

# Installation & Operation Manual

## **5850E Series** **Mass Flow Controllers & Meters**

**BROOKS**<sup>®</sup>  
INSTRUMENT

*Beyond Measure*

# Essential Instructions

## Read this page before proceeding!

Brooks Instrument designs, manufactures and tests its products to meet many national and international standards. Because these instruments are sophisticated technical products, you must properly install, use and maintain them to ensure they continue to operate within their normal specifications. The following instructions must be adhered to and integrated into your safety program when installing, using and maintaining Brooks Products.

- Read all instructions prior to installing, operating and servicing the product. If this instruction manual is not the correct manual, please see back cover for local sales office contact information. Save this instruction manual for future reference.
- If you do not understand any of the instructions, contact your Brooks Instrument representative for clarification.
- Follow all warnings, cautions and instructions marked on and supplied with the product.
- Inform and educate your personnel in the proper installation, operation and maintenance of the product.
- Install your equipment as specified in the installation instructions of the appropriate instruction manual and per applicable local and national codes. Connect all products to the proper electrical and pressure sources.
- To ensure proper performance, use qualified personnel to install, operate, update, program and maintain the product.
- When replacement parts are required, ensure that qualified people use replacement parts specified by Brooks Instrument. Unauthorized parts and procedures can affect the product's performance and place the safe operation of your process at risk. Look-alike substitutions may result in fire, electrical hazards or improper operation.
- Ensure that all equipment doors are closed and protective covers are in place, except when maintenance is being performed by qualified persons, to prevent electrical shock and personal injury.

## Pressure Equipment Directive (PED)

All pressure equipment with an internal pressure greater than 0.5 bar (g) and a size larger than 25mm or 1" (inch) falls under the Pressure Equipment Directive (PED). The Directive is applicable within the European Economic Area (EU plus Norway, Iceland and Liechtenstein). Pressure equipment can be traded freely within this area once the PED has been complied with.

- Section 1 of this manual contains important safety and operating instructions related to the PED directive.
- Meters described in this manual are in compliance with EN directive 97/23/EC module H *Conformity Assessment*.
- All Brooks Instrument Flowmeters fall under fluid group 1.
- Meters larger than 25mm or 1" (inch) are in compliance with category I, II, III of PED.
- Meters of 25mm or 1" (inch) or smaller are Sound Engineering Practice (SEP).

## ESD (Electrostatic Discharge)

### CAUTION

**This instrument contains electronic components that are susceptible to damage by static electricity. Proper handling procedures must be observed during the removal, installation or other handling of circuit boards or devices.**

#### Handling Procedure:

1. Power to unit must be removed.
2. Personnel must be grounded, via a wrist strap or other safe, suitable means before any printed circuit card or other internal device is installed, removed or adjusted.
3. Printed circuit cards must be transported in a conductive container. Boards must not be removed from protective enclosure until immediately before installation. Removed boards must immediately be placed in protective container for transport, storage or return to factory.

#### Comments

This instrument is not unique in its content of ESD (electrostatic discharge) sensitive components. Most modern electronic designs contain components that utilize metal oxide technology (NMOS, SMOS, etc.). Experience has proven that even small amounts of static electricity can damage or destroy these devices. Damaged components, even though they appear to function properly, exhibit early failure.

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## Purpose

The Brooks® Model 5850E Flow Controller is a mass flow measurement device designed for accurately measuring and rapidly controlling flows of gases. This instruction manual is intended to provide the user with all the information necessary to install, operate and maintain the Brooks 5850E Mass Flow Controller. This manual is organized into five sections:

Section 1	Introduction
Section 2	Installation
Section 3	Operation
Section 4	Maintenance & Troubleshooting
Section 5	Replacement Parts
Back Cover	Warranty, Local Sales/Service Contact Information

It is recommended that this manual be read in its entirety before attempting to operate or repair the Model 5850E.

## Description

The Brooks Model 5850E Mass Flow Controller is used widely in the Semiconductor Industry as well as many others, where manual, electronic or computer controlled gas handling occurs. The Model 5850E consists of three basic units: a flow sensor, a control valve and an integral electronic control system. This combination produces a stable gas flow, which eliminates the need to continuously monitor and readjust gas pressures. Standard features include:

- **Fast Response Control** permits rapid gas settling times with little or no over/undershoot. (Refer to Figure 1-1.)
- **Soft Start** provides a flow ramping function which slows down the introduction of the process gas for those processes which cannot tolerate rapid flow transition. (Refer to Section 2-6 and Figure 1-2.)
- **Valve Override** permits the user to fully open and close the control valve independent of the command setting. (Refer to Section 2-8.)
- **Setpoint (Command)** permits the user to program the mass flow controller with an external 0-5 Vdc command potentiometer. (Refer to Section 2-7.)
- **Low Command Valve Inhibit (Auto Shut-off)** prevents the valve from opening whenever the set-point is less than 2% of full scale.
- **Removable Cleanable Sensor** permits the user to clean or replace the sensor. (Refer to Section 4-4.)
- **Output Limiting** prevents possible damage to delicate data acquisition devices by limiting the output to +6.8 Vdc and -0.7 Vdc.

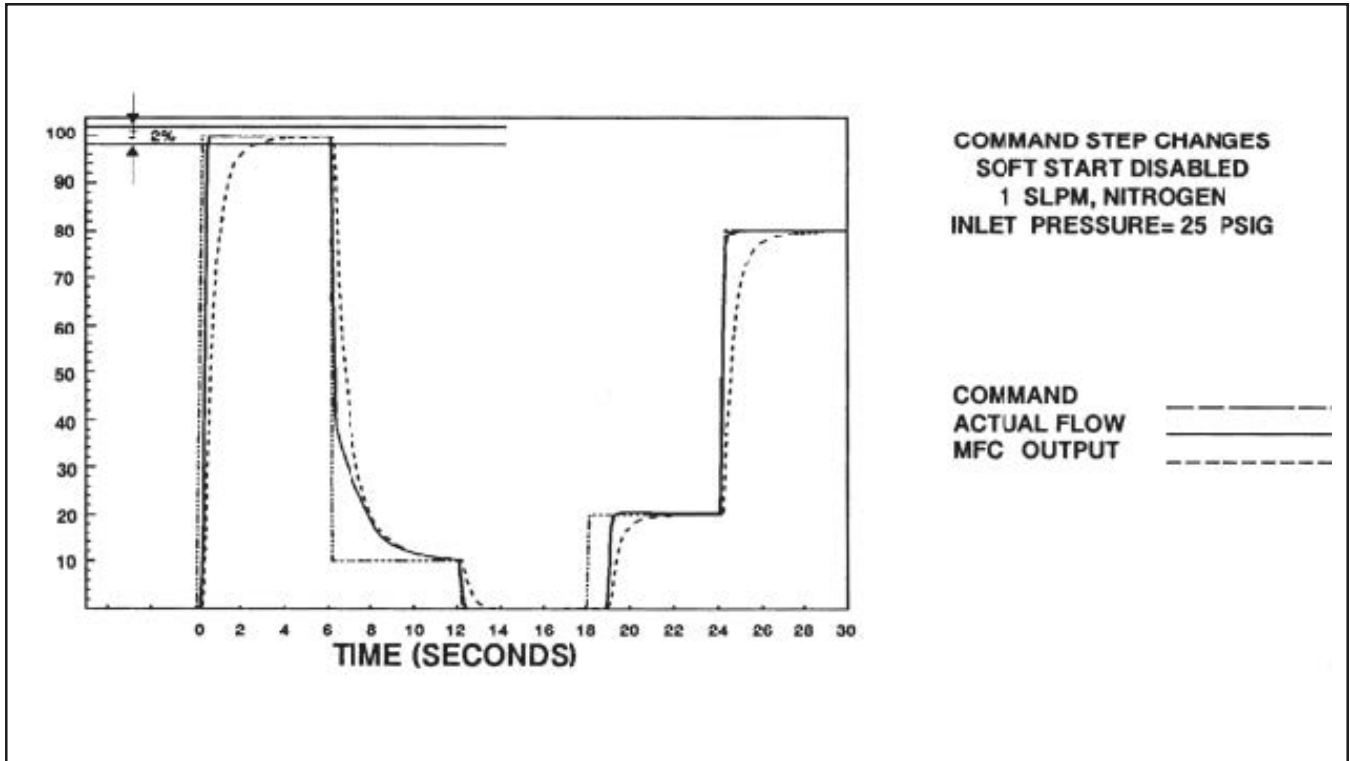


Figure 1-1 Command Steps, Soft Start Disabled

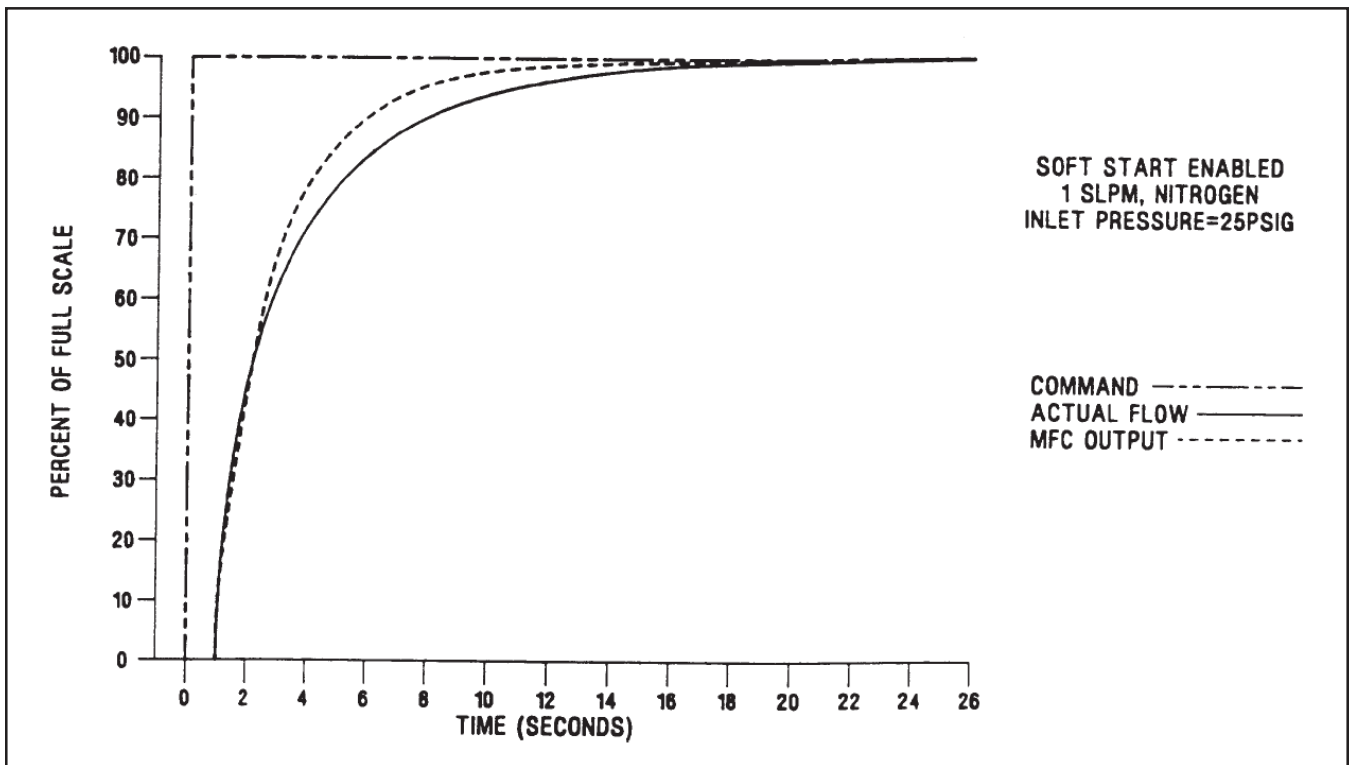


Figure 1-2 0 - 100% Command Step, Soft Start Enabled.

- **Valve Off** accessed via terminal J on the Card Edge or Pin 4 on the D-Connector version. This feature allows the user to close the control valve independently of the command signal by supplying a TTL level low signal to the proper terminal. This function is useful when performing repetitive flow operations or as a safety shutdown. (Refer to Section 2-11.)
- **Valve Test Point/Purge** accessed via terminal D on the Card Edge or Pin 7 on the D-Connector version. This feature allows the user to monitor the control valve voltage during operation. Shorting the valve test point pin to power supply common will cause the valve to open regardless of command input voltage. (Refer to Section 2-10.)
- **Remote Transducer Input** accessed via Terminal 5 on the Card Edge or Pin 15 on the D-connector version. This feature allows the use of the integral control electronics and valve to regulate flow in response to the signal from an external 0-5 Vdc signal. The mass flow signal from the Model 5850E is still available for process monitoring. (Refer to Section 2-9.)

## Specifications

### WARNING

Do not operate this instrument in excess of the specifications listed below. Failure to heed this warning can result in serious personal injury and/or damage to the equipment.

### CAUTION

It is the user's responsibility to select and approve all materials of construction. Careful attention to metallurgy, engineered materials and elastomeric materials is critical to safe operation.

#### Standard Ranges:

3 sccm to 30 slpm\* (Nitrogen equivalent)

\*Standard temperature and pressure in accordance with SEMI (Semiconductor Equipment and Materials International) standard: 0°C and 101.3 kPa (760 Torr).

#### Accuracy:

±1% full scale including linearity at calibration conditions.

±1.5% full scale including linearity for flow ranges greater than 20 slpm.

#### Repeatability:

0.25% of rate

#### Response Time:

Less than 3 seconds response to within 2% of full scale final value with a 0 to 100% command step.

#### Power Requirements (NC Valve):

+15 Vdc ±5%, 35 mA

-15 Vdc ±5%, 180 mA

3.5 watts power consumption

**Power Requirements (NO Valve):**

+15 Vdc  $\pm 5\%$ , 215 mA  
-15 Vdc  $\pm 5\%$ , 180 mA  
11.85 watts power consumption

**Ambient Temperature Limits:**

Operating: 40°F to 150°F (5°C to 65°C)  
Non-operating: -13°F to +212°F (-25°C to 100°C)

**Working Pressure:**

1500 psi (10.342 mPa) maximum

**Differential Pressure:**

5 to 50 psi (minimum pressure drop depends on gas and range). Refer to Orifice Sizing, Section 4-6.

**Output Signal:**

0-5 Vdc into 2000 ohms or greater. Maximum ripple 3 mV.

**5 Volt Reference Output:**

5 Volts  $\pm 0.2\%$ . Maximum load 1 k ohms.

**Temperature Sensitivity:**

Zero: less than  $\pm 0.075\%$  F.S. per degree C.  
Span: less than  $\pm 1.0\%$  F.S. shift over 10-50°C range

**Power Supply Sensitivity:**

$\pm 0.09\%$  full scale per % power supply voltage variation

**Mounting Attitude Sensitivity:**

$\pm 0.5\%$  maximum full scale deviation after re-zeroing

**Command Input:**

0-5 Vdc. Input resistance 200 k ohm

**Leak Integrity:**

$1 \times 10^{-9}$  Atm. cc/sec Helium

**Control Range:**

50 to 1

**Mechanical Connection:**

Compatible with most popular mass flow controllers. Refer to Figure 2-1.

**Electrical Connection:**

Card edge, 20 terminals, gold over low stress nickel plated copper. 15-pin D-Connector (DA-15P)



### Receipt of Equipment

When the equipment is received, the outside packing case should be checked for damage incurred during shipment. If the packing case is damaged, the local carrier should immediately be notified regarding his liability. A report should be submitted to the Product Service Department, Brooks Instrument, 407 West Vine Street, Hatfield, Pennsylvania 19440.

Remove the envelope containing the packing list. Outside of your clean area, carefully remove the equipment from the packing case. Make sure spare parts are not discarded with the packing material. Inspect for damaged or missing parts.

### Recommended Storage Practice

If intermediate or long-term storage is required for equipment, as supplied by Brooks Instrument, it is recommended that said equipment be stored in accordance with the following:

- a. Within the original shipping container.
- b. Store in a sheltered area, with the following conditions.
  1. Ambient temperature 21°C (70°F) nominal, 32°C (90°F) maximum and 7°C (45°F) minimum.
  2. Relative humidity 45% nominal, 60% maximum and 25% minimum. Upon removal from storage, a visual inspection should be conducted to verify the condition of the equipment is "as received". If the equipment has been in storage for an excess of ten (10) months or in conditions in excess of those recommended, all pressure boundary seals should be replaced and the device subjected to a pneumatic pressure test in accordance with applicable vessel codes.

### Return Shipment

Prior to returning any Brooks equipment to the factory, contact the factory -for a Return Materials Authorization Number (RMA#). This can be obtained at Brooks Instrument, Product Service Department, 407 West Vine Street, Hatfield, PA 19440-0903, or call toll free 1-888-554-FLOW (3569).

Also, completion of Form RPR003-1, Brooks Instrument Decontamination Statement, as well as, a Material Safety Data Sheet (MSDS) for the fluid(s) used in the meter, is required before any Brooks Personnel can begin processing the equipment. Copies of the form can be obtained at one of the locations above.

### Gas Connections

Standard inlet and outlet connections supplied on the Model 5850E are 1/4" compression fittings for flow rates up to 10 slpm, and 3/8" compression fittings for higher flow rates.

Optional VCO™ and VCR™ connections are available upon request. Prior to installation, make certain all piping is clean and free of obstructions. Install the piping in such a manner that permits easy removal if the instrument is to be removed for cleaning or test bench troubleshooting.

### Installation (Refer to Figs. 2-1 through 2-4)

#### **⚠ CAUTION**

**When installing the controller, care should be taken that no foreign materials enter the inlet or outlet of the instrument. Do not remove the protective end caps until time of installation.**

#### **⚠ CAUTION**

**Any sudden change in system pressure may cause mechanical damage to elastomer materials. Damage can occur when there is a rapid expansion of fluid that has permeated elastomer materials. The user must take the necessary precautions to avoid such conditions.**

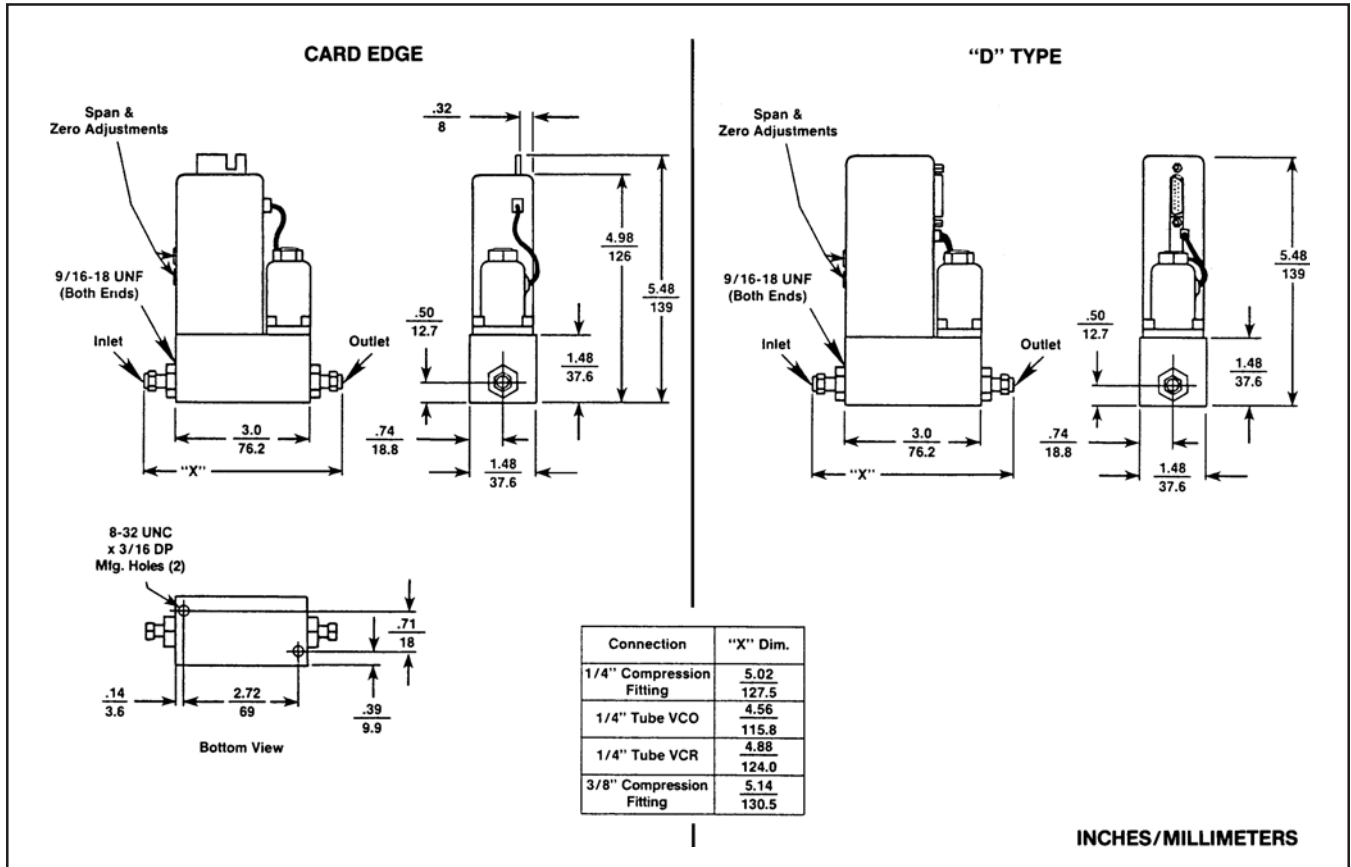


Figure 2-1 Model 5850E Dimensions

**⚠ CAUTION**

Any Brooks Instrument mass flow meter or flow controller with a 15 pin D-Connector PC Board bearing the "CE Mark" must use a 100% shielded cable and metal shell mating connectors. The shield is tied over 360 degrees to the shell at both ends. This is mandatory to be in compliance with the EMC Directive (89/336/EEC). Refer to Appendix A.

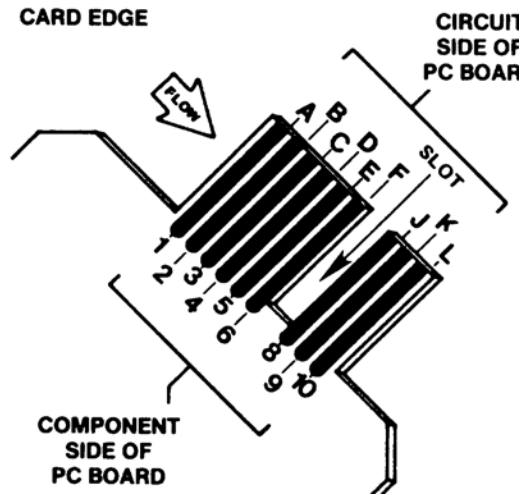
Recommended installation procedures:

- a. The Model 5850E should be located in a clean, dry atmosphere relatively free from shock and vibration.
- b. Leave sufficient room for access to the electrical components.
- c. Install in such a manner that permits easy removal if the instrument requires cleaning.

**⚠ CAUTION**

When used with a reactive (sometimes toxic) gas, contamination or corrosion may occur as a result of plumbing leaks or improper purging. Plumbing should be checked carefully for leaks and the controller purged with clean, dry N<sub>2</sub> before use.

- d. The Model 5850E Mass Flow Controller can be installed in any position. However, mounting in orientations other than the original factory calibration (see data sheet) will result in a ±0.5% maximum full scale shift after re-zeroing.



Terminal Designation

Unit UFC-1000	Tylan FC-280	Tylan FC-260	Brooks 5850E	Card Edge	Brooks 5850E	Tylan FC-260	Tylan FC-280	Unit UFC-1000
Chassis Ground	Chassis Ground	Chassis Ground	Chassis Ground	1 A	Command Input	Command Input	Command Input	Command Input
Supply Common	0-5 Volt Signal Common	0-5 Volt Signal Common	0-5 Volt Signal Common	2 B	Command Common	Command Common	Signal & Command Common	Command Common
0-5 Volt Signal Output	0-5 Volt Signal Output	0-5 Volt Signal Output	0-5 Volt Signal Output	3 C	Supply Voltage Common	Supply Voltage Common	Return	Common
+ 15 Vdc Supply	+ 15 Vdc Supply	+ 15 Vdc Supply	+ 15 Vdc Supply	4 D	Valve Test Point/Purge	Valve Test Point	Not Used	Valve Test Point/Purge
Not Used	Not Used	Not Used	Remote Transducer Input***	5 E	Not Used	Valve Not Used Point	Test	Not Used
Not Used	Zener Test	Zener Test	Not Used	6 F	-15 Vdc Supply	-15 Vdc Supply	-15 Vdc Supply	-15 Vdc Supply
Slot	Slot	Slot	Slot	7 H*	Slot	Slot	Slot	Slot (G)
Not Used	Not Used	Not Used	Not Used	8 J*	Not Used	Not Used	Not Used	Not Used (H)
Not Used	Not Used	Not Used	Valve Override	9 K*	Not Used	Not Used Open/Close	Valve	Not Used (I)
Common	Not Used	Not Used	+ 5V Ref. *** or Valve Return or Not Used	10 L*	Valve Off	Not Used Off	Not Used	Valve Off (J)

\* Unit designates Pins H, J, K, & L as G, H, I, & J  
 \*\* Jumper Selectable  
 \*\*\* Factory Activated Option

Figure 2-2 Model 5850E Card Edge Connector Comparison Guide

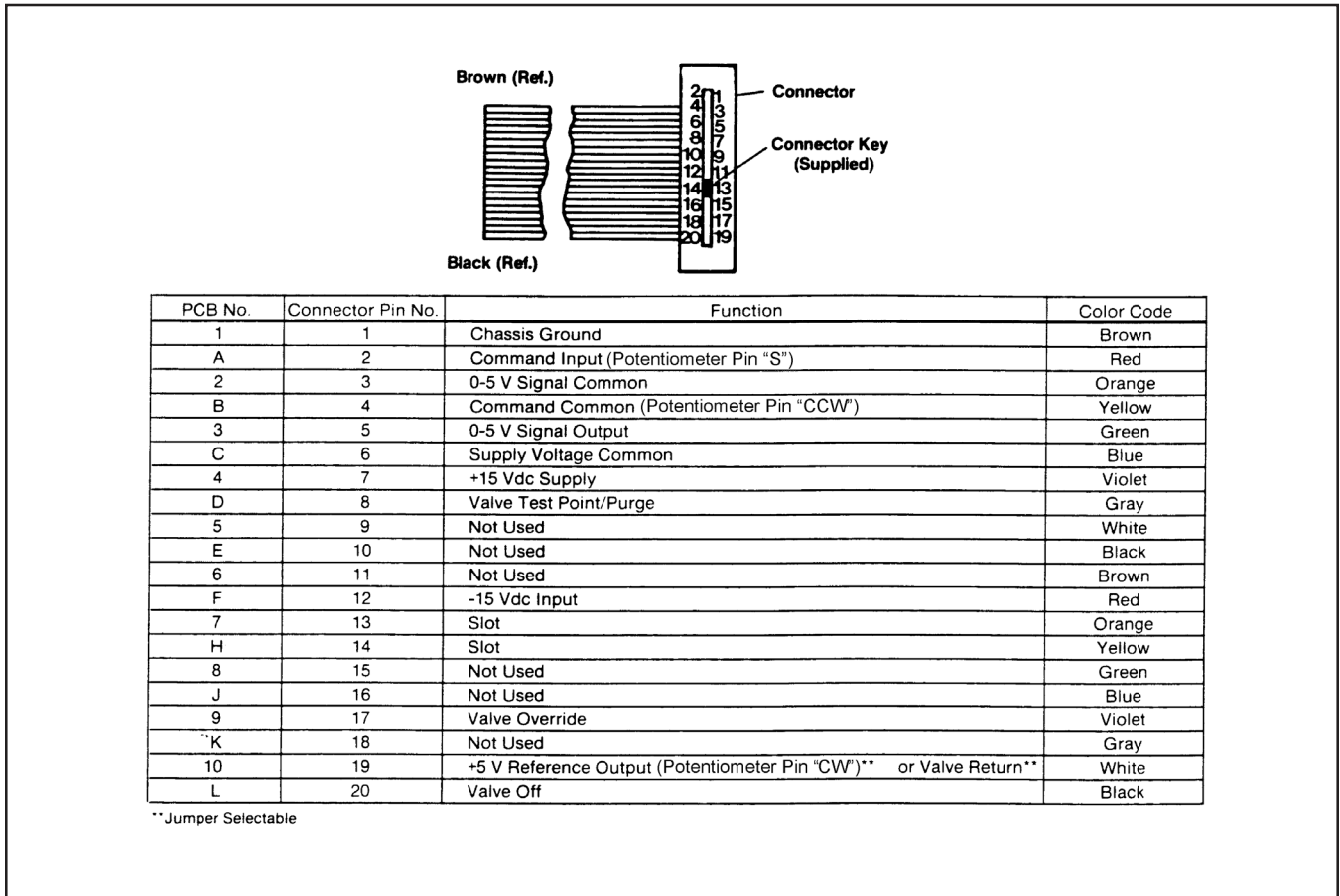


Figure 2-3 Model 5850E Card Edge Connector Hookup Diagram

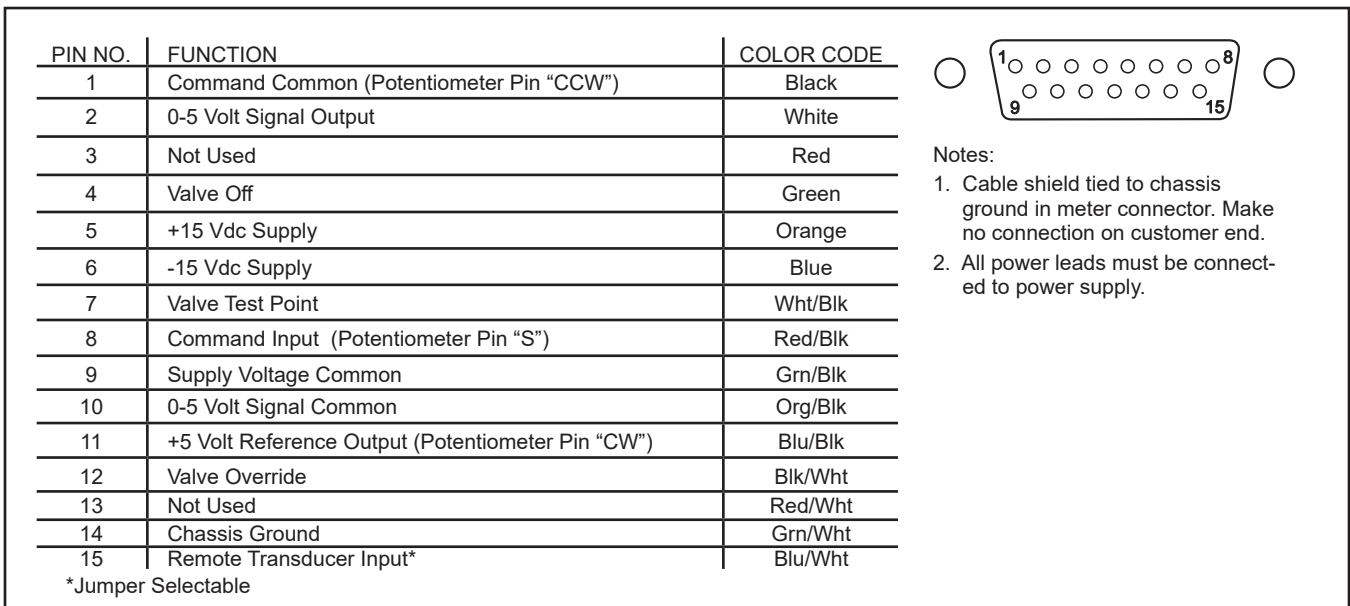


Figure 2-4 D-Connector Pin Arrangement

- e. When installing controllers with full scale flow rates of 10 slpm or greater, be aware that sharp, abrupt angles in the system piping directly upstream of the controller may cause a small shift in accuracy. If possible, have at least ten pipe diameters of straight tubing upstream of the Model 5850E Mass Flow Controller.

Note: The control valve in the Model 5850E provides precision control and is not designed for positive shut-off. If positive shut-off is required, it is recommended that a separate shut-off valve be installed in-line.

**⚠ CAUTION**

Since the Model 5850E control valve is not a positive shutoff, a separate solenoid valve may have been installed for that purpose. It should be noted that a small amount of gas may be trapped between the downstream side of the mass flow controller and the solenoid which will result in a surge upon actuation of the controller. This surge can be reduced in magnitude by locating, close together, the controller and solenoid valve or by moving the solenoid valve upstream of the controller.

**In-Line Filter**

It is recommended that an in-line filter be installed upstream from the controller to prevent the possibility of any foreign material entering the flow sensor or control valve. The filtering element should be replaced periodically or ultrasonically cleaned.

Maximum Flow Rate	Recommended Filter Size
100 sccm	1 micron
500 sccm	2 micron
1 to 5 slpm	7 micron
10 to 30 slpm	15 micron

Table 2-1 Recommended Filter Size.

**Note: The above lists the maximum recommended porosity for each flow range. It is recommended that the minimum micron porosity that does not limit the full scale flowrate be used.**

**Electrical Interfacing**

To insure proper operation, the Model 5850E must be connected per Figures 2-3 and 2-4, and configured according to Sections 2-6 to 2-13.

As a minimum the following connections must be made for new installations:

- Chassis Ground
- 0-5 Volt Signal Common 0-5 Volt Signal Output +15 Vdc Supply
- 15 Vdc Supply Command Input
- Command Common
- Supply Voltage Common
- Valve Return (Refer to Section 2-12 for jumper configuration)

For installations which replace Unit Instruments UFC-1000's, (Card Edge version) Pin 10 is frequently grounded. In these situations the 5 Volt reference output must be disabled. Refer to Section 2-12.

For installations which will be connected to Brooks secondary electronics, the Card Edge version must have the 5 Volt reference enabled on Pin 10 and the D-Connector version should be configured for external valve return. Refer to Section 2-12. If the Model 5850E was shipped as a system with Brooks secondary electronics then the electronics will already be configured properly.

Note: To obtain access to the jumpers for the following options the electronics cover can must be removed. Remove the can by removing the three screws and the valve connector. The can must be replaced before returning the unit to service.

### Soft Start

Refer to Figures 3-3 and 3-4. To enable soft start, place the red jumper on the controller printed circuit board at J2 in the (ss) position.

To disable soft start, place the red jumper on the controller printed circuit board at J2 in the (n) position.

### Remote Setpoint (Command) Input

If the mass flow controller is to be commanded by an external 0-5 Vdc signal, the command potentiometer is not used.

The command input hookup is as follows:

- a. Card Edge Connector  
Connect the external command voltage to Terminal A and external command return to Terminal B. Refer to Figures 2-2 and 2-3.
- b. D-Connector  
Connect the external command voltage to Terminal 8 and external command return to Terminal 1. Refer to Figure 2-4.

### Valve Override

The valve override function allows full opening and closing of the valve independent of the command setting. The unique command reset feature prevents flow overshoot when the controller goes from valve override closed to normal control. The valve override for the mass flow controller is as follows:

- a. To open the valve, apply +15 Vdc to the valve override terminal.
- b. To close the valve, apply -15 Vdc to the valve override terminal.
- c. Isolating the valve override terminal returns the controller to normal operation.
  1. Card Edge  
The valve override function can be accessed from Terminal 9. Refer to Figure 2-3.  
Note: For normal operation, Terminal 9 must be left open (floating).
  2. D-Connector  
The valve override function is accessed from Terminal 12. Refer to Figure 2-4.

### Remote Transducer Input

Refer to Figures 3-3 and 3-4. To allow the Model 5850E control circuitry and valve to be used with a 0-5 Vdc external transducer signal, a green jumper is moved to the lower two pins at J7. With this feature enabled, a 0-5 Vdc signal may be applied to the external transducer input terminal. The Model 5850E controller circuitry will modulate the valve position to increase or decrease the flow rate to maintain the transducer output at the desired set-point. The control circuitry is reverse acting, e.g., for an increase in transducer output, the flow will correspondingly be decreased.

### Valve Test Point/Purge

Refer to Figures 2-2, 2-3 and 2-4. The valve voltage can be monitored on Pin D of the Card Edge version and Pin 7 of the D-Connector version. This voltage relative to circuit common is proportional to the valve voltage per the following equation:

$$\text{Valve Voltage} = (1.53 \times \text{TP3}) + 20.7$$

(Note: The valve voltage calculation is an approximate value.)

Shorting the valve test point pin to power supply common will cause the valve to open regardless of command input voltage.

### Valve Off

Refer to Figures 2-2, 2-3 and 2-4. The control valve can be forced closed regardless of command input signal by applying a TTL level low (< .4 Vdc) to Terminal L of the Card Edge version or Pin 4 of the D-Connector version. A TTL level high or floating at this pin has no effect.

## ⚠ CAUTION

**Do not ground Terminal 10 when 5 Volt reference output is enabled. Irreparable damage to the printed circuit board may result.**

### Five-Volt Reference Output/Valve Drive Configuration

#### a. Card Edge

Refer to Figures 2-3 and 3-3. Terminal 10 can be jumper selected as 5 Volt reference output, external valve return or “not used.” The 5 Volt reference output is required if a potentiometer is to be used to generate the command signal. To enable the 5 Volt reference output on Terminal 10, place the yellow jumper at J1 in the D-E position. To disable the 5 Volt reference output, place the yellow jumper at J1 in the E-F position.

To minimize the effect of resistance in the connection wiring, a separate “external valve return” can be accessed on Pin 10. To enable this feature, place the black jumper at J1 in the B-D position and connect Terminal 10 to power supply common. If the “external valve return” is not enabled, place the black jumper at J1 in the B-C position.

Note: If the “external valve return” feature is not enabled, the valve voltage is returned internally on the printed circuit board and the connection wiring resistance must be less than 0.2 ohms.

#### b. D-Connector

Refer to Figures 2-4 and 3-4. The 5 Volt reference is always available on Pin 11.

To minimize the effect of resistance in the connection wiring, a separate “external valve return” can be accessed on Pin 3. To enable this feature, place the black jumper at J1 in the B-D position and connect Pin 3 to power supply common. If the “external valve return” is not enabled, place the black jumper at J1 in the B-C position.

Note: If the “external valve return” feature is not enabled, the valve voltage is returned internally on the printed circuit board and the connection wiring resistance must be less than 0.2 ohms.



### Theory of Operation

The thermal mass flow sensing technique used in the Model 5850E works as follows:

A precision power supply provides a constant power heat input (P) at the heater which is located at the midpoint of the sensor tube. Refer to Figure 3-1. At zero, or no flow conditions, the heat reaching each temperature sensor is equal. The temperatures T1 and T2, therefore, are equal. When gas flows through the tube, the upstream sensor is cooled and the downstream sensor is heated which produces a temperature difference. The temperature difference T2-T1 is directly proportional to the gas mass flow. The equation is:

$$DT = A * P * Cp * m$$

Where:

DT	=	Temperature difference T2 - T1 (°K)
Cp	=	Specific heat of the gas at constant pressure (kJ/kg-°K)
P	=	Heater power (kJ/s)
m	=	Mass flow (kg/s)
A	=	Constant of proportionality (S <sup>2</sup> -°K <sup>2</sup> /kJ <sup>2</sup> )

A bridge circuit interprets the temperature difference and a differential amplifier generates a linear 0-5 Vdc signal directly proportional to the gas mass flow rate.

The flow restrictor shown in Figure 3-1 performs a ranging function similar to a shunt resistor in an electrical ammeter. The restrictor provides a pressure drop that is linear with flow rate. The sensor tube has the same linear pressure drop/flow relationship. The ratio of the restrictor flow to the sensor tube flow remains constant over the range of the meter. Different restrictors have different pressure drops and produce controllers with different full scale flow rates. The span adjustment, in the electronics, affects the fine adjustment of the controller's full scale flow.

In addition to the mass flow sensor, the Model 5850E Mass Flow Controller has an integral control valve and control circuit as shown in Figure 3-2. The control circuit senses any difference between the flow sensor signal and adjusts the current in the modulating solenoid valve to increase or decrease the flow. The Model 5850E has the following features incorporated in the integral control circuit:

#### Fast Response

Adjusted by the anticipate potentiometer, this circuit, when properly adjusted, allows the high frequency information contained in the sensor signal to be amplified. This provides a faster responding flow signal for remote indication and use by the control valve.

#### Soft Start

This is enabled by moving a jumper on the printed circuit board. This circuit provides a slow injection of the gas as a protection to the process, particularly those using a volatile or reactive gas. Full gas flow is achieved in approximately 15 seconds. Refer to Section 2-6.



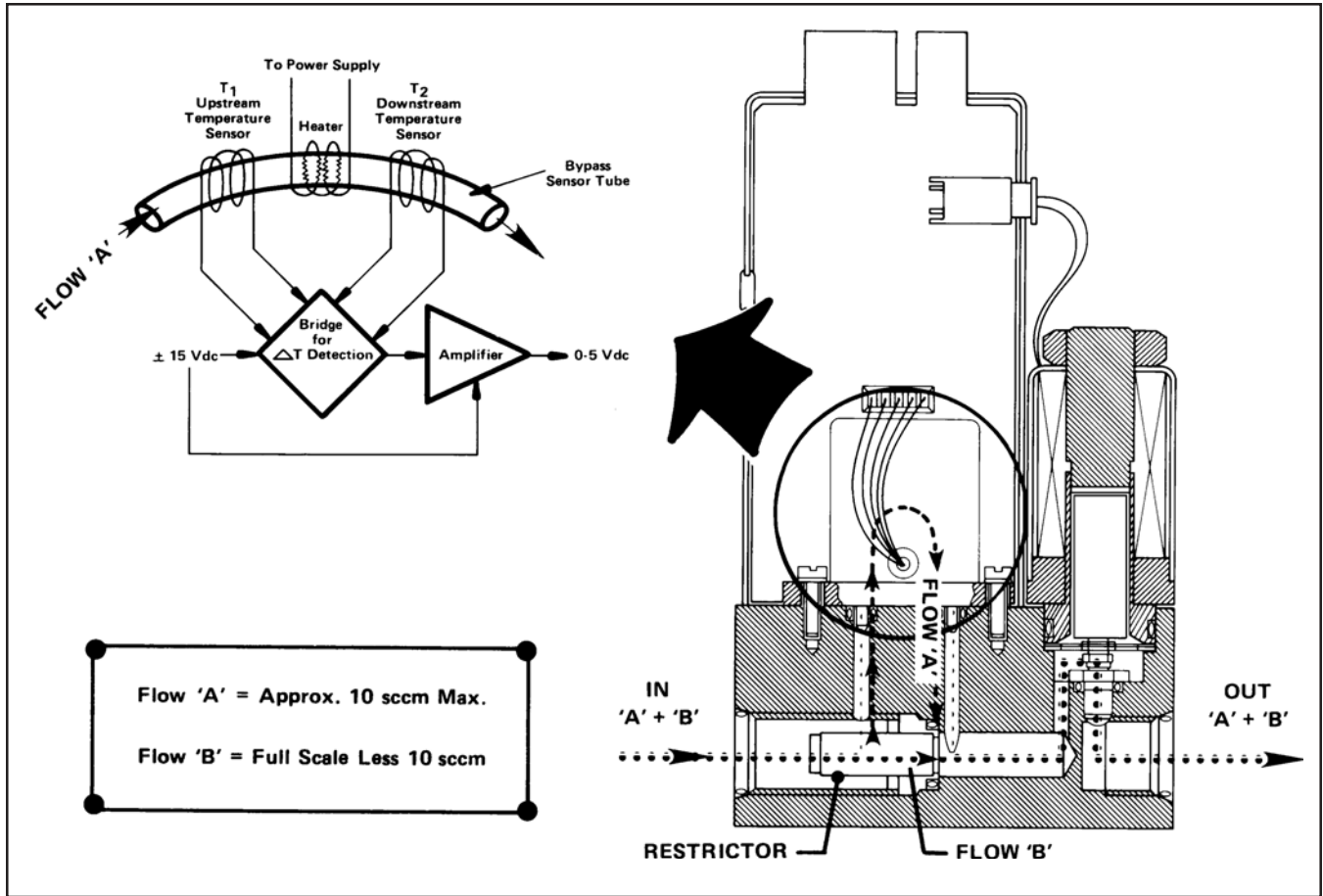


Figure 3-1 Flow Sensor Operational Diagram

**Precision 5 Volt Reference**

This allows direct connection of a command potentiometer to provide a 0-5 Volt command signal to the controller. A precision ten-turn 2K ohm potentiometer, with an integral turn counter, is recommended as this will permit repeatable adjustments of command to one part in 1,000. Refer to Section 2-13 for activation.

**Valve Override**

Allows, independent of the command setting, full opening and closing of the control valve. Refer to Section 2-8.

**Valve Off**

Accessed via Terminal L on the Card Edge or Pin 4 on the D-Connector version, this feature allows the user to close, independently of the command signal, the control valve by supplying a TTL level low signal to the proper terminal. This function is useful when performing repetitive flow operations or as a safety shutdown. Refer to Section 2-11.

**Valve Test Point/Purge**

Accessed via terminal D on the Card Edge or Pin 7 on the D-Connector version of the Model 5850E only. This feature allows the user to monitor the control valve voltage during operation, also grounding this terminal will cause the control valve to open independent of the command signal. Refer to Section 2-11.

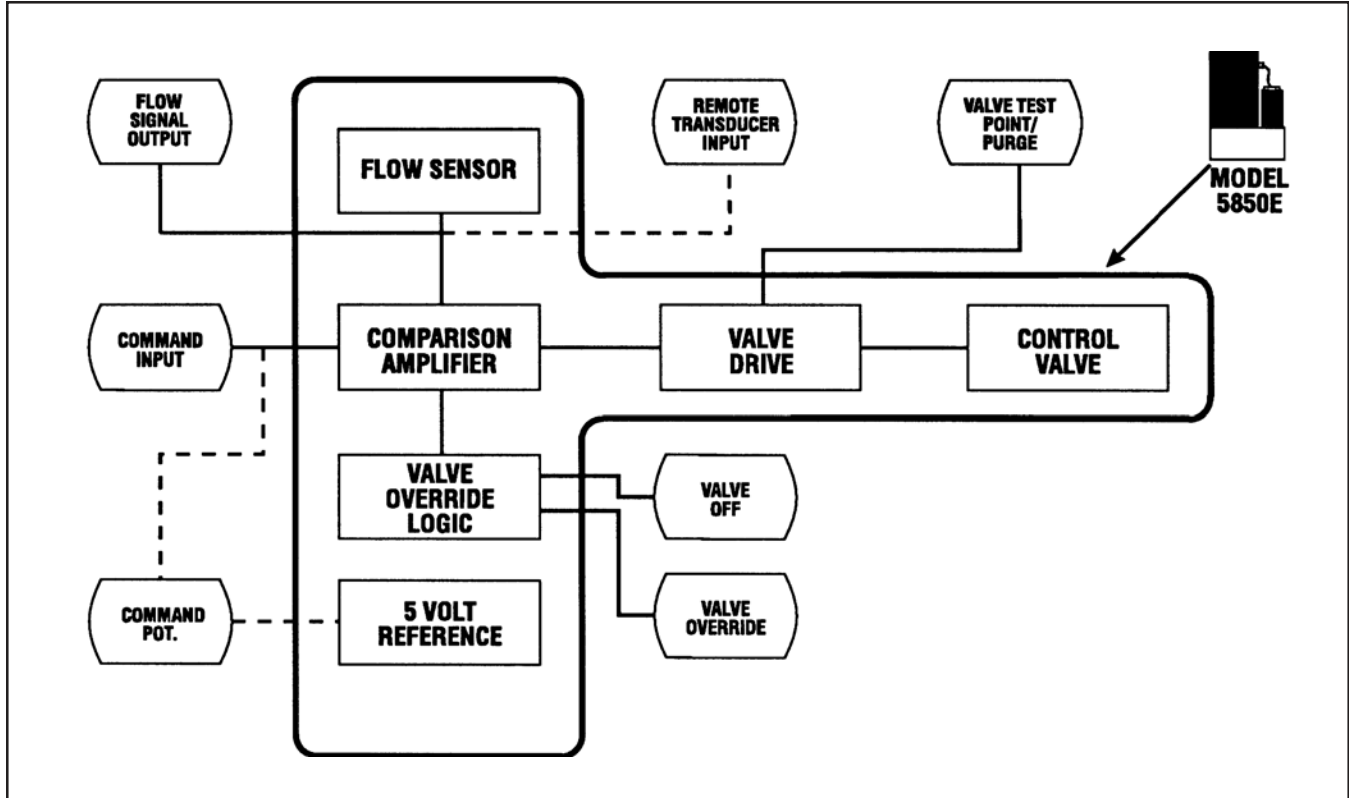


Figure 3-2 Flow Control System Block Diagram

### Remote Transducer Input

Accessed via terminal 5 on the Card Edge or Pin 15 on the D-Connector version. This feature allows the use of the integral control electronics and valve with the signal from an external 0-5 Vdc signal. The mass flow signal from the Model 5850E is still available for process monitoring. Refer to Section 2-9.

### Operating Procedure

- Apply power to the controller and allow approximately 45 minutes for the instrument to warm-up and stabilize its temperature.
- Turn on the gas supply.
- Command 0% flow and observe the controllers output signal. If the output is not 0 mVdc ( $\pm 10$  mVdc), check for leaks and if none are found, refer to the re-zeroing procedure in Section 3-3.
- Set the command for the desired flow rate to assume normal operation.

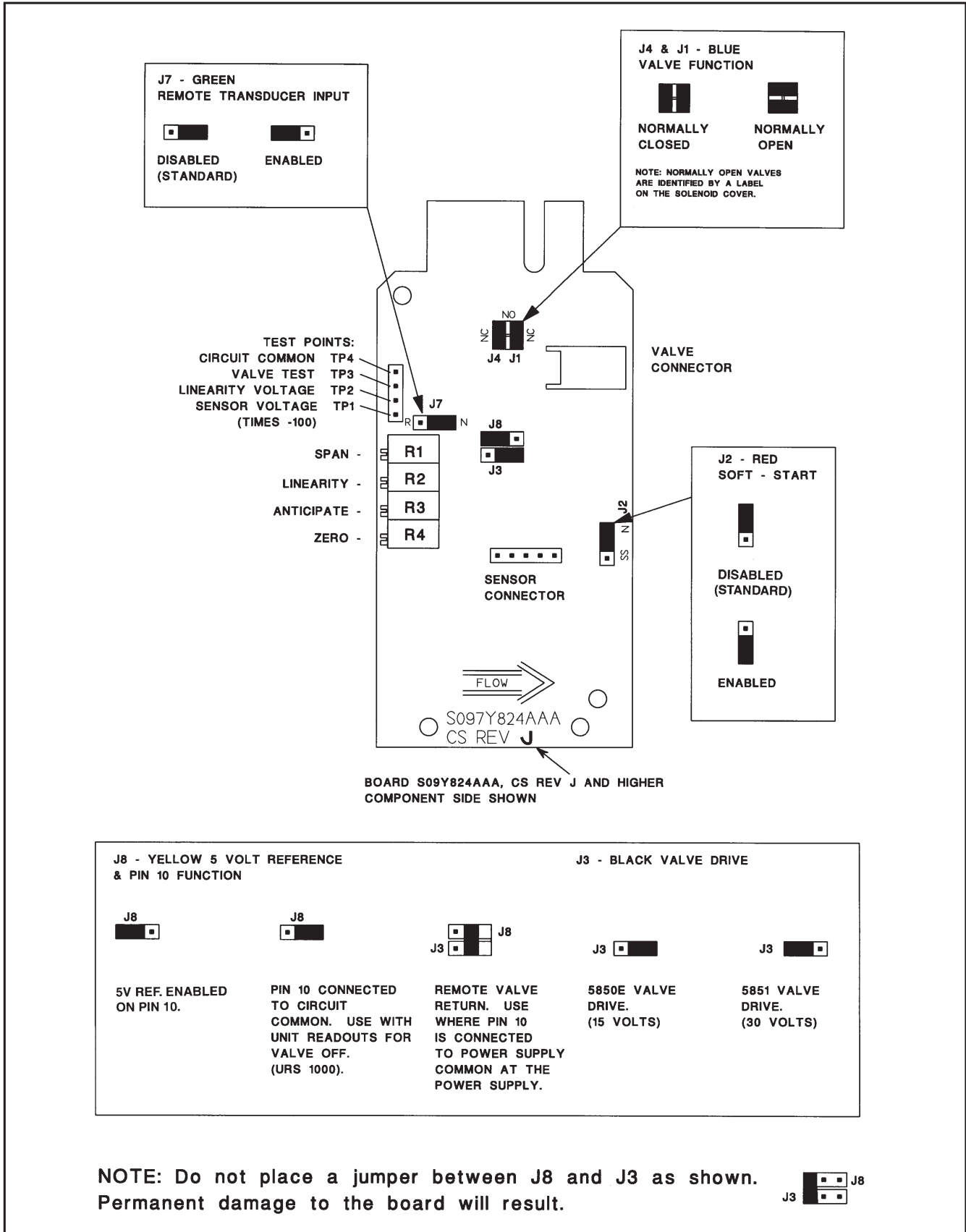


Figure 3-3 Card Edge PC Board Jumper Location and Function

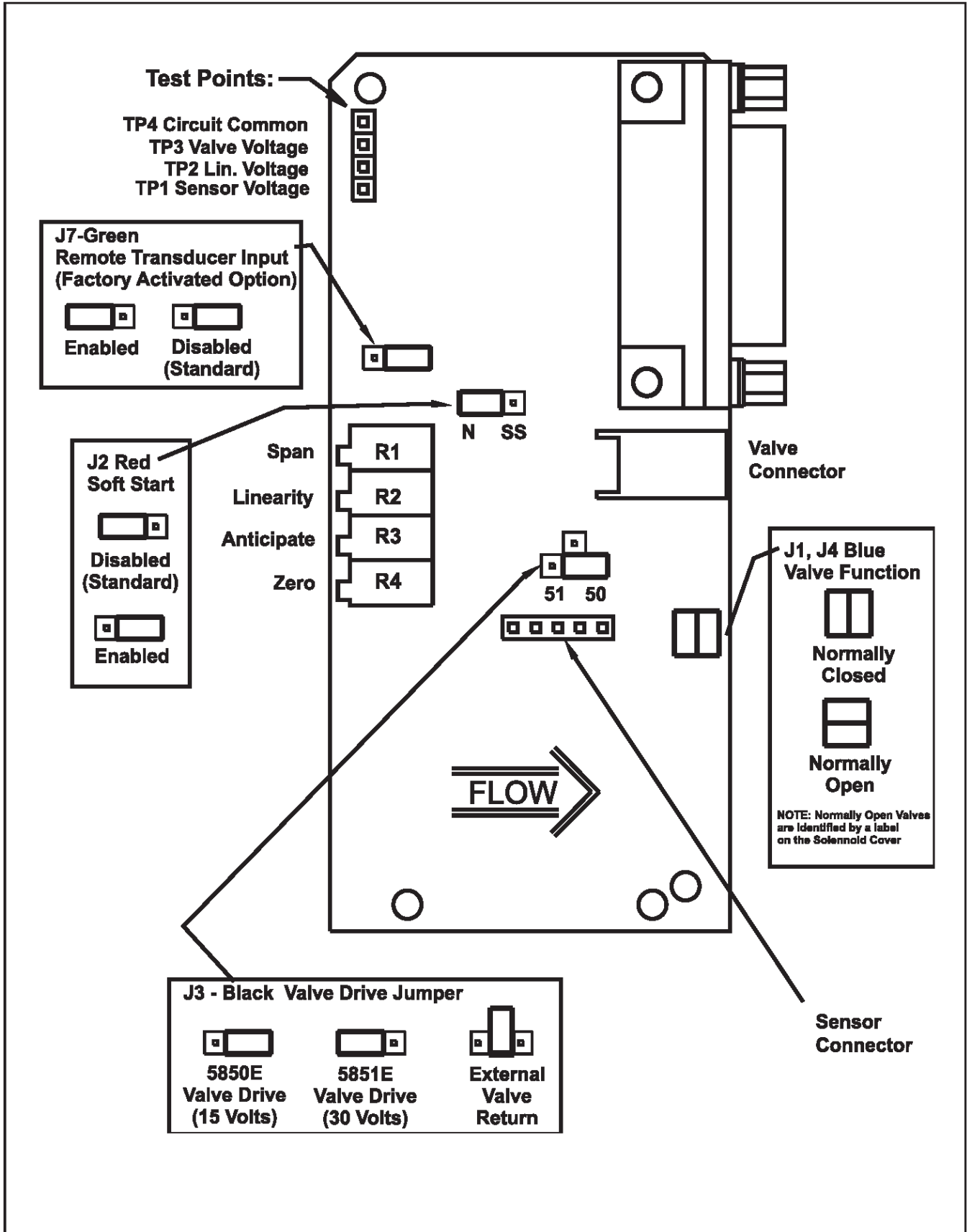


Figure 3-4 D-Connector PC Board Jumper Location and Function

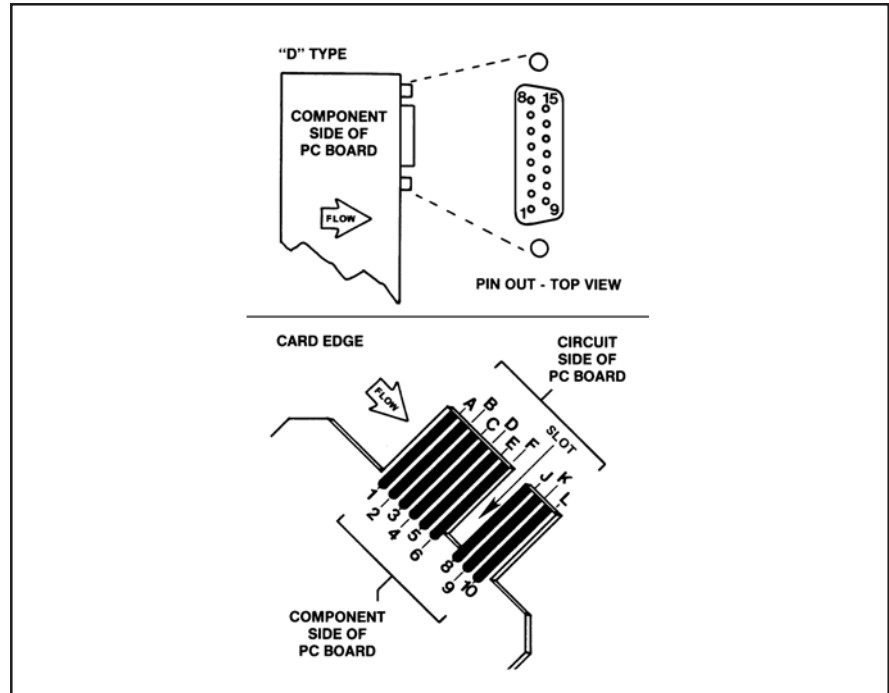


Figure 3-5 Model 5850E Calibration Connections

### Zero Adjustment

Each Model 5850E is factory adjusted to provide a zero  $\pm 10$  mVdc signal at zero flow. The adjustment is made in our calibration laboratory which is temperature controlled to  $21.1^{\circ}\text{C}$  ( $70^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ). After initial installation and warm-up in the gas system, the zero flow indication may be other than the factory setting. This is primarily caused by changes in temperature between the calibration laboratory and the final installation. The zero flow reading can also be affected, to a small degree, by changes in line pressure and mounting attitude.

To check zero, always mount the controller in its final configuration and allow a minimum of twenty minutes for the temperature of the controller and its environment to stabilize. Using a suitable voltmeter, check the controller output signal. If it differs from the factory setting, adjust it by removing the lower pot hole plug which is located closest to the controller body. Adjust the zero potentiometer (refer to Figure 3-6) until the desired output signal is obtained.

### Calibration Procedure

Note 1: If the valve has been disassembled and any of the following parts have been replaced, the control valve adjusting procedure in Section 4-4c must be performed before the Model 5850E is calibrated.

- orifice
- valve stem
- plunger
- lower guide spring
- valve seat

Note 2: Calibration of the Model 5850E mass flow controller requires the use of a digital voltmeter (DVM) and a precision flow standard calibrator such as the Brooks Instrument's Vol-U-Meter®. It is recommended that the calibration be performed only by trained and qualified service personnel.

Note 3: If the mass flow controller is to be used on a gas other than the calibration gas, apply the appropriate sensor conversion factor. Size the orifice for actual operating conditions.

**⚠ CAUTION**

**For the card edge model, do not ground Pin 10 with the 5 Volt reference enabled. Irreparable damage to the printed circuit board will result.**

Note 4: If Brooks' secondary electronics are being used as a power supply during the calibration, the 5 Volt reference must be enabled on the Card Edge version for proper operation (see Section 2-13). Remember to deactivate the 5 Volt reference before installing the calibrated mass flow controller in the system where Terminal 10 is grounded.

- a. With the controller installed in an unpressurized gas line, apply power and allow approximately 45 minutes for warm-up. During the warm-up, adjustment and calibration check procedures do not allow the control valve to open when gas flow is not present. This situation is not a normal operating mode and will cause abnormal heat-up of the control valve. With this abnormally warm valve, the meter will be difficult to calibrate. This situation can be prevented by switching the valve override "closed" when there is no gas flow or by setting the command to less than one percent (1%). Also, avoid unnecessary periods with the valve override "open."
- b. Adjust the anticipate potentiometer with 20 clockwise full turns. Next, adjust the anticipate potentiometer with 10 counterclockwise turns to center the potentiometer. This will provide a rough adjustment of this circuit and make the flow more stable for calibration.
- c. Connect the DVM positive lead to the 0-5 Volt signal output (Terminal 3 Card Edge, Pin 2 D-Connector) and the negative lead to signal com-mon (TP4). Adjust the zero potentiometer for an output of zero mV  $\pm$ 2 mV.
- d. Apply pressure to the system and insure that the zero signal repeats within 2 mV of the voltage set in Step "c" above. If the zero does not repeat, check for leakage.  
Note: Controllers supplied with all metal or Teflon valve seats do not provide tight shut-off. A 0-8% leak-through is typical. For metal or Teflon seat controllers, close a downstream shut-off valve and observe the zero signal.
- e. Set the command potentiometer (connected to terminals A, B and 10 of the Card Edge connector and Terminals 1, 8 and 11 of the D-Connector) for 100% of flow (5.000V). Connect the DVM positive lead to TP2 (linearity voltage) and the negative lead to TP4 (signal common). Adjust the linearity potentiometer for an output of 0.0V (zero volts).
- f. Connect the DVM positive lead to TP1 (-100x sensor voltage) and the negative lead to TP4 (circuit common). The command potentiometer should still be set at 100% flow (5.000V). Measure the flow rate using suitable volumetric calibration equipment. To adjust the controller to the proper full scale flow, calculate a new TP1 voltage using the following equation:

$$\frac{\text{New TP1 Voltage}}{\text{Voltage}} = \frac{\text{measured TP1 voltage}}{\text{measured flow rate}} \times \text{desired flow rate}$$

Adjust the span potentiometer until the voltage at TP1 is equal to the value calculated above. Recheck the flow rate after the flow is stable (at least two minutes). Repeat this check and adjustment procedure until the measured flow rate is within 1% of the desired flow rate. Note: The voltage at TP1 is -100 times the output voltage (+100 times for Current I/O Version) of the sensor. This voltage can range from -1.2 to -12 Volts, however, it is recommended that this voltage stay between -2.0 and -9.0 Volts for proper operation. If the recommended voltage range exceeds the desired range, accuracy and/or signal stability may not be achieved. If one of the limits is reached, check the restrictor and orifice sizing procedures. Refer to Sections 4-6 and 4-7 respectively.

- g. Set the command potentiometer for zero percent of flow. Connect the DVM positive lead to flow signal output (Terminal 3 Card Edge, Pin 2 D-Connector) and the negative lead to TP4. Readjust the zero potentiometer for an output of zero mV ±2 mV as necessary.
- h. Set the command potentiometer for 50% of flow (2.500V) and measure the flow rate. Calculate the error as a percentage of full scale.

$$\text{Full Scale Error} = 100\% \frac{\text{Measured Flow Rate} - \text{Desired Flow Rate}}{\text{Full Scale Flow Rate}}$$

Example:

What is the percent of full scale error when full scale is equal to 100 sccm?

Measured flow rate = 48.5 sccm, Desired flow rate = 50.0 sccm

$$\text{Full Scale Error} = 100 \frac{(48.5 - 50)}{100} = -1.5\%$$

- i. Calculate the TP2 correction voltage: (error recorded in Step “h”) x 0.450 Volts

Example:

Error = -1.5%

TP2 correction voltage = -1.5 x 0.450 = -0.675 Volts

New TP2 voltage = zero volts + (-0.675) = -0.675 Volts

- j. Set the command potentiometer for 100% flow (5.000V). Connect the DVM positive lead to TP2 and the negative lead to TP4.
- k. Adjust the linearity potentiometer for an output equal to the new calculated TP2 voltage.
- l. Repeat Steps “f, g and h.”
  1. If the error recorded in Step “h” is less than 0.5%, then the calibration procedure is complete.
  2. If the error is greater than 0.5%, set the command potentiometer for 100% (5.000V). Connect the DVM positive lead to TP2 (linearity voltage) and the negative lead to TP4 (circuit common). Calculate a new TP2 voltage as follows:

$$\text{New TP2 voltage} = \frac{\text{error recorded in Step "i"}}{\text{Step "i"}} \times 0.450\text{V} + \text{measured TP2 voltage}$$

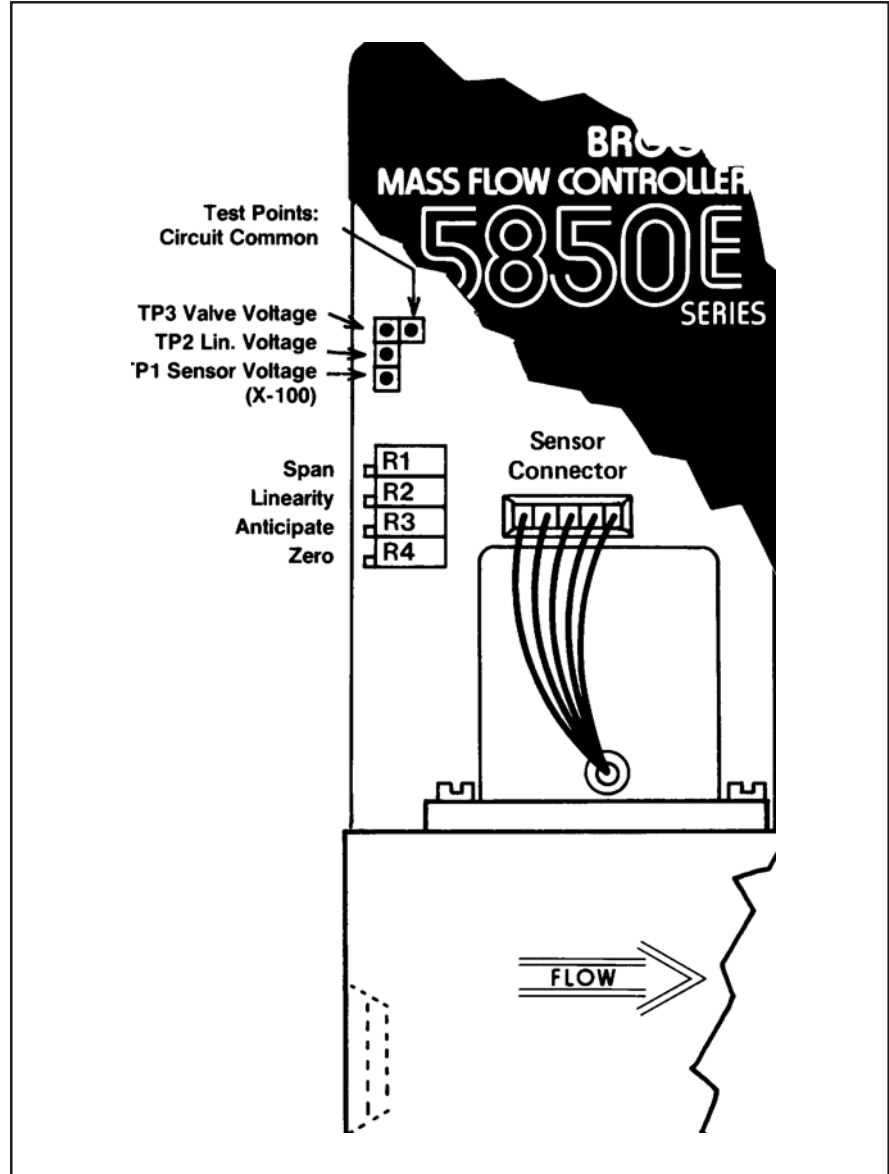


Figure 3-6 Adjustment Potentiometer Location

Example:

Controller error = 0.7%

Measured TP2 voltage = -0.567 Volts

TP2 correction =  $0.7 \times 0.450 = 0.315$  Volts

New TP2 correction =  $0.315 + (-0.567) = -0.252$  Volts

Adjust the linearity potentiometer for an output equal to the new TP2 voltage and then repeat Steps "f," "g" and "h."

Note: The voltage at TP2 can range from -10 to +3 Volts. It is recommended, however, that this voltage stay between -2.5 and +2.5 Volts for proper operation. If the recommended voltage range is exceeded, the desired accuracy and/or signal stability may not be achieved. If one of the limits is reached, check the restrictor sizing (refer to Section 4-7).



**Response****Fast Response Adjustment**

Two methods of adjusting the step response of the Model 5850E mass flow controllers can be used. No. 1 describes a method that will get the step response close to optimum quickly and without any flow measuring equipment. This method should be used when the response time of the flow controller is not critical to overall system performance. No. 2 describes a method that will allow adjustment of the Model 5850E mass flow controller to optimum step response. Adjustment of the fast response circuit will not affect the accuracy of the flow controller as adjusted in Section 3-4.

1. Fast response adjustment (3 seconds response specification not guaranteed)

Note: This procedure requires an oscilloscope, chart recorder or a DVM with a sample speed of three samples per second or greater to monitor the rate of change of the output signal.

- a. Set the command potentiometer for 100% of flow (5.000V) and wait about 45 seconds for the flow output signal to stabilize.
- b. Step the command signal to 0% or activate valve override closed to stop the flow. Observe the flow signal output as it decays.
- c. The behavior of the flow signal during this transition between 100% and zero percent flow indicates the adjustment required of the anticipate potentiometer. Refer to Figure 3-7.

1. If the flow signal decays to -.05 to -.5 Volt, then rises to zero Volts, the anticipate potentiometer is properly adjusted.
2. If the flow signal decays rapidly and goes below -.5 Volt before rising to zero Volt, the anticipate potentiometer must be adjusted clockwise and Steps "a" and "b" repeated.
3. If the flow signal decays slowly and does not go below -.5 Volt, the anticipate potentiometer must be adjusted counterclockwise and Steps "a" and "b" repeated.

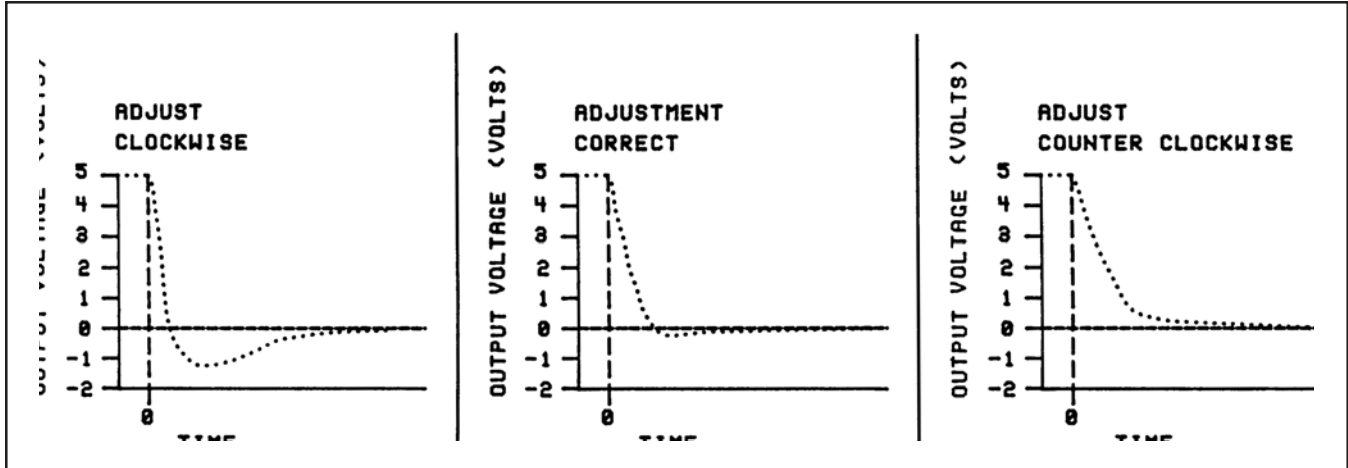


Figure 3-7 Fast Response Adjustment

#### Fast response adjustment (3 second response specification guaranteed)

Adjustment of the anticipate potentiometer to obtain a flow rate performance to be within 2% of flow rate commanded in less than three seconds (six seconds for Current I/O Version) after command change requires the use of a fast response flowmeter (500 millisecond response to be within 0.2% of final value or better) in series with the Model 5850E and a storage oscilloscope or recorder.

- Make a step change in command to the controller from zero to 100% of full scale flow and record the output signal of the fast response flowmeter.
- If this signal shows more than 4% overshoot, adjust the anticipate potentiometer one-half to one turn counterclockwise. If the signal does not show overshoot, but is not within 2% full scale of final value after three seconds (six seconds for Current I/O Version), adjust the anticipate potentiometer one-half to one turn clockwise. Set the command potentiometer for zero percent of flow.
- Repeat Steps "a" and "b" until the fast response flowmeter output signal meets the specified response requirements.

Note: With the above equipment, the anticipate potentiometer can be adjusted to give optimum response characteristics for any process.

## General

No routine maintenance is required on the Model 5850E. If an in-line filter is used, the filtering element should periodically be replaced or ultrasonically cleaned.

	<p><b>! WARNING</b></p> <p><b>METER/CONTROLLER SEAL COMPATIBILITY</b></p>
<p>Products in this manual may contain metal or elastomeric seals, gaskets, O-rings or valve seats. It is the "user's" responsibility to select materials that are compatible with their process and process conditions. Using materials that are not compatible with the process or process conditions could result in the Meter or Controller leaking process fluid outside the pressure boundary of the device, resulting in personnel injury or death.</p> <p>It is recommended that the user check the Meter or Controller on a regular schedule to ensure that it is leak free as both metal and elastomeric seals, gaskets, O-rings and valve seats may change with age, exposure to process fluid, temperature, and /or pressure.</p>	

## Troubleshooting

<p><b>! WARNING</b></p>
<p>If it becomes necessary to remove the instrument from the system, power to the device must be disconnected.</p>

<p><b>! CAUTION</b></p>
<p>It is important that this controller only be serviced by properly trained and qualified personnel.</p>

## A. System Checks

The Model 5850E is generally used as a component in gas handling systems which can be quite complex. This can make the task of isolating a malfunction in the system a difficult one. An incorrectly diagnosed malfunction can cause many hours of unnecessary downtime. If possible, make the following system checks before removing a suspected defective mass flow controller for bench troubleshooting or return, especially if the system is new.

1. Verify a low resistance common connection, correct power supply voltage and that signals are reaching and leaving the controller. The breakout board, P/N S273Z649AAA - Card Edge version or P/N S273Z668AAA - D-Connector version listed in Section 5, will make this job much easier.
2. Verify that the process gas connections have been correctly terminated and leak-checked.
3. If the mass flow controller appears to be functioning but cannot achieve set-point, verify that sufficient inlet pressure and pressure drop are available at the controller to provide the required flow.
4. Verify that all user selectable jumpers are in their desired positions (refer to Figures 3-3 and 3-4).

**⚠ WARNING**

**If it becomes necessary to remove the controller from the system after exposure to toxic, pyrophoric, flammable or corrosive gas, purge the controller thoroughly with a dry inert gas such as Nitrogen before disconnection the gas connections. Failure to correctly purge the controller could result in fire, explosion or death. Corrosion or contamination of the mass flow controller, upon exposure to air, may also occur.**

**B. Bench Troubleshooting**

1. Properly connect the mass flow controller to a  $\pm 15$  Vdc power supply command voltage source and connect an output signal readout device (4-1/2 digit voltmeter recommended) to Terminals 2 and 3 or D-Connector Pins 2 and 10 (refer to Figures 2-2 and 2-3). Apply power, set the command voltage to zero and allow the controller to warm-up for 45 minutes. Do not connect to a gas source at this time. Observe the output signal and, if necessary, perform the zero adjustment procedure (Section 3-3). If the output signal will not zero properly, refer to the sensor troubleshooting section and check the sensor. If the sensor is electrically functional, the printed circuit board is defective and will require replacement.

2. Connect the controller to a source of the gas on which it was originally calibrated. Command 100% flow and adjust the inlet and outlet pressures to the calibration conditions. Verify that the output signal reaches and stabilizes at 5.000 Volts. Vary the command voltage over the 2 to 100% range and verify that the output signal follows the set-point.

Apply +15 Volts to the valve override input (refer to Figures 2-3 and 2-4 for terminal assignments) and verify that the output exceeds 5.000 Volts.

Apply -15 Volts to the valve override terminal and verify that the output signal falls below 0.100 Volts. If possible, connect a flow measurement device in series with the mass flow controller to observe the actual flow behavior and verify the accuracy of the mass flow controller. If the mass flow controller functions as described above, it is functioning properly and the problem is most likely elsewhere. Table 4-1 lists possible malfunctions which may be encountered during bench troubleshooting.

**C. Sensor Troubleshooting**

If it is believed the sensor coils are either open or shorted, troubleshoot using Table 4-2. If any of the steps do not produce expected results, the sensor assembly is defective and must be replaced. Refer to Section 4-4 for the disassembly and assembly procedures to use when replacing the sensor.

Note: Do not attempt to disassemble the sensor.

**D. Cleaning**

Should the Model 5850E Mass Flow Controller require cleaning due to deposition, use the following procedures:

1. Remove the unit from the system.
2. Refer to Section 4-4 to disassemble the controller.

**⚠ CAUTION**

**Do not soak the sensor assembly in a cleaning solution. If solvent seeps into the sensor assembly, it will probably damage the sensor, or, at least, significantly alter its operating characteristics.**

3. Use a hemostat or tweezers to push a 0.007" dia. piano wire through the flow sensor tube to remove any contamination. For best results push the wire into downstream opening of the sensor tube (end closest to the control valve). The sensor tube can be flushed with a non-residuous solvent (Freon TF™ recommended). A hypodermic needle filled with solvent is a convenient means to accomplish this.

Table 4-1 Bench Troubleshooting

Trouble	Possible Cause	Check/Corrective Action
Actual flow overshoots setpoint by more than 5% full scale.	Anticipate potentiometer out of adjustment.	Adjust anticipate potentiometer. Refer to Section 3-5 .
Output stays at 0 Volts regardless of command and there is no flow through the controller.	Clogged Sensor. Refer to Section 4-4.	Clean sensor. Refer to cleaning.
Output stays at 0 Volts regardless of command and there is no flow through the controller.	Clogged Control Valve Card Edge Version internal reference is being used as the command source and the yellow jumper is in the E-F position. -15 Volts applied to the valve override input Defective printed circuit board Valve voltage not returned, pin L at common. "Valve-off" pin grounded.	Check TP3 with the command valve at 100%. If the voltage is more negative than -11V for NC Valve or +11V for NO Valve, disassemble and repair the control valve. Refer to Section 4-4C and 2-10. Refer to Section 2-12. Check valve override input. Refer to Figures 2-3 & 2-4 for terminal assignments. Replace printed circuit board. Refer to Section 4-4. Check jumper for external valve return. Refer to Section 2-12. Check "Valve-off" input. Refer to Figures 2-3 and 2-4 for terminal assignments.
Output signal stays at +6.8V regardless of command and there is flow through the controller.	Valve stuck open or leaky. +15V applied to the valve override input. Defective printed circuit board. Command input floating. Pin D connected to common.	Clean and/or adjust control valve. Refer to cleaning procedure and/or Section 4-4C. Check the valve override terminal. Refer to Figures 2-3 & 2-4 for terminal assignments. Replace printed circuit board. Refer to Section 4-4. Connect command signal. Refer to Figures 2-3 and 2-4 for terminal assignments. Remove Pin D from common.
Output signal follows setpoint at higher commands but will not go to zero.	Leaky control valve Excessive resistance in valve voltage	Disassemble and repair valve. Refer to Section 4-4C. Reduce wiring resistance or re-configure controller for "External Valve Return". Refer to Section 2-12.
Output signal follows setpoint at lower commands but does not reach full scale.	Insufficient inlet pressure or pressure drop. Partially clogged sensor.	Adjust pressure, inspect the filters and clear/replace as necessary. Check calibration. Refer to Section 3-4.
Partially clogged valve. Valve out of adjustment. Valve guide spring failure. Controller grossly out of calibration. Flow is higher than desired.	Disassemble and repair control valve. Refer to Section 4-4. Adjust valve. Refer to Section 4-4. Controller oscillates (see below). Partially clogged sensor.	Clean sensor, refer to the cleaning procedure.
Controller grossly out of calibration. Flow is lower than desired.	Partially clogged restrictor.	Replace restrictor. Refer to Section 4-4.
Controller oscillates.	Pressure drop or inlet pressure excessive. Oversized orifice. Valve out of adjustment. Anticipate potentiometer out of adjustment. Faulty pressure regulator. Defective printed circuit board.	Adjust pressures. Check orifice size. Refer to Section 4-6. Adjust valve. Refer to Section 4-4. Adjust anticipate potentiometer. Refer to Section 3-5. Check regulator output. Replace printed circuit board. Refer to Section 4-4.

An alternate method for flushing out the sensor is to replace the restrictor element with a low flow plug restrictor. This plug forces all the flow through the sensor and may dislodge any obstructions. With the valve orifice removed, subject the flow controller to a high differential pressure. Pressurizing the outlet of the MFC higher than the inlet may help force the obstruction upstream and out of the sensor tube.

4. Inspect the orifice for clogging by holding it in front of a light source and looking for light through the bore. Clean by soaking in a suitable non-residuous solvent and directing a stream of compressed clean, dry Nitrogen through the bore.

**SENSOR SCHEMATIC**

WIRE COLOR	PIN NO.	FUNCTION
White	4	Sensor common
Yellow	1	Heater
Blue	5	Heater common
Red	2	Upstream temperature sensor (Su)
Black	3	Downstream temperature sensor (Sd)

Note: Sensors manufactured before 9/88 used a wire harness interconnect, newer sensors use a "Flex" cable.

**Flex Circuit Wire Numbers**

OHMMETER CONNECTION	RESULT IF ELECTRICALLY FUNCTIONAL
Yellow and white to body (ground) (Pin 1 or 4 to body)	Open circuit on ohmmeter. If either heater (yellow), or sensor common (white) are shorted, an ohmmeter reading will be obtained.
White to red (Pin 4 to Pin 2)	Nominal 1100 ohms reading.
White to black (Pin 4 to Pin 3)	Depending on temperature and ohmmeter current.
Blue to yellow (Pin 5 to Pin 1)	Nominal 1200 ohm reading.

Table 4-2 Sensor Troubleshooting

5. Deposits of silicon dioxide may be removed by soaking the internal parts in solution of 5% hydrofluoric acid (5 parts hydrofluoric acid and 95 parts water (H<sub>2</sub>O)) followed by FreonTF.
6. Sintered type restrictor elements should be replaced as it is not possible to adequately remove deposits from them. Wire mesh and A.C.L.F.E. type restrictor elements can be cleaned in an ultrasonic bath. Refer to Section 4-7 for the correct restrictor to use.
7. Blow all parts dry with clean, dry Nitrogen and reassemble Refer to Section 4-4b, (assembly).
8. Purge the assembled controller with clean, dry Nitrogen.
9. Perform the calibration procedure in Section 3-4.
10. When the controller is reinstalled in the system, the connections should be leak-tested and the system purged with clean, dry Nitrogen for 30 minutes prior to start-up to prevent the formation of deposits.

**Sensor Tube**

The sensor tube is part of a calibrated flow divider that is designed to operate within a preset gas flow range. The sensor assembly may be removed or replaced by referring to Section 4-4, Disassembly and Assembly. If the sensor assembly is cleaned and reinstalled, a calibration check should be performed. Refer to Section 3-4.

### Disassembly and Assembly

The Model 5850E Mass Flow Controller may be disassembled in the field by the user for cleaning, re-ranging or servicing. Disassemble and assemble the controller as follows: (for normally open valves N.O.) Figures 3-3 and 3-4 show the location and function of jumpers. The jumpers J4 and J1 (blue) must be in the position indicated for a normally open valve.

Figure (labeled 4-2) showing the location and function of valve adjustment spacers. Valve adjustment is not required for normal installation and operation of the mass flow controller. If adjustment is required, consult the factory for information.

Figure (labeled 5-1) showing an exploded view of the controller and specific parts to the normally open N.O. valve.

Note: The Model 5850E Mass Flow Controller should be disassembled and assembled in a clean environment to prevent particulate contamination.

#### A. Disassembly

The numbers in ( ) refer to the spare parts exploded view in Figure 5-1.

#### **⚠ WARNING**

**Do not attempt to disassemble the mass flow controller until pressure has been removed and purging has been performed. Hazardous gas may be trapped in the valve assembly which could result in explosion, fire or serious injury.**

1. Remove the jam nut (1) on top of the valve assembly.
2. Unplug the valve connector from the electronics cover and remove the coil assembly (2).
3. Remove the hex socket screws (3) securing the valve retaining plate (4) attaching the valve stem assembly (6)(NC valve - Normally Closed) or (34) (NO Valve - Normally Open).

#### **⚠ CAUTION**

**When performing the following procedure the valve stem must be removed without cocking it to prevent damage to the valve spring.**

4. Carefully remove the valve stem assembly (6)(NC Valve) or (34)(NO Valve).
5. Remove the plunger assembly (7,8,9,11)(NC Valve) or (35,31,32,8,9,11) (NO Valve).
6. Remove and note the position of the valve spring spacers (10), which may be located above and/or below the lower guide spring (8). Remove the preload spacer spring (33)(NO Valve).
7. Unscrew the orifice (12) from the flow controller body(14).
8. Carefully unscrew the valve seat (11) from the plunger assembly (7)(NC Valve) or the plunger assembly (31,32,35)(NO Valve).  
Note the position and number of spacers (9) that are stacked on the threaded end of the valve seat.
9. Remove the three screws (20) attaching the electronics cover. Remove the electronics cover (23).

#### **⚠ CAUTION**

**Be careful not to stress the sensor lead wire to sensor assembly junction when removing the sensor connector from the PC Board. If the sensor lead wires are stressed an open in the sensor wiring could result.**



10. Unplug the sensor connector from the PC Board. Remove the two screws securing the bracket (24) and PC Board (15). Remove the bracket and PC Board.
11. Remove the two screws (18) and washers (19) securing the sensor assembly (16). Remove the sensor assembly.

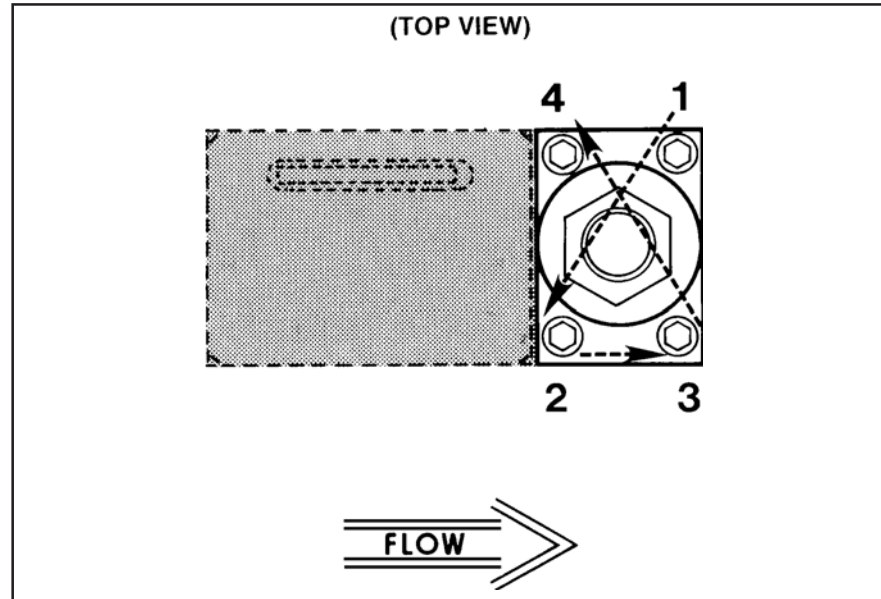


Figure 4-1 Torque Sequence for the Valve Retainer Plate

Note: Do not attempt to disassemble the sensor assembly.

### CAUTION

**Do not scratch the O-ring sealing service.**

12. Remove the sensor assembly O-rings (17) from the flow controller body (14). Using the Brooks O-ring removal tool will help prevent scratching the sealing surface.
13. Remove the adapter fittings (27) from the flow controller body (14). 14.Remove the restrictor assembly (21) from the inlet side of the flow controller body (14) using the restrictor tool (part of service tool kit listed in Section 5, Table 5-2).

#### B. ASSEMBLY

### CAUTION

**Do not get Halocarbon lubricant on the restrictor element (21) or hands. This is a special inert lubricant which is not easily removed.**

Note: It is recommended that all O-rings be replaced during controller assembly. All O-rings should be lightly lubricated with Halocarbon lubricant (part of O-ring kit, Section 5) prior to their installation.

1. Examine all parts for signs of wear or damage, replace as necessary.
2. Place the restrictor O-ring (22) on the restrictor assembly. Screw the restrictor assembly (21) into the inlet side of the flow controller body using the restrictor tool, tighten hand tight.



**CAUTION**

**The following steps must be performed as written. Placing the O-rings on the sensor before it is installed will result in damage to the O-rings causing a leak.**

3. Press the lubricated sensor O-rings (17) into the flow controller body (14). Install the sensor assembly and secure with two screws (18) and washers (19) tightened to 15 in/lbs.
4. Install the orifice (12) and its O-ring (13), using a 3/8 nut driver. Insure that the orifice is fully seated but do not overtighten.
5. Insert the valve preload spacers (10)(NC Valve) or (33)(NO Valve), if used, into the valve cavity in the flow controller body (14). Use care to preserve the correct order.
6. Place the spacers (9) and spring (8) on the valve seat (11) in the same order as noted in step 8 of the disassembly. Screw the valve seat (11) into the plunger assembly (7)(NC Valve) or (35,31,32)(NO Valve). Tighten the assembly until there is no looseness, but do not over-tighten.
7. Install the valve plunger assembly (7, 8, 9 and 11)(NC Valve) or (35,31,32,8,9,11)(NO Valve) on the preload spacers (10). Install air gap spacers (10), if used on top of the valve spring.
8. Install the valve stem assembly (6), secure with the valve retaining plate (4) and four hex socket screws (3). When installing the screws they should first make light contact with the plate, which should be checked to insure that it makes full contact around the stem assembly. Torque the screws securing the valve retaining plate in diagonal pattern (Refer to Figure 4-1) to 17 in/lbs.
9. Install the coil assembly (2) over the valve stem assembly (6)(NC Valve) or (34)(NO Valve) install extension spacer nut (3)(NO Valve) and secure with jam nut (1).
10. Install the printed circuit (PC) Board (15), secure with the bracket (24) and two screws. Plug the connector from the sensor assembly onto the PC Board. The flow arrow on the connector should be pointing toward the valve assembly.
11. Install the electronics cover (23) on the controller, secure with three screws (20). Plug the connector from the valve coil into the PC Board through the hole in the electronics cover.
12. Prior to installation leak and pressure test to any applicable pressure vessel codes.

**C. Control Valve Adjustment**

The Model 5850E control valve has been factory adjusted to insure proper operation. Readjustment is only required if any of the following parts have been replaced:

- orifice (12)
- valve stem (6)
- plunger (7)
- lower guide spring (8)
- valve seat (11)

The valve is adjusted in Brooks' mass flow controllers by adding spacers (9 and 10) to the control valve assembly to vary the air gap and initial preload. Spacers are used to affect the proper adjustment because they provide a reliable and repeatable means for adjustment. Screw type adjustment mechanisms can change with pressure or vibration and introduce an additional dynamic seal that is a potential leak site and source for contamination. Refer to Fig. 4-2 for spacer locations.

In April 1989 a new valve stem and plunger combination was incorporated into the Model 5850E to improve the performance of the valve. These parts can be used as replacements in any Model 5850E, but the stem and plunger must be replaced at the same time.

The new style parts can be identified by a slightly curved surface on the bottom surface of the valve stem and two small groves in the plunger. The old style parts have a flat surface on

the bottom of the stem and one or no groove in the plunger. Please refer to Figure 4-2 for an illustration of the difference.

Valves incorporating the old style parts may or may not have a small diameter air gap spacer, and always use two lower guide springs. The new style parts always include a .010" thick small diameter air gap spacer. For devices with an orifice diameter of 0.020" and less the 0.025" thick lower guide spring is used. For devices with an orifice diameter of 0.032" and larger the 0.020" lower guide spring is used. Although the newer valve parts are assembled slightly differently than the old parts, the adjustment procedure that follows is the same for both types of parts.

The preload determines the initial force that is required to raise the valve seat off the orifice and start gas flow. If the preload is insufficient, the valve will not fully close and gas will leak through. If the preload is excessive, the magnetic force generated between the plunger and stem will not be sufficient to raise the plunger and the valve will not open.

The airgap is the space between the top of the plunger and stem. The airgap determines the force between the plunger and stem at a given voltage and the total travel of the valve. If the airgap is too small, the plunger travel may not be sufficient to fully open the valve. Also, the magnetic force may be too high for a given valve coil voltage. If the airgap is too large, the magnetic force will not be sufficient to raise the plunger and the valve will not open.

Note: Prior to starting the valve adjustment procedure, check to insure that the orifice is properly seated and that the valve parts are not bent or damaged.

1. Adjustment Procedure (Refer to Section 5, Spare Parts, for the spacer kit)
  - a. Remove the electronics cover (23) from the controller. Insure that the connector from the coil assembly (2) is properly reconnected to the PC Board after the electronics cover is removed.
  - b. Perform the electrical and gas connections to the controller following the instructions in Section 2 of this manual. Use a clean, dry inert gas, such as Nitrogen, for this procedure. Do not apply gas pressure to the controller at this time.
  - c. Disassemble the control valve following the procedure given in Section 4-4a, above. Note the number, locations and thicknesses of all the spacers (9 and 10).
  - d. Decrease the preload of the valve by 0.005 inches either by removing a 0.005" small preload spacer or by adding a 0.005" large preload spacer. Refer to Fig.4-2.
  - e. Reassemble the valve following the assembly procedure in Section 4-4a.
  - f. Command 0% flow, apply normal operating pressure and check for valve leak-through by observing the output signal.
  - g. If the valve leaks-through, increase the preload by 0.005" and go to Step h. If the valve does not leak-through, repeat Steps d, e, f and g.
  - h. Apply the normal operating gas pressure and command 100% flow (5.000 Volts on Terminal A, Pin 2).

Note: Due to possible heat capacity and density differences between the test gas and actual process gas for which the mass flow controller was sized, it may be necessary to increase the inlet pressure to obtain proper control at 100% flow.
  - i. Measure the valve voltage by connecting a voltmeter between Test Point 3 (TP3) and Test Point 4 (TP4). Refer to Figure 4-3.  
Valve Voltage = (1.53 x TP3) + 20.7
  - j. If the flow controller output signal is 100% (5.0V) and the valve voltage is less than 11.5 Volts, the valve adjustment is complete.

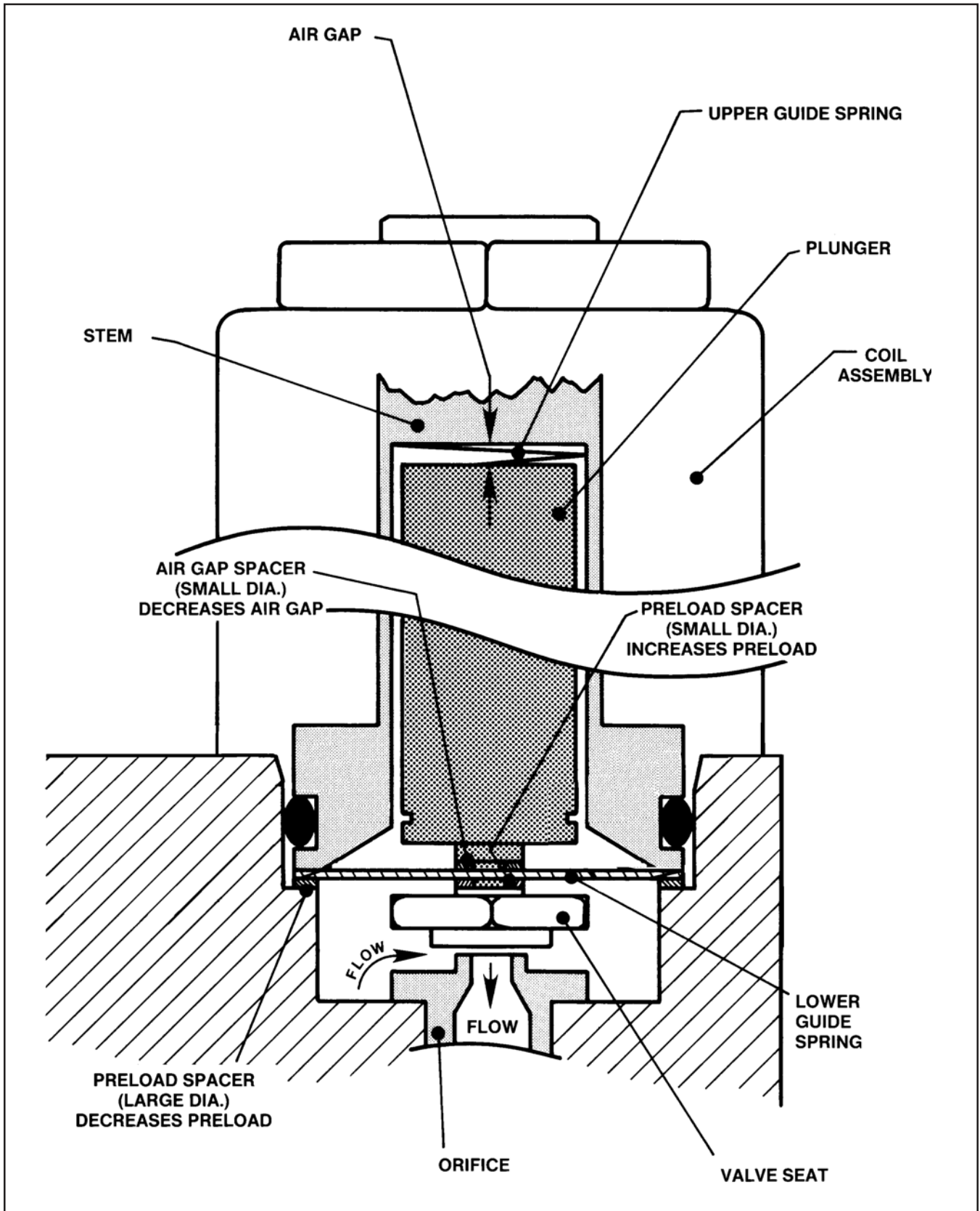


Figure 4-2a Valve Adjusting Spacer Locations (Normally Closed valve N.C.)

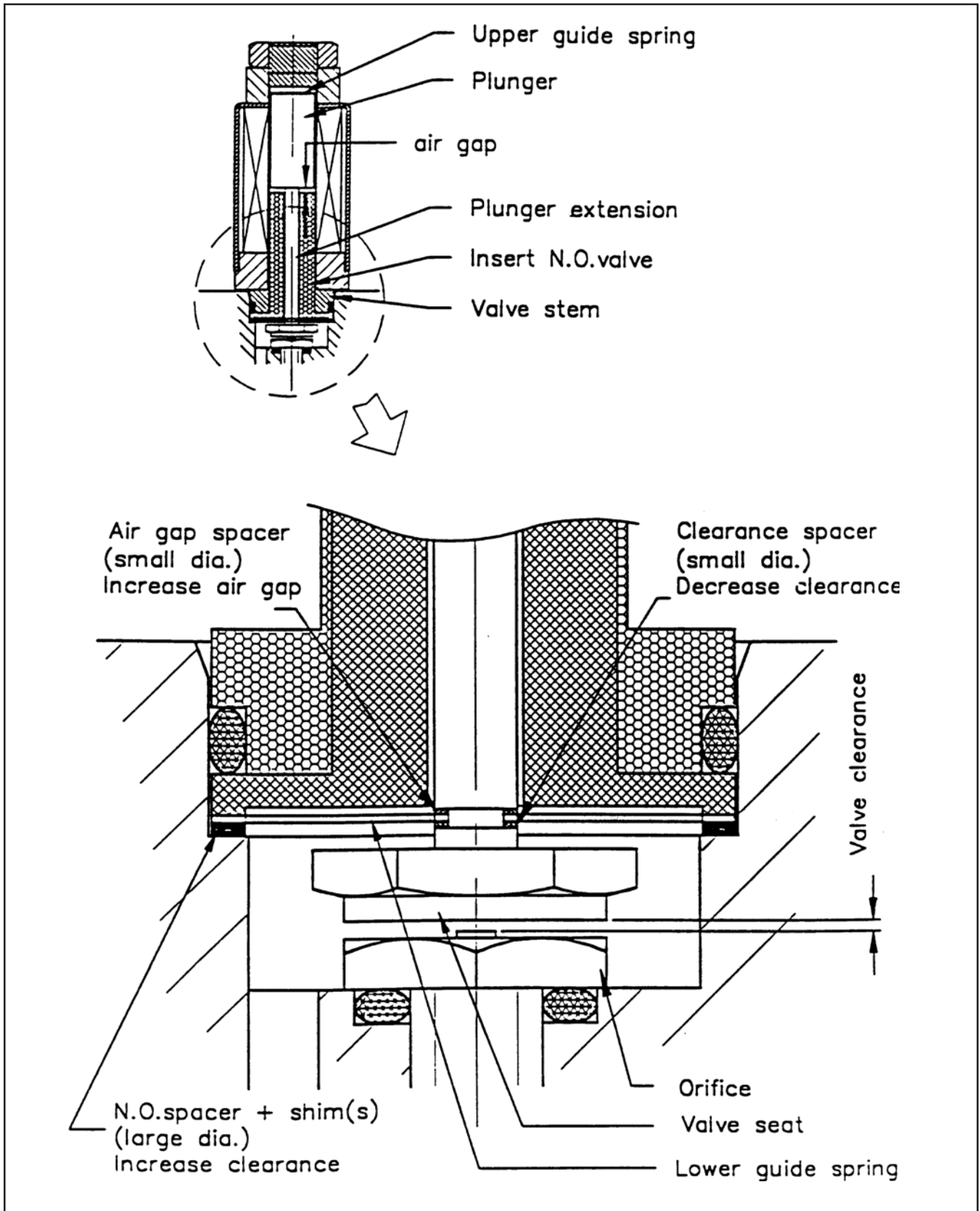


Figure 4-2b Valve Adjusting Spacer Locations (Normally Open valve N.O.)

k. If the flow controller output signal is 100% (5.0V) and the valve voltage is less than 11.5 Volts, the valve adjustment is complete.

l. Proceed to Section 3 and perform 3-4 Calibration Procedure, if required.

### Gas Conversion Factors

If a mass flow controller is operated on a gas other than the gas it was calibrated with, a scale shift will occur in the relation between the output signal and the mass flow rate. This is due to the difference in heat capacities between the two gases. This scale shift can be approximated by using the ratio of the molar specific heat of the two gases or by sensor conversion factor. A list of sensor conversion factors is given in Table 4-3. To change to a new gas, multiply the output reading by the ratio of the gas factor for the desired gas by the gas factor for the calibration gas.

$$\text{Actual Gas Flow Rate} = \text{Output Reading} \times \frac{\text{Factor of the New Gas}}{\text{Factor of the Calibration Gas}}$$

Example:

The controller is calibrated for nitrogen.

The desired gas is carbon dioxide

The output reading is 75 sccm when carbon dioxide is flowing

Then  $75 \times 0.773 = 57.98$  sccm

In order to calculate the conversion factor for a gas mixture, the following formula should be used:

$$\text{Sensor Conversion Factor}_{\text{Mixture}} = \frac{100}{\frac{P_1}{\text{Sensor Conversion Factor}_1} + \frac{P_2}{\text{Sensor Conversion Factor}_2} + \frac{P_3}{\text{Sensor Conversion Factor}_3}}$$

Where,

$P_1$  = percentage (%) of gas 1 (by volume)

$P_2$  = percentage (%) of gas 2 (by volume)

$P_3$  = percentage (%) of gas 3 (by volume)

Example: The desired gas is 20% Helium (He) and 80% Chlorine (Cl) by volume. The desired full scale flow rate of the mixture is 20 slpm. Sensor conversion factor for the mixture is:

$$\text{Mixture Factor} = \frac{100}{\frac{20}{1.386} + \frac{80}{0.876}} = 0.945$$

Nitrogen equivalent flow =  $20 / 0.945 = 21.16$  slpm Nitrogen It is generally accepted that the mass flow rate derived from this equation is only accurate to  $\pm 5\%$ . The sensor conversion factors given in Table 4-4 are calculated based on a gas temperature of 21°C and a pressure of one atmosphere. The specific heat of most gases is not strongly pressure, and/ or temperature, dependent. However, gas conditions that vary widely from these reference conditions may cause an additional error due to the change in specific heat caused by pressure and/or temperature.

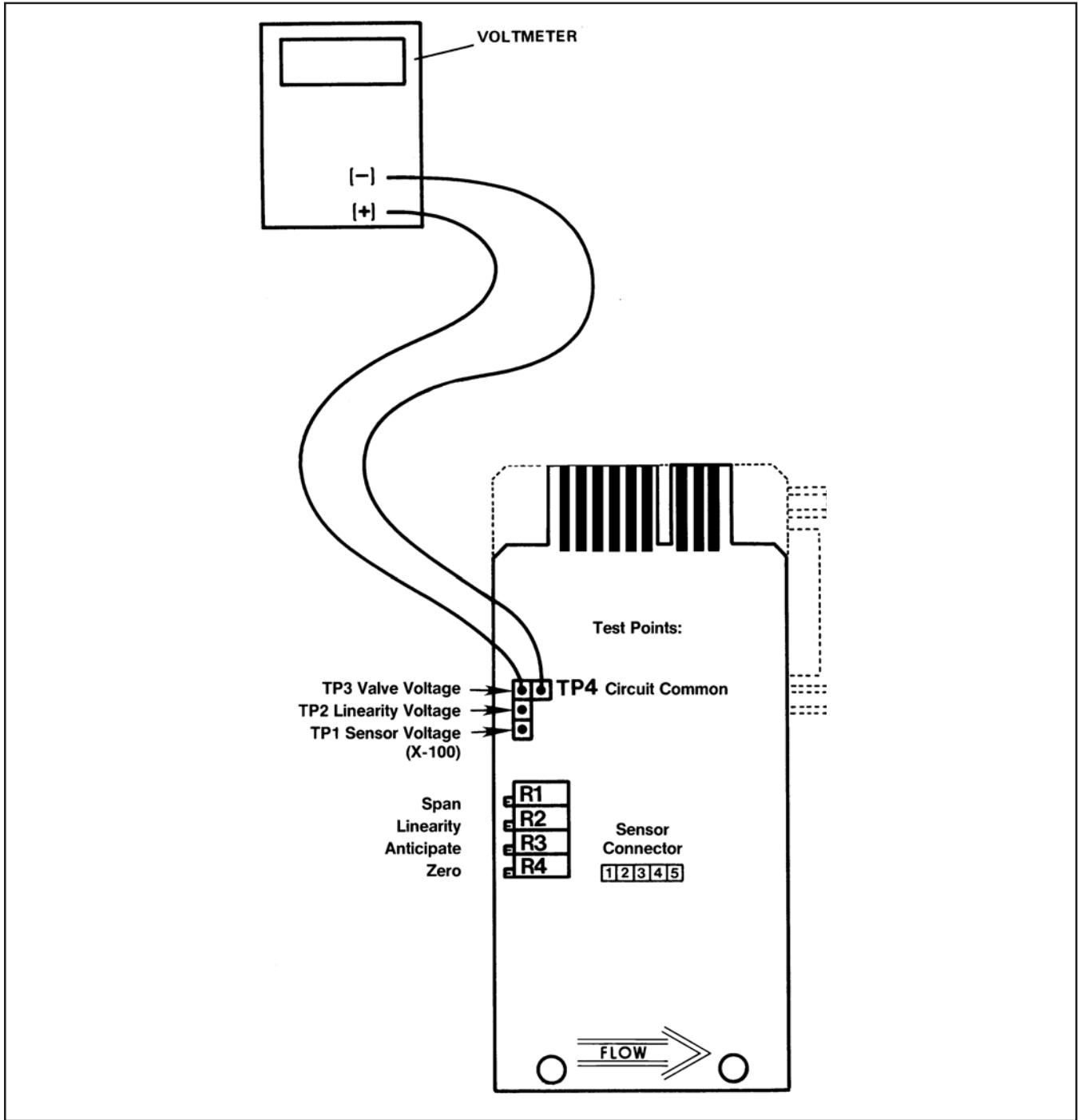


Figure 4-3 Voltmeter Connections for Valve Adjustment



Table 4-3 Conversion Factors (Nitrogen Base)

GAS NAME	FORMULA	SENSOR FACTOR	ORIFICE FACTOR	DENSITY (kg/m <sup>3</sup> )
Acetylene	C <sub>2</sub> H <sub>2</sub>	0.615	0.970	1.173
Air	Mixture	0.998	1.018	1.293
Allene	C <sub>3</sub> H <sub>4</sub>	0.478	1.199	1.787
Ammonia	NH <sub>3</sub>	0.786	0.781	0.771
Argon	Ar	1.395	1.195	1.784
Arsine	AsH <sub>3</sub>	0.754	1.661	3.478
Boron Trichloride	BCl <sub>3</sub>	0.443	2.044	5.227
Boron Trifluoride	BF <sub>3</sub>	0.579	1.569	3.025
Bromine Pentafluoride	BrF <sub>5</sub>	0.287	2.502	7.806
Bromine Trifluoride	BrF <sub>3</sub>	0.439	2.214	6.108
Bromotrifluoroethylene	C <sub>2</sub> BrF <sub>3</sub>	0.326	2.397	7.165
Bromotrifluoromethane f-13B1	CBrF <sub>3</sub>	0.412	2.303	6.615
1,3-Butadiene	C <sub>4</sub> H <sub>6</sub>	0.354	1.413	2.491
Butane	C <sub>4</sub> H <sub>10</sub>	0.257	1.467	2.593
1-Butene	C <sub>4</sub> H <sub>8</sub>	0.294	1.435	2.503
CIS-2-Butene	C <sub>4</sub> H <sub>8</sub>	0.320	1.435	2.503
Trans-2-Butene	C <sub>4</sub> H <sub>8</sub>	0.291	1.435	2.503
Carbon Dioxide	CO <sub>2</sub>	0.740	1.255	1.977
Carbon Disulfide	CS <sub>2</sub>	0.638	1.650	3.393
Carbon Monoxide	CO	0.995	1.000	1.250
Carbon Tetrachloride	CCl <sub>4</sub>	0.344	2.345	6.860
Carbon Tetrafluoride f-14	CF <sub>4</sub>	0.440	1.770	3.926
Carbonyl Fluoride	COF <sub>2</sub>	0.567	1.555	2.045
Carbonyl Sulfide	COS	0.680	1.463	2.180
Chlorine	Cl <sub>2</sub>	0.876	1.598	3.214
Chlorine Dioxide	ClO <sub>2</sub>	0.693	1.554	3.011
Chlorine Trifluoride	ClF <sub>3</sub>	0.433	1.812	4.125
2-Chlorobutane	C <sub>4</sub> H <sub>9</sub> Cl	0.234	1.818	4.134
Chlorodifluoromethane f-22	CHClF <sub>2</sub>	0.505	1.770	3.906
Chloroform (Trichloromethane)	CHCl <sub>3</sub>	0.442	2.066	5.340
Chloropentafluoroethane f-115	C <sub>2</sub> ClF <sub>5</sub>	0.243	2.397	7.165
Chlorotrifluoroethylene	C <sub>2</sub> ClF <sub>3</sub>	0.337	2.044	5.208
Chlorotrifluoromethane f-13	CCLF <sub>3</sub>	0.430	1.985	4.912
Cyanogen	(CN) <sub>2</sub>	0.498	1.366	2.322
Cyanogen Chloride	CLCN	0.618	1.480	2.730
Cyclobutane	C <sub>4</sub> H <sub>8</sub>	0.387	1.413	2.491
Cyclopropane	C <sub>3</sub> H <sub>6</sub>	0.505	1.224	1.877
Deuterium	D <sub>2</sub>	0.995	0.379	0.177
Diborane	B <sub>2</sub> H <sub>6</sub>	0.448	1.000	1.235
Dibromodifluoromethane f-12B2	CBBr <sub>2</sub> F <sub>2</sub>	0.363	2.652	8.768
1,2-Dibromotetrafluoroethane f-114B2	C <sub>2</sub> Br <sub>2</sub> F <sub>4</sub>	0.215	2.905	10.53
Dichlorodifluoromethane f-12	CCL <sub>2</sub> F <sub>2</sub>	0.390	2.099	5.492
Dichlorofluoromethane f-21	CHCl <sub>2</sub> F	0.456	1.985	4.912
Dichlorosilane	SiH <sub>2</sub> Cl <sub>2</sub>	0.442	1.897	4.506
1,2-Dichloroethane	C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	0.382	1.879	4.419
1,2-Dichlorotetrafluoroethane f-114	C <sub>2</sub> Cl <sub>2</sub> F <sub>4</sub>	0.231	2.449	7.479
2,2 Dichloro	C <sub>2</sub> HC <sub>2</sub> F <sub>3</sub>	0.259	2.336	6.829
1,1-Difluoro-1-Chloroethane	C <sub>2</sub> H <sub>3</sub> ClF <sub>2</sub>	0.341	1.957	4.776
1,1-Difluoroethane	CH <sub>3</sub> CHF <sub>2</sub>	0.415	1.536	2.940
1,1-Difluoroethylene	CH <sub>2</sub> CF <sub>2</sub>	0.458	1.512	2.860
Diethylsilane	C <sub>2</sub> H <sub>6</sub> Si	0.183	1.775	3.940
Difluoromethane f-32	CF <sub>2</sub> H <sub>2</sub>	0.627	1.360	2.411
Dimethylamine	(CH <sub>3</sub> ) <sub>2</sub> NH	0.370	1.269	2.013
Dimethylether	(CH <sub>3</sub> ) <sub>2</sub> O	0.392	1.281	2.055
2,2-Dimethylpropane	C(CH <sub>3</sub> ) <sub>4</sub>	0.247	1.613	3.244
Disilane	Si <sub>2</sub> H <sub>6</sub>	0.332	1.493	2.779
Ethane	C <sub>2</sub> H <sub>6</sub>	0.490	1.038	1.357
Ethanol	C <sub>2</sub> H <sub>5</sub> O	0.394	1.282	2.057
Ethylacetylene	C <sub>4</sub> H <sub>6</sub>	0.365	1.384	2.388
Ethyl Chloride	C <sub>2</sub> H <sub>5</sub> Cl	0.408	1.516	2.879
Ethylene	C <sub>2</sub> H <sub>4</sub>	0.619	1.000	1.261
Ethylene Oxide	C <sub>2</sub> H <sub>4</sub> O	0.589	1.254	1.965
Fluorine	F <sub>2</sub>	0.924	1.163	1.695
Fluoroform f-23	CHF <sub>3</sub>	0.529	1.584	3.127
Germane	GeH <sub>4</sub>	0.649	1.653	3.418
Germanium Tetrachloride	GeCl <sub>4</sub>	0.268	2.766	9.574
Halothane (R-123B1)	C <sub>2</sub> HBrClF <sub>3</sub>	0.257	2.654	8.814
Helium	He	1.386	0.378	0.178
Hexafluoroacetone	F <sub>3</sub> CCOCF <sub>3</sub>	0.219	2.434	7.414
Hexafluorobenzene	C <sub>6</sub> F <sub>6</sub>	0.632	2.577	8.309
Hexafluoroethane f-116	C <sub>2</sub> F <sub>6</sub>	0.255	2.219	6.139
Hexafluoropropylene (HFP)	C <sub>3</sub> F <sub>6</sub>	0.249	2.312	6.663
Hexamethyldisilane (HMDS)	(CH <sub>3</sub> ) <sub>6</sub> Si <sub>2</sub>	0.139	2.404	7.208
Hexane	C <sub>6</sub> H <sub>14</sub>	0.204	1.757	3.847

Table 4-3 Conversion Factors (Nitrogen Base) (Continued)

GAS NAME	FORMULA	SENSOR FACTOR	ORIFICE FACTOR	DENSITY (kg/m <sup>3</sup> )
Hydrogen	H <sub>2</sub>	1.008	0.269	0.090
Hydrogen Bromide	HBr	0.987	1.695	3.645
Hydrogen Chloride	HCL	0.983	1.141	1.639
Hydrogen Cyanide	HCN	0.744	0.973	1.179
Hydrogen Fluoride	HF	0.998	0.845	0.893
Hydrogen Iodide	HI	0.953	2.144	5.789
Hydrogen Selenide	H <sub>2</sub> Se	0.837	1.695	3.613
Hydrogen Sulfide	H <sub>2</sub> S	0.850	1.108	1.539
Iodine Pentafluoride	IF <sub>5</sub>	0.283	2.819	9.907
Isobutane	C <sub>4</sub> H <sub>10</sub>	0.260	1.440	2.593
Isobutene	C <sub>4</sub> H <sub>8</sub>	0.289	1.435	2.503
Isopentane	C <sub>5</sub> H <sub>12</sub>	0.211	1.605	3.222
Krypton	Kr	1.382	1.729	3.708
Methane	CH <sub>4</sub>	0.763	0.763	0.717
Methylacetylene	C <sub>3</sub> H <sub>4</sub>	0.473	1.196	1.782
Methyl Bromide	CH <sub>3</sub> Br	0.646	1.834	4.236
3-Methyl-1-butene	C <sub>5</sub> H <sub>10</sub>	0.252	1.584	3.127
Methyl Chloride	CH <sub>3</sub> CL	0.687	1.347	2.308
Methyl Fluoride	CH <sub>3</sub> F	0.761	1.102	1.518
Methyl Mercaptan	CH <sub>3</sub> S	0.588	1.313	2.146
Methyl Silane	CH <sub>3</sub> Si	0.393	1.283	2.061
Methyl Trichlorosilane (MTS)	CH <sub>3</sub> Cl <sub>3</sub> Si	0.267	2.310	6.675
Methyl Vinyl Ether	C <sub>3</sub> H <sub>6</sub> O	0.377	1.435	2.567
Monoethanolamine	C <sub>2</sub> H <sub>7</sub> NO	0.305	1.477	2.728
Monoethylamine	C <sub>2</sub> H <sub>5</sub> NH <sub>2</sub>	0.359	1.269	2.013
Monomethylamine	CH <sub>3</sub> NH <sub>2</sub>	0.565	1.067	1.420
Neon	Ne	1.398	0.847	0.902
Nickel Carbonyl	Ni(CO) <sub>4</sub>	0.212	2.371	7.008
Nitric Oxide	NO	0.995	1.030	1.339
Nitrogen	N <sub>2</sub>	1.000	1.000	1.251
Nitrogen Dioxide	NO <sub>2</sub>	0.758	1.713	2.052
Nitrogen Trifluoride	NF <sub>3</sub>	0.501	1.598	3.168
Nitrogen Trioxide	N <sub>2</sub> O <sub>3</sub>	0.443	1.649	3.389
Nitrosyl Chloride	NOCL	0.644	1.529	2.913
Nitrous Oxide	N <sub>2</sub> O	0.752	1.259	1.964
Octafluorocyclobutane	C <sub>4</sub> F <sub>8</sub>	0.169	2.672	8.933
Oxygen	O <sub>2</sub>	0.988	1.067	1.429
Oxygen Difluoride	OF <sub>2</sub>	0.672	1.388	2.402
Ozone	O <sub>3</sub>	0.738	1.310	2.138
Pentafluoroethane f-125	C <sub>2</sub> HF <sub>5</sub>	0.287	2.070	5.360
Pentane (n-Pentane)	C <sub>5</sub> H <sub>12</sub>	0.212	1.605	3.222
Perchloryl Fluoride	ClO <sub>3</sub> F	0.448	1.905	4.571
Perfluorobutane	C <sub>4</sub> F <sub>10</sub>	0.738	2.918	10.61
Perfluoro-2-Butene	C <sub>4</sub> F <sub>8</sub>	0.268	2.672	8.933
Perfluoromethyl-vinylether	PMVE	0.296	2.029	5.131
Perfluoropropane	C <sub>3</sub> F <sub>8</sub>	0.179	2.591	8.396
Pentane (n-Pentane)	C <sub>5</sub> H <sub>12</sub>	0.212	1.605	3.222
Phosgene	COCL <sub>2</sub>	0.504	1.881	4.418
Phosphine	PH <sub>3</sub>	0.783	1.100	1.517
Phosphorous Pentafluoride	PF <sub>5</sub>	0.346	2.109	5.620
Phosphorous Trifluoride	PF <sub>3</sub>	0.495	1.770	3.906
Propane (same as CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub> )	C <sub>3</sub> H <sub>8</sub>	0.343	1.274	2.008
Propylene (Propene)	C <sub>3</sub> H <sub>6</sub>	0.401	1.234	1.875
Rhenium Hexafluoride	ReF <sub>6</sub>	0.230	3.279	13.41
Silane	SiH <sub>4</sub>	0.625	1.070	1.440
Silicon Tetrachloride	SiCL <sub>4</sub>	0.310	2.465	7.579
Silicon Tetrafluoride	SiF <sub>4</sub>	0.395	1.931	4.648
Sulfur Dioxide	SO <sub>2</sub>	0.728	1.529	2.858
Sulfur Hexafluoride	SF <sub>6</sub>	0.270	2.348	6.516
Sulfur Tetrafluoride	SF <sub>4</sub>	0.353	1.957	4.776
Sulfur Trioxide	SO <sub>3</sub>	0.535	1.691	3.575
Sulfuryl Fluoride	SO <sub>2</sub> F <sub>2</sub>	0.423	1.931	4.648
Tetrachloromethane	CCL <sub>4</sub>	0.344	2.345	6.858
Tetrafluoroethylene (TFE)	C <sub>2</sub> F <sub>4</sub>	0.361	1.905	4.526
Tetrafluorohydrazine	N <sub>2</sub> F <sub>4</sub>	0.367	1.926	4.624
Trichlorofluoromethane f-11	CCL <sub>3</sub> F	0.374	2.244	6.281
Trichlorosilane	SiHCL <sub>3</sub>	0.329	2.201	6.038
Trimethoxyborane (TMB)	B(OCH <sub>3</sub> ) <sub>3</sub>	0.300	1.929	4.638
1,1,2-Trichloro-1,1,2-Trifluoroet f-113	C <sub>2</sub> Cl <sub>3</sub> F <sub>3</sub>	0.231	2.520	7.920
Trimethylamine	(CH <sub>3</sub> ) <sub>3</sub> N	0.316	1.467	2.639
Tungsten Hexafluoride	WF <sub>6</sub>	0.227	3.264	13.28
Uranium Hexafluoride	UF <sub>6</sub>	0.220	3.548	15.70
Vinyl Bromide	C <sub>2</sub> H <sub>3</sub> Br	0.524	1.985	4.772
Vinyl Chloride	C <sub>2</sub> H <sub>3</sub> CL	0.542	1.492	2.788
Vinyl Fluoride	C <sub>2</sub> H <sub>3</sub> F	0.576	1.281	2.046
Water Vapor	H <sub>2</sub> O	0.861	0.802	0.804
Xenon	Xe	1.383	2.180	5.851



### Orifice Sizing

The Orifice Sizing Nomograph, Figure 4-4, is used to calculate the control valve's orifice size when changing any or all of the following factors from the original factory calibration:

**gas**  
**operating pressure (inlet and outlet)**  
**flow range**

The flow controller's orifice is factory-sized to a preselected gas, operating pressure and flow range. Note that the orifice is marked with its size in thousandths of an inch. When changing the aforementioned factors, calculate the new orifice size by following the procedure and example outlined in the following paragraphs.

**Example: Determine the orifice size for the following conditions:**

Gas:	Hydrogen
Flow Rate:	2,000 sccm
Outlet Pressure:	30 psig
Inlet Pressure:	50 psig

1. Determine Nitrogen equivalent flow rate (refer to Table 4-3).

$$Q_{\text{NITROGEN}} = Q_{\text{GAS}} \times \sqrt{\frac{P_{\text{GAS}}}{P_{\text{NITROGEN}}}}$$

OR

$$Q_{\text{NITROGEN}} = Q_{\text{GAS}} \times \sqrt{\frac{SG_{\text{GAS}}}{SG_{\text{NITROGEN}}}}$$

Where:

$Q_{\text{NITROGEN}}$	=	Nitrogen equivalent flow rate (sccm)
$Q_{\text{GAS}}$	=	Desired flow rate of the gas (sccm)
$P_{\text{NITROGEN}}$	=	Density of Nitrogen at 70°F
$P_{\text{GAS}}$	=	Density of the gas (taken at customer temperature)
$SG_{\text{GAS}}$	=	Specific gravity of the gas (taken at customer temperature)

Refer to Table 4-4 for specific gravities.

Example:

$$\begin{aligned} Q_{\text{GAS}} &= 2,000 \text{ sccm} \\ \sqrt{\frac{SG_{\text{GAS}}}{SG_{\text{NITROGEN}}}} &= .269 \end{aligned}$$

$$\begin{aligned} Q_{\text{NITROGEN}} &= Q_{\text{GAS}} \times \sqrt{\frac{SG_{\text{GAS}}}{SG_{\text{NITROGEN}}}} \\ &= 2,000 \times .269 \\ &= 538 \text{ sccm Nitrogen} \end{aligned}$$

In order to calculate the orifice conversion factor when using a gas mixture, the following formula must be used:

$$\text{Orifice Conversion Factor Mixture} = \sqrt{\frac{P_1 \left( \frac{\text{Orifice Conversion Factor 1}}{100} \right) + P_2 \left( \frac{\text{Orifice Conversion Factor 2}}{100} \right) + P_n \left( \frac{\text{Orifice Conversion Factor n}}{100} \right)}{Q_{\text{GAS}} \times 100}}$$

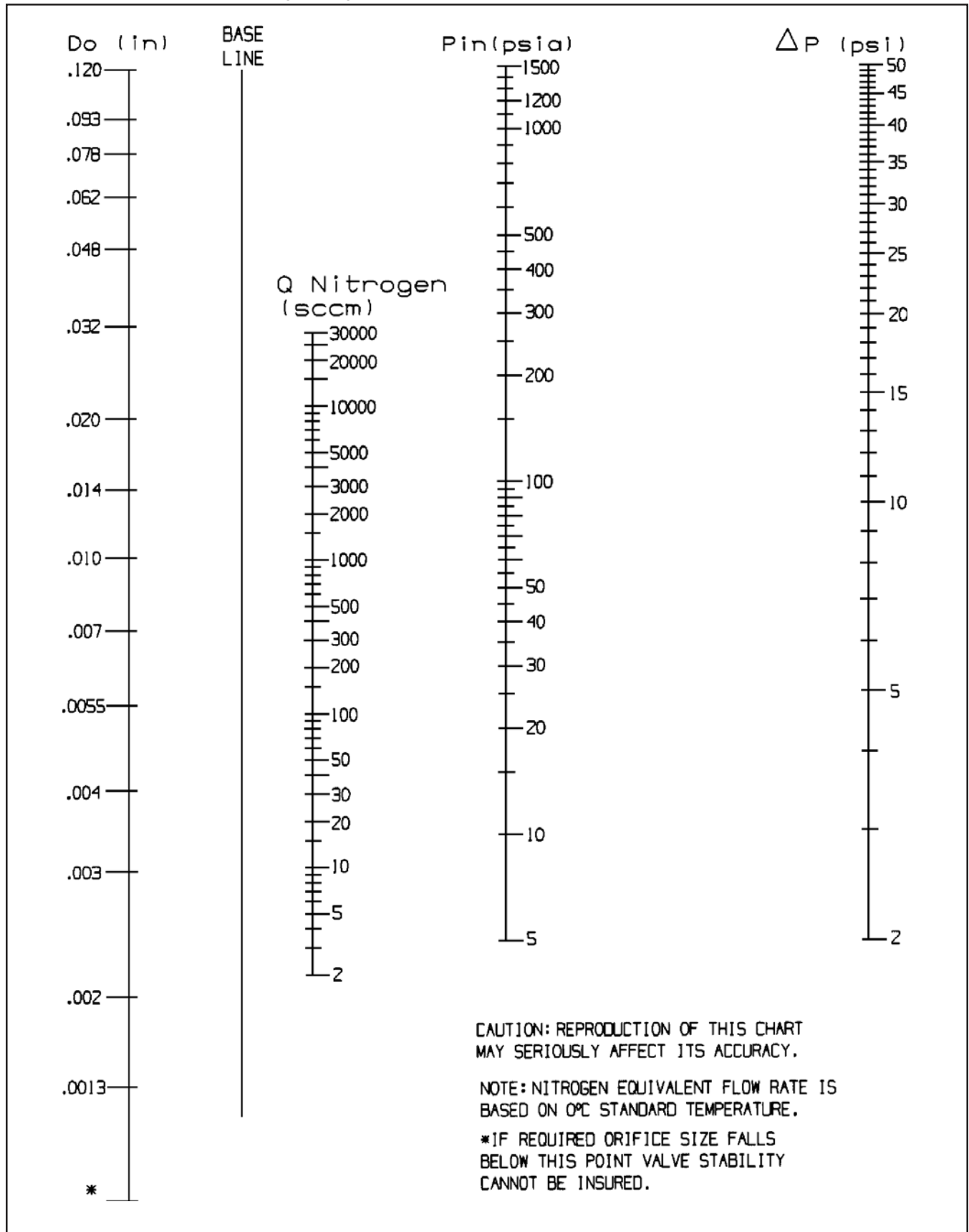
Where  $P_1$  = percentage by volume of gas 1  
 $P_2$  = percentage by volume of gas 2  
 $P_n$  = percentage by volume of gas n

Example: Find the Nitrogen equivalent for 20 slpm of a 20% Helium and 80% Chlorine gas mixture.

$$\begin{aligned} \text{Orifice Conversion Factor Mixture} &= \frac{20(.378) + 80(1.598)}{100} \end{aligned}$$

$$\begin{aligned} Q_{\text{NITROGEN}} &= Q_{\text{GAS}} (\text{orifice conversion factor}) \\ &= 20 \times 1.439 \\ &= 28.78 \text{ slpm Nitrogen} \end{aligned}$$

Table 4-4 Model 5850E Orifice Sizing Nomograph



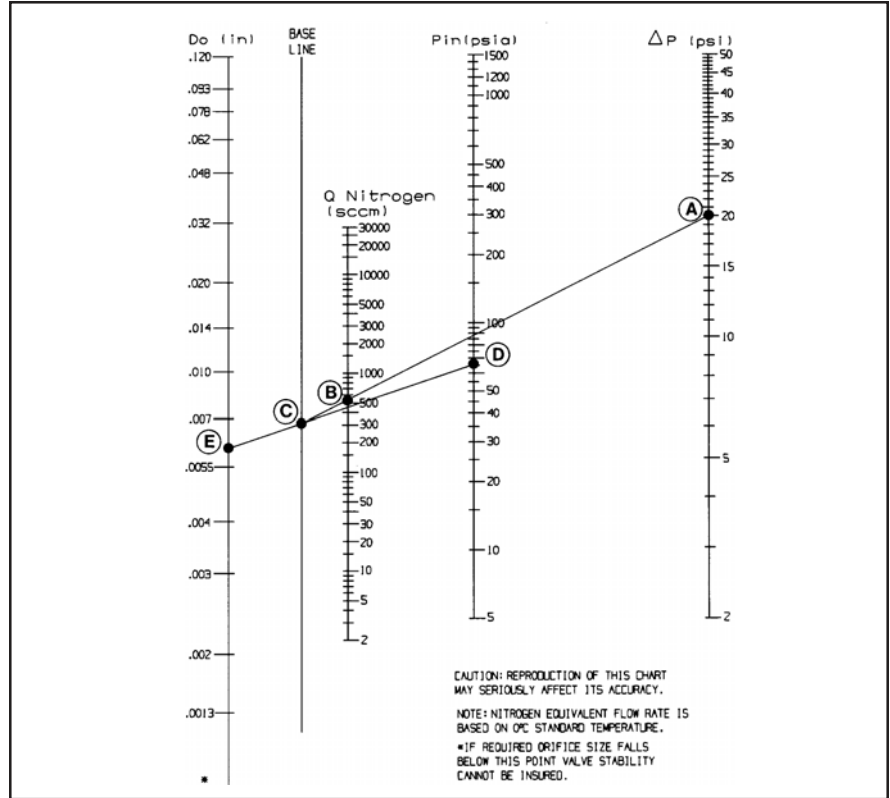


Figure 4-4 Example Nomograph

2. If inlet and outlet pressures are given in gauge pressure (psig) add 14.7 to convert to absolute pressure (psia).

Outlet Pressure — 30 psig + 14.7 = 44.7 psia

Inlet Pressure — 50 psig + 14.7 = 64.7 psia

3. Determine Critical Pressure Drop

Critical pressure drop occurs when the outlet pressure (psia) is less than half the inlet pressure (psia) or

$$P_{\text{outlet}} < \frac{P_{\text{inlet}}}{2}$$

If these conditions exist, the pressure drop (Dp) should be calculated as follows:

$$Dp = \frac{P_{\text{in}}}{2}$$

Dp = Pressure drop (psi)

P<sub>in</sub> = Inlet pressure (psia)

If these conditions do not exist, pressure drop equals the inlet pressure minus the outlet pressure.

$$\text{Is } 44.7 \text{ psia} < \frac{64.7 \text{ psia}}{2} \quad ? \quad \text{No.}$$

$$\text{Then } Dp = 64.7 - 44.7 = 20 \text{ psi}$$

4. Using the nomograph, locate the pressure drop (psi) on the vertical line marked "Dp" (Point A).
5. Locate the Nitrogen equivalent flow rate (sccm Nitrogen) on the vertical line marked " $Q_{\text{Nitrogen}}$ " (Point B).
6. Draw a line connecting Dp and  $Q_{\text{Nitrogen}}$  and extend it to the baseline. Mark this point (Point C).
7. Locate inlet pressure (psia) on the vertical line marked " $P_{\text{in}}$ " (Point D).
8. Draw a line connecting  $P_{\text{in}}$  (Point D) and baseline (Point C) and then extend this line to the vertical line marked  $D_o$  (orifice diameter, inches) (Point E).
9. This point on the line is the minimum orifice size for the given conditions. If this point is between two orifice sizes, select the next largest size orifice to ensure adequate flow. If the orifice selected falls below .0013, choose .0013 size orifice.

For the example in Figure 4-5, the .007 size orifice would be selected.

### Restrictor Sizing

The restrictor assembly is a ranging device for the sensor portion of the controller. It creates a pressure drop which is linear with flow rate. This diverts a sample quantity of the process gas flow through the sensor. Each restrictor maintains the ratio of sensor flow to restrictor flow, however the total flow through each restrictor is different. Different restrictors (micron porosity and active area) have different pressure drops and produce controllers with different full scale flow rates. For a discussion of the interaction of the various parts of the controller, you are urged to review Section 3-1 (Theory of Operation).

If the restrictor assembly has been contaminated with foreign matter, the pressure drop vs. flow characteristics will be altered and it must be cleaned or replaced. It may also be necessary to replace the restrictor assembly when the mass flow controller is to be calibrated to a new flow rate.

Restrictor assembly replacement should be performed only by trained personnel. The tools required for the removal/replacement procedure are as follows:

Appropriate size wrench for the removal of the inlet process connection Restrictor removal tool (contained in service tool kit P/N S-778-D-017-AAA)

Restrictor O-ring, refer to the spare parts Section 5, for the correct part number.

### Restrictors

The Model 5850E Series Mass Flow Controllers use three types of restrictor assemblies depending on full scale flowrate and expected service conditions.

1. Porous sintered metal for air equivalent flow rates up to and including 9.5 slpm. The porosity ranges from 1-40 microns. This type of assembly is least expensive and should be used when the gas stream will not contain any particulate matter.
2. Sintered wire mesh for air equivalent flow rates above 3.5 slpm. These restrictor assemblies are made from a cylinder of sintered wire mesh and are easily cleaned if they become contaminated in service.
3. Anti-Clog Laminar Flow Element (ACLFE). This type of restrictor assembly is used for air equivalent flow rates less than 3.4 slpm. The ACLFE is much more tolerant to particulate contamination than the sintered metal assembly. This is especially important when handling semiconductor gases that tend to precipitate particles. The ACLFE will also improve accuracy when operating at very low pressures.

### Sizing

All Model 5850E Series Restrictor Assemblies are factory adjusted to provide a 115 mm water column pressure drop for a specific flow rate. This corresponds to the desired full scale flow rate. A list of restrictor assemblies used in the Model 5850E Series Mass Flow Controllers is shown in Table 4-5.

Example:

The desired gas is Silane (SiH<sub>4</sub>).  
 The desired full scale flow rate is 200 sccm.  
 Sensor conversion factor is 0.625 from Table 4-4.  
 Nitrogen equivalent flow = 200/0.625 = 320 sccm Nitrogen.

In the example above a size P restrictor would be selected. Both the sintered metal and ACLFE are available for this size. Either type will work however, since Silane is known to precipitate silicon dioxide particles when contaminated an anti-clog laminar flow element should be selected for this application.

Note: If the calculated flow rate is such that two different size restrictors could be used, always select the larger size.

If a mixture of two or more gases are being used the restrictor selection must be based on the Nitrogen equivalent flow rate of the mixture.

Example:

The desired gas is 20% Helium (He) and 80% Chlorine (Cl) by volume.  
 The desired full scale flow rate of the mixture is 20 slpm.  
 Sensor conversion factor for the mixture is:

$$\text{Mixture Factor} = \frac{100}{\frac{20}{1.386} + \frac{80}{0.876}} = 0.945$$

Nitrogen equivalent flow = 20/.945 = 21.16 slpm Nitrogen. In this example a Size 4 Wire Mesh Assembly would be selected.

Table 4-5 Model 5850E Standard Restrictors

Size	Range SCCM Air Equivalent Flow		Part Number		
	Low	High	Sintered	ACLFE	Wire Mesh
D	8.022	11.36	S 110 Z 296*	S 110 Z 275*	
E	11.23	15.90	S 110 Z 297	S 110 Z 276	
F	15.72	22.26	S 110 Z 298	S 110 Z 277	
G	22.01	31.17	S 110 Z 299	S 110 Z 278	
H	30.82	43.64	S 110 Z 300	S 110 Z 279	
J	43.14	61.09	S 110 Z 301	S 110 Z 280	
K	60.40	85.53	S 110 Z 302	S 110 Z 281	
L	84.56	119.7	S 110 Z 303	S 110 Z 282	
M	118.4	167.6	S 110 Z 304	S 110 Z 283	
N	165.7	234.7	S 110 Z 305	S 110 Z 284	
P	232.0	328.6	S 110 Z 306	S 110 Z 285	
Q	324.8	460.0	S 110 Z 307	S 110 Z 286	
R	454.8	644.0	S 110 Z 308	S 110 Z 287	
S	636.7	901.6	S 110 Z 309	S 110 Z 288	
T	891.4	1262.	S 110 Z 310	S 110 Z 289	
U	1248.	1767.	S 110 Z 311	S 110 Z 290	
V	1747.	2474.	S 110 Z 312	S 110 Z 291	
W	2446.	3464.	S 110 Z 313	S 110 Z 292	
X	3424.	4849.			S 110 Z 319*
Y	4794.	6789.			S 110 Z 321
1	6711.	9504.			S 110 Z 317
2	9396.	13310.			S 110 Z 228
3	13150.	18630.			S 110 Z 226
4	18420.	30000.			S 110 Z 224

\*Materials: BMT = 316 Stainless Steel (ACLFE only)

BMA = Sintered 316 Stainless Steel (wire mesh and sintered)

Note: For flow rates less than 8 sccm use the low flow plug, P/N 618-K-019-BMT in place of a restrictor assembly and install a low flow filler ring P/N 724 Z 429 BMT in the valve cavity after the orifice is installed.





Table 5-1 Model 5850E Replacement Parts List

Item No.	Qty.	Description	Part Number
1	1	Jam Nut	573B027ACK
2	1	Coil Assembly	S185Z271AAA
3	4	Screw, Valve	751C322AWA
4	1	Retaining Plate	715Z169AH%
5	1	O-ring, Valve Stem, Size 016	375B016***
6	1	Valve Stem: Normally Closed Valve	949Z194QOT
6A	1	Valve Stem: Normally Open Valve	949Z215BMT
6B	1	Valve Plug	953Z068BMT
6C	1	Valve Ring	763Z064***
7	1	Valve O-ring	375B016***
31	1	Valve Plunger Assy: Normally Closed Valve	S622Z165AAA
32	1	Normally Open Valve	S622Z203QOT
8	1	Insert Sleeve Normally Open Valve	456Z071QOT
9	AR	Plunger Extension Normally Open Valve	622Z200BMT
9	AR	Lower Guide Spring,unit with NO ORIFICE	820Z109DR%
10	AR	Normally Closed Valve .001-.014 orifice	820Z109DR%
10	AR	Normally Closed Valve .020-.120 orifice	820Z110DR%
33	1	Normally Open Valve all orifice sizes	820Z110DR%
		Small Valve Spacer, 0.005" Thick	810A362BMA
		Small Valve Spacer, 0.010" Thick	810A363BMA
		Large Valve Spacer, 0.005" Thick	810A368BMA
		Large Valve Spacer, 0.010" Thick	810A361BMA
		Preload Spacer, Spring Normally Open valve	810A388BMT
11	1	Valve Seat with Viton Insert	S715Z051AAG
		Valve Seat with Buna Insert	S715Z050AAG
		Valve seat w/Kalrez insert (<or=200 psig)	S715Z297AAG
		Valve Seat with Kalrez Insert (>200 psig)	S715Z163AAA
		Valve Seat Solid 316 Stainless Steel	715Z181BNT
12	1	Orifice (Refer to Section 4-6for sizing)	Stainless 577Z375BMT 577Z376BMT 577Z377BMT 577Z378BMT 577Z381BMT 577Z383BMT 577Z385BMT 577Z387BMT 577Z391BMT 577Z393BMT 577Z395BMT 577Z397BMT 577Z398BMT 577Z399BMT 577Z400BMT
13	1	O-ring, Orifice, Size 008	375B008***
14	1	Controller Body	092Z768BI%
15	1	PC Board Assembly (D-Connector)	097Y847AAA
16	1	Sensor Assembly	S774Z508AAA
17	2	O-ring, Sensor, Size 004	375B004***
18	2	Allen Nut, Sensor-Body	753B269AWA
19	2	Lock Washer, Sensor	962D006AWA
20	5	Screw, Sensor-PC Board-Cover	753L056AWZ
21	1	Restrictor Assembly and Components (Refer to Section 4-7 for sizing)	
22	1	O-ring, Restrictor, Size 109	375B109***
23	1	Electronics Cover Can (D-Connector)	219Z432EA%

\*\*\*QTA=Viton, SUA=Buna, TTA=Kalrez, AR=As Required, NS=NS Not Shown

Table 5-1 Model 5850E Replacement Parts List (continued)

Item No.	Quantity	Description	Part Number	
NS	2	Fitting, 1/4" Compression, Swagelok	320B136BMA	
		Fitting, 1/4" Male VCR, Cajon	315Z036BMA	
		Fitting, 1/4" Male VCO, Cajon	315Z035BMA	
		Fitting, 3/8" Compression	320B150BMA	
		Fitting, 3/8" Male VCO (3/8" or 1/2" Tube)	315Z033BMA	
		Fitting, 3/8" Male VCR (3/8" or 1/2" Tube)	315Z034BMA	
27	2	O-Ring, Fitting, Size 906	375B906***	
NS	2	O-Ring, VCO Gland, Size 010	375B010***	
NS	1	O-Ring, End Block, Size 029	375B029***	
NS	1	Interconnecting Cables D-Connector on one end with notermiation on the other end	Length	D-Connector
			5 Feet	S124Z361AAA
			10 Feet	S124Z362AAA
			25 Feet	S124Z363AAA
			50 Feet	S124Z435AAA
NS	2	8-32 Mounting Screw	Customer Supplied	
28	1	End Block with Integral Inlet Screen	S079Z200AAA	
29	4	Screw, End Block	751Z105AAO	

\*\*\* QTA = Viton, SUA = Buna, TTA = Kalrez  
AR As required, NS Not Shown

Table 5-2 Tool and Spare Part Kits for 5850E Series

<p>5850/5851 Series Service Tool Kit P/N S778D017AAA Permits the complete disassembly of the 5850i for servicing Contains: 1 — O-Ring Removal Tool 1 — Potentiometer Adjustment Tool 1 — Ball Point Allen Wrench 1 — Phillips Screw Driver 1 — Nut Driver for Orifice 1 — Restrictor Removal Tool 1 — Common Screw Driver</p>	<p>5851 Header Removal Tool P/N S817Z036AAA</p> <p>0550/5851 Orifice Removal Tool P/N S908Z049AAA</p> <p>5850/5851 Series Calibration Cover - "D" Connector P/N 909Z017EAD</p>
<p>5850/5851 Series Break Out Board Assembly( Not for S Series! ) P/N S273Z668AAA</p> <p>Installs directly between mass flow controller and interconnecting cable. Allows convenient access to all signals for easy trouble-shooting of system.</p> <p>Contains: 1 — Break Out PC Board 1 — 5 Foot Extension Cable 1 — Terminal PC Board</p>	<p>5850/5851 Series Valve Shim Kit P/N S810A372BMA</p> <p>Contains: 1 — .010" Large Spacer 2 — .005" Large Spacers 1 — .010" Small Spacer 2 — .005" Small Spacers</p>

\*\*\* QTA = Viton, SUA = Buna, TTA = Kalrez

NOTE: Additional publication available:  
T-086 Mass Flow Controller Contamination Control

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