is important to note that the controller section of the 1559A 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: The use of a set point voltage source of low impedance (<20K Ω) is necessary for concurrence between set point and flow signal output.

SECTION 6

TROUBLESHOOTING

6.1 TROUBLESHOOTING CHART

Symptoms	Possible Cause	Remedy
No signal output with gas flowing or overrange at zero (after warm up)	Flow is on and above meter range	Isolate Mass Flow Controller from Flow Source
	Cable improper	Check cable for type and damage
	Electronics	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 Section 3
Controller does not function	Valve misadjusted	Readjust valve
	Valve override function applied	Disconnect
	Electronics	Return for service
Unit produces large pressure drop or will not pass full flow	Clogged Sensor tube and/or bypass	Return for service
	Valve misadjusted	Readjust valve
Unit exhibits large temp. coef.	Electronics	Return for service
		Check placement of flow meter in hot system
Unit is non-linear or exhibits erratic operation	Electronics	Return for service
Oscillation	Too high a controller gain setting	Reduce (turn counter-clockwise)
	Incorrect upstream pressure regulator	Check manufacturers specifications

SECTION 7

MAINTENANCE

7.1 GENERAL

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

IF IT IS NECESSARY TO RETURN THE INSTRUMENT TO MKS FOR REPAIR, PLEASE CONTACT ANY MKS CALIBRATION/SERVICE CENTER LISTED ON THE INSIDE OF THE BACK COVER FOR AN ERA NO. (EQUIPMENT RETURN AUTHORIZATION NUMBER) TO EXPEDITE HANDLING AND ASSURE PROPER SERVICING OF YOUR INSTRUMENT.

7.2 ORIFICE ADJUSTMENT - 1559 FLOW CONTROLLER ONLY

All control valve seals are 100% leak-checked at the factory prior to shipment. With no power applied to the control valve, the valve should have a leak rate of less than 0.1% F.S. when the valve is positioned vertically, base down, and 1 atmosphere differential pressure is applied. Should unacceptable leakage exist because of different operating conditions or normal wear, adjustment is achieved as follows:

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

2. Loosen the 11/16" (across flats) coil nut located just above the solenoid.

3. Loosen the four socket head screws on the body of the control valve using a 5/32" allen wrench.

4. Adjust the inner shaft assembly to provide a leak rate of 0.1% F.S. Use a 3/16" allen wrench.

   Turn the inner shaft assembly 5° - 10° at a time, each time observing a change in leakage.

   Turn an additional 10° - 15° beyond the threshold of acceptable leakage. Excessive clockwise adjustment may reduce maximum flow control or impair control response.

5. Tighten socket screws and coil nut.

6. Check leak rate. Repeat steps 1-5 if the leak rate is unacceptable (i.e., zero or > 0.1% F.S.).

7. Drive the control valve fully open for 15 minutes. After this warm up period, test the 1559A to insure that Full Scale can be achieved.

   If Full Scale flow cannot be reached, repeat Steps 1 and 2, and turn the inner shaft assembly 5° - 10° counter-clockwise. Go to Step 4.

   If leakage cannot be corrected by this adjustment procedure, return the unit to MKS Instruments for service.

SECTION 8

GAS CORRECTION FACTORS AND METER SELECTION

8.1 GENERAL

The gas correction factor (GCF) is a number used to indicate the ratio of flow rates of different gases which will produce the same output voltage from a flowmeter. Experience has shown that these values are theoretical and actual flows cannot be guaranteed.* The GCF is a function of specific heat, density, and molecular structure of the gases. If nitrogen is used as the base-line gas (GCF=1), the GCF of any other gas is found by using the equation:

$$C_x = \frac{.3106\ S}{p_x Cp_x}$$

where:

C_x	=	GCF of gas X
p_x	=	Density if gas X at 0°Cm gms/liter
Cp_x	=	Specific heat of gas X, cal/gm°C
.3106	=	pCp for nitrogen at 0°C
S	=	Molecular Structure correction factor

Molecular Structure	S
Monatomic Gases	1.030
Diatomic Gases	1.000
Triatomic Gases	0.941
Polyatomic Gases	0.880

TABLE OF VALUES
OF
MOLECULAR STRUCTURE CORRECTION FACTORS

* MKS is in the process of verifying and correcting the values for its flowmeter technology using our Califlow® Primary Flow Standards. It is unclear at present whether or not our work will be applicable to other Thermal Mass flow meters.

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 GCF for CCl_4 - .31

2. Apply the ratio of GCF's to determine the equivalent of N_2 (X). $\frac{1.00}{.31} = \frac{X}{100}$; X = 323 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.

4. If, for example, we had calculated 600 sccm instead of 323, one would still choose the 500 sccm meter, as any meter may be respanned to a maximum of 120% of its nominal rating and remain linear.

The following Chart includes values of GCF for commonly used gases.

Gas Flow Conversion Chart

GAS	SYMBOL	SPECIFIC HEAT,Cp cal/g°C	DENSITY g/l@°C	CONVERSION FACTOR
Air	—	.240	1.293	1.00
Ammonia	NH_3	.492	.760	.73
Argon	Ar	.1244	1.782	1.39
Arsine	AsH_3	.1167	3.478	.67
Boron Trichloride	BCl_3	.1279	5.227	.41
Bromine	Br_2	.0539	7.130	.81
Carbon Dioxide	CO_2	.2016	1.964	.70[1]
Carbon Monoxide	CO	.2488	1.250	1.00
Carbon Tetrachloride	CCl_4	.1655	6.86	.31
Carbon Tetrafluoride (Freon - 14)	CF_4	.1654	3.926	.42
Chlorine	Cl_2	.1144	3.163	.86
Chlorodifluoromethane (Freon - 22)	$CHClF_2$	.1544	3.858	.46
Chloropentafluoroethane (Freon - 115)	C_2ClF_5	.164	6.892	.24
Chlorotrifluoromethane (Freon - 13)	$CClF_3$	.153	4.660	.38
Cyanogen	C_2N_2	.2613	2.322	.61
Deuterium	D_2	1.722	.1799	1.00
Diborane	B_2H_6	.508	1.235	.44
Dibromodifluoromethane	CBr_2F_2	.15	9.362	.19
Dichlorodifluoromethane (Freon - 12)	CCl_2F_2	.1432	5.395	.35
Dichlorofluoromethane (Freon - 21)	$CHCl_2F$	.140	4.592	.42
Dichloromethylsilane	$(CH_3)_2SiCl_2$	.1882	5.758	.25
Dichlorosilane	SiH_2Cl_2	.150	4.506	.40
1,2-Dichlorotetrafluoroethane (Freon 114)	$C_2Cl_2F_4$	.160	7.626	.22
1,1-Difluoroethylene (Freon - 1132A)	$C_2H_2F_2$	.224	2.857	.43
2,2-Dimethylpropane	C_5H_{12}	.3914	3.219	.22
Ethane	C_2H_6	.4097	1.342	.50
Fluorine	F_2	.1873	1.695	.98
Fluoroform (Freon - 23)	CHF_3	.176	3.127	.50
Freon - 11	CCl_3F	.1357	6.129	.33
Freon - 12	CCl_2F_2	.1432	5.395	.35
Freon - 13	$CClF_3$	.153	4.660	.38
Freon - $13B_1$	$CBrF_3$	.1113	6.644	.37
Freon - 14	CF_4	.1654	3.926	.42
Freon - 21	$CHCl_2F$	.140	4.592	.42
Freon - 22	$CHClF_2$	.1544	3.858	.46
Freon - 23	CHF_3	.176	3.127	.50
Freon - 113	$C_2Cl_3F_3$	.161	8.360	.20
Freon - 114	$C_2Cl_2F_4$	.160	7.626	.22
Freon - 115	C_2ClF_5	.164	6.892	.24
Freon - 116	C_2F_6	.1843	6.157	.24
Freon - C318	C_4F_8	.185	8.397	.17

GAS	SYMBOL	SPECIFIC HEAT,Cp cal/g°C	DENSITY g/l@°C	CONVERSION FACTOR
Freon - 1132A	$C_2H_2F_2$	.224	2.857	.43
Helium	He	1.241	.1786	.—[2]
Hexafluoroethane (Freon - 116)	C_2F_6	.1843	6.157	.24
Hydrogen	H_2	3.419	.0899	.—[2]
Hydrogen Bromide	HBr	.0861	3.610	1.00
Hydrogen Chloride	HCl	.1912	1.627	1.00
Hydrogen Fluoride	HF	.3479	.893	1.00
Isobutylene	C_4H_8	.3701	2.503	.29
Krypton	Kr	.0593	3.739	1.543
Methane	CH_4	.5328	.715	.72
Methyl Fluoride	CH_3F	.3221	1.518	.56
Molydenum Hexafluoride	MoF_6	.1373	9.366	.21
Neon	Ne	.246	.900	1.46
Nitric Oxide	NO	.2328	1.339	.99
Nitrogen	N_2	.2485	1.250	1.00
Nitrogen Dioxide	NO_2	.1933	2.052	.74
Nitrogen Trifluoride	NF_3	.1797	3.168	.48
Nitrous Oxide	N_2O	.2088	1.964	.71
Octafluorocyclobutane (Freon - C318)	C_4F_8	.185	8.937	.17
Oxygen	O_2	.2193	1.427	1.00
Pentane	C_5H_{12}	.398	3.219	.21
Perfluoropropane	C_3F_8	.194	8.388	.17
Phosgene	$COCl_2$	.1394	4.418	.44
Phosphine	PH_3	.2374	1.517	.76
Propane	C_3H_8	.3885	1.967	.36
Propylene	C_3H_6	.3541	1.877	.41
Silane	SiH_4	.3189	1.433	.60
Silicon Tetrachloride	$SiCl_4$	.1270	7.580	.28
Silicon Tetrafluoride	SiF_4	.1691	4.643	.35
Sulfur Dioxide	SO_2	.1488	2.858	.69
Sulfur Hexafluoride	SF_6	.1592	6.516	.26
Trichlorofluoromethane (Freon - 11)	CCl_3F	.1357	6.129	.33
Trichlorosilane	$SiHCl_3$	.1380	6.043	.33
1,1,2-Trichloro - 1,2,2 Trifluoroethane (Freon - 113)	CCl_2FCClF_2 $C_2Cl_3F_3$	.161	8.360	.20
Tungsten Hexafluoride	WF_6	.0810	13.28	.25
Xenon	Xe	.0378	5.858	1.32

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

NOTE: Standard Pressure is defined as 760 mmHg (14.7).
Standard Temperature is defined as 0°C.