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VC4900 Series Vapor Controllers

- Designed for the demanding requirements of low vapor pressure liquid delivery

Vapor Controllers
VC4900
VC4901
VC4902
VC4900O
VC4901O
VC4902O
VC4900M
VC4901M
VC4902M
VC4900MO
VC4901MO
VC4902MO

MILLIPORE

909541-001 Rev C, 9/99

VC4900 Series Vapor Controllers

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1 DESCRIPTION

Tylan General Model VC-4900 series Vapor Controllers extend the service envelope of our proven line of VC-4900 series Vapor controllers into low absolute pressure range to accurately and reliably measure and control the mass flow rate of gases and liquid vapors. They have been specifically designed to allow operation on any gas having a known molar specific heat (pC_P).

The VC-4900 series has a user-adjustable range from 10 sccm to 30 slm full-scale flow rate. The required range is met by selecting the bypass and orifice that have the required ranges and then fine tuning by changing the number of discs in the bypass or changing to discs with a different number of slots or different slot depth.

If a range change becomes necessary and the new range is outside the range of the orifice, the orifice will have to be changed. If the change is small, this change may be accomplished by adjusting the valve.

The instrument operates on ±15 VDC power, provides a 0 to 5.0 VDC indicated output signal linearly proportional to the flow rate, is RFI protected and is both mechanically and electrically interchangeable with most Tylan General mass vapor controllers. The VC-4901is equipped with a 15-pin “D” connector and the VC-4902 is equipped with a 9-pin “D” connector. Either can have 0-5 VDC or 4-20mA input/output signals. For simplicity, references in this manual are to a card edge style P.C. Board, ±15 VDC power source and 0-5 VDC input/output signals. Other inherent design features include:

- Balanced Power Load
- Enhanced stability of both zero and span
- Auto Zero Function
- Metal seals with ultra-high leak integrity of 1 x 10^{-10} atm-cc/sec. He (VC-4900M/4901M/4902M)
- Fast response with minimal overshoot
- Normally closed or normally open solenoid valve with both mechanical and electrical “purge” capability.
- Remote electronics option for high-temperature applications
- Integral heater option
- Ultralow pressure drop.

The VC-4900 series of vapor control instruments include:

Model	Flow Range	Connector
VC-4900(O)*	10 sccm to 30 slm	card edge
VC-4901(O)*		15-pin “D”
VC-4902(O)*		9-Pin "D"
VC-4900M(O)*(EP)**	10 sccm to 30 slm	card edge
VC-4901M(O)*(EP)**	with metal seals	15-pin “D”
VC-4902M(O)*(EP)**		9-Pin "D"

*“O” designates normally open valve option

**“EP” designates Electro-polished option

“J” option4-20 mA input/output signals
(available with instruments that have a “D” connector).

2 PRINCIPLE OF OPERATION

The vapor controller is a self-contained, closed-loop control system which measures the mass rate of gaseous flow through the instrument, compares this with an externally commanded flow rate, and adjusts the valve to control the flow to the commanded level. The vapor controller consists of four basic elements which accomplish this function.

- The flow sensor
- The bypass, or flow-splitter, which determines the full-scale flow range of the measuring section
- The control valve
- The electronics which condition the flow signal and drive the control valve.

2-1 Flow Sensor

The flow sensor consists of two self-heated resistance thermometers wound around the outside diameter of a thin-walled capillary tube. These coils, each having a resistance of 330 ±13 ohms at 24°C, are connected in a bridge circuit and supplied with a regulated current. The heat generated by the power dissipated in the coils raises the tube temperature approximately 70°C above ambient. At no flow, this heat is symmetrically distributed along the tube. With gas flowing in the sensor tube, heat is carried downstream. The resulting shift in temperature makes the upstream sensor cooler than the downstream sensor. This temperature difference (and its corresponding electrical resistance difference) is directly proportional to the mass flow rate of the gas through the tube. The bridge output, being a direct function of the resistance difference, is amplified and further linearized by the electronics to give a 0 to 5.0 VDC indication of flow rate. Increasing the flow rate well above the full-scale range of the instrument will eventually cool the entire sensor tube and the output signal will reverse and asymptotically approach zero.

The capillary tube is dimensioned to have minimal mass (for fast response) and an extremely large length-to-diameter ratio to ensure laminar flow over the full operating range.

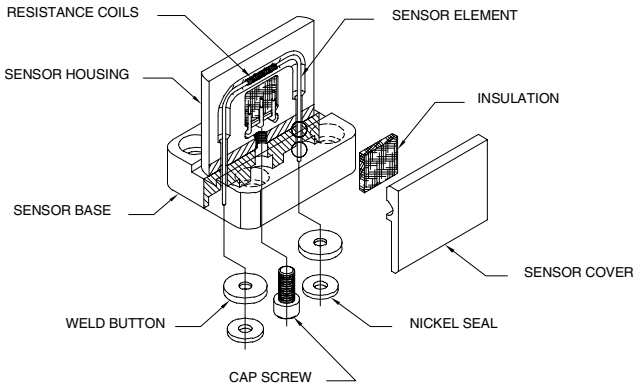


Figure 1: **Flow Sensor (Metal Sealed Instruments)**

The housing which encases the sensor tube is precisely configured to minimize both external and internal natural convection currents from one coil to the other, thus allowing the instrument to be mounted in any position with no zero adjustment required to re-establish the original calibration. This patent-pending configuration minimizes the mass of the sensor resulting in a time constant that is one-third that of other sensors of similar design. Overall vapor controller response can therefore be dynamically controlled to eliminate overshoot.

2-2 Bypass (Flow-splitter)

The bypass, which is located in the primary flow path in the base assembly, produces a linear pressure drop versus flow rate between the inlet and outlet of the sensor tube, which in turn produces a 0 to 100% sensor flow for 0 to 100% flow of the instrument. In order to ensure a constant ratio between sensor flow and total flow (independent of pressure, temperature and gas properties), the bypass arrangement has been designed to maintain the flow well within the laminar region of fluid flow over the entire range of the instrument.

The bypass consists of a stack of slotted discs held in place by a bypass nut. Gas flows through the nut and is directed to the outer diameter of the discs where it flows radially through the slots and exits through the opening between the inner diameter of the discs and the triangular extension of the nut.

The slots have a sufficient length to diameter ratio to maintain laminar flow over the operating range of the sensor, thereby providing the constant and independent flow split.

By varying the slot depth, the number of slots per disc, and the number of discs per assembly, the bypass can be adjusted to provide the required full scale pressure drop of the sensor coincident with the desired full scale range of the flowmeter.

Bypass assemblies are factory-built to specific ranges with the discs held in place by a removable Teflon washer. Each assembly is packaged separately and identified by part number and/or range.

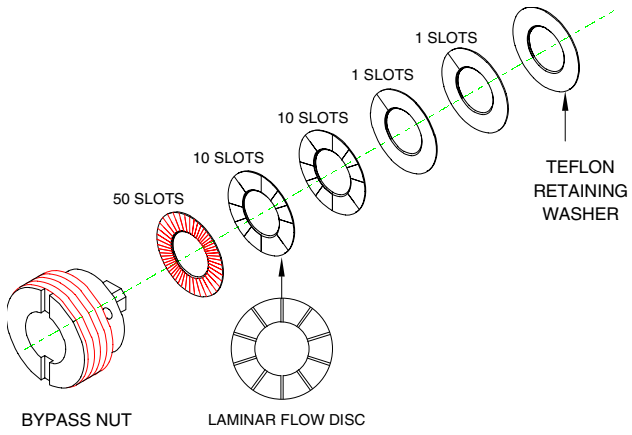


Figure 2: **Bypass (Exploded View)**

2-3 Valve (Mass Vapor controllers only)

The control valve is a normally-closed solenoid valve which is extremely fast, easily adjusted, and has 2% or better shutoff capability. Except for the dynamic plunger, all gas wetted metal surfaces are of type 316L stainless steel. The plunger is constructed of type 446 stainless steel. (321 stainless steel is also used in the metal seal solenoid valve.)

The range of the valve is determined by the size of the control orifice, which is screwed into the controller base. These precision valve seats are type 316L stainless steel and provide excellent control resolution by engagement with the Teflon® face of the valve poppet. The valve seats are easily replaceable for cleaning and instrument range changing.

The valve seat is designed to provide a relatively constant control range (stroke) over the entire flow range. Different ranges within the full range of a particular valve seat are accommodated by the amount of voltage applied to the valve. This arrangement provides consistent dynamic response and static stability with only a minimal need for electronic"tuning."

An adjustment on top of the valve is provided to allow for setting the relative position between the valve poppet and valve seat following re-assembly after cleaning or seat replacement *(see Adjustment Procedures)*. This adjusting nut may also be used to mechanically open the valve for purging purposes in the event of a power failure or an instrument malfunction, which may necessitate removing the instrument from the gas system.

2-4 Electronics

The electronics consist of a circuit board with a hybrid autozero circuit soldered in place. Surface mount technology is utilized in the VC-4900 series.

Referring to the Electrical Hook-Up Diagram, J0 is the card edge connector which interfaces with the external control system. A positive 5 volt regulator supplies power to the Auto-Zero circuit and also provides the reference voltage required for the "Valve OFF" function. The negative 5 volt regulator provides the reference for the sensor bridge constant current source and the linearization circuit. Refer to the *Electrical Hook-Up Diagram* for pin designations.

The Current Source delivers a constant 14.6 milliamps for large bore sensor (12.7 milliamps for small bore sensor) to the sensor bridge which "floats" between the plus and minus supplies. This arrangement gives extremely high common-mode rejection and allows insensitive operation over a wide range of supply voltage levels. The Sensor Bridge circuit contains the zero and span temperature compensation networks.

The Flowmeter Amplifier circuit amplifies the sensor output signal, the gain of which is adjusted by RP2 at 40% full scale flow rate. This circuit also incorporates a speed-up filter which provides for matching the sensor response to the actual flow rate response during a transient flow

condition. The AC gain versus frequency is adjusted by RP3. This adjustment is fine-tuned by observing the output waveform in response to step changes in setpoint and actual flow rate.

The Linearity circuit provides a variable gain versus input voltage allowing correction for any non-linearity of the sensor output signal. The adjustment is made by RP4 at 100% full-scale flow rate.

The Auto-Zero circuit provides periodic correction of zero offset due to long term sensor drift, temperature and pressure variations, or other environmental causes. This feature ensures long term calibration accuracy and eliminates the need for periodic manual zero adjustment. The range of correction is limited to ±2.5% of full scale to prevent erroneous correction of an undetectable leak or defective sensor.

The auto-zero function is activated either by commanding ≤1% of full scale flow rate which automatically closes the control valve or connecting pin L to common. After 80 to 100 seconds, the output signal is compared with (and driven to) zero within 2.5 seconds. This correction is maintained until the next update. The current or latest correction can be permanently stored in memory by an external command such that in the event of power loss, the output will return to zero when power is re-applied. The auto-zero functions may be inhibited either externally by connecting pin J to common *(See Electrical Hook-Up Diagram)* or internally, by removing jumper JP2. See Appendix C for more information.

The Valve Control circuit compares the flowmeter output signal with the command voltage (setpoint) and varies the voltage to the valve to throttle the flow to the commanded level via closed loop control. The ramp circuit limits the rate of change of the setpoint allowing the sensor output to "keep-up", thus minimizing overshoot during step changes in commanded flow rate. If a slower response is desired, jumper JP1 can be removed to give a 10-15% per second rate of change to the desired flow rate.

While the integral and derivative functions of the PID control circuit are relatively fixed, the proportional band (gain) of the circuit is adjusted by the ratio of R52 to R50. The values of these resistors are selected during dynamic response testing to optimize the transient response of the control loop, and vary depending on the range, gas, and intended operating conditions of the instrument.

The control logic can be overridden externally to either open or close the valve in accordance with specific process requirements. *(See Electrical Hook-Up Diagram)*.

NOTE: While connecting pin D to common will partially open the valve, connecting pin D to +15 VDC will drive the valve to the full "purge" position.

The Balanced Power Load circuit has been designed to limit the current in the common line to a maximum of ±5 milliamps. This limits the control error to less than 0.2% per 100 feet of interconnect cable between the vapor controller and its setpoint/readout control system. This is a 20:1 improvement over most conventional designs.

2-5 Cover

The cover is made of steel and is grounded to the flow base and the chassis ground connection. This, in conjunction with the roll-off and filter capacitors in the electronics provides excellent EMI protection.

3 INSTALLATION

⚠ WARNING

THE FLOW BASE AND REMOTE ELECTRONICS MODULES MUST BE MATCHED BY SERIAL NUMBER FOR PORPER OPERATION AND WARRANTY COVERAGE.

For maximum performance and service life, the instrument should be installed in a clean, dry atmosphere, relatively free of shock and vibration. Sufficient room for access to the electronics and plumbing should be provided to facilitate maintenance and removal for cleaning. Fitting caps should not be removed from the instrument until installation.

3-1 Gas Connections

Since the control valve in the instrument is not intended to provide positive shut-off, it is recommended that a separate shut-off valve be installed in series (upstream to eliminate a flow surge during turn-on, downstream to prevent back migration of contaminants into the control valve, or both).

ELASTOMER SEALED INSTRUMENTS: VCR® fittings are available with elastomer sealed models. Tubing should be pre-cleaned and polished to eliminate particulate contamination and ensure leak-tight operation. After installation of the instrument and prior to its use, the plumbing system should be thoroughly leak-tested and purged.

VC-4900M METAL SEALED: Two types of ultra-high vacuum fittings are available including VCR® and tube weld. Due to the degree of electropolishing and ultraclean preparation, the VC-4900M should be installed in a prepared ultrapure gas delivery system. After installation of the instrument and prior to its use, the gas delivery system should be thoroughly leak tested and purged. If positive shut-off is required it is recommended that a pneumatic positive shut-off valve be installed in series with the mass vapor controller.

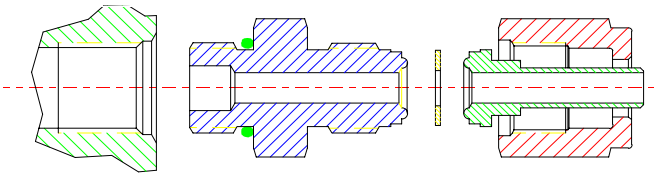


Figure 3: Gasket Seal

3-2 Electrical Connections

Refer to the appropriate electrical hookup diagram.

POWER: Any ±15 VDC power supply meeting the requirements as designated in the specifications may be used to energize the instrument.

CONTROL SIGNAL: Any 0 to 5.0 VDC command voltage having a source impedance of 2500 ohms or less may be used. The input impedance of the vapor controller is 0.5 megohm (minimum). 4-20 mA current option is available on the VC-4901 and VC-4902.

OUTPUT INDICATION: Any 0 to 5.0 VDC meter with at least 1000 ohms/volt can be used to provide visual indication of the mass flow rate. Recorders, voltage dividers (for conversion to provided the total load impedance is no less than 2000 ohms. engineering units), and other instrumentation may be added, provided the total load impedance is no less than 2000 ohms. The source impedance of the flowmeter output signal is less than 0.5 ohm.

VALVE OFF: A TTL low signal will override the control signal, close the valve and trigger the autozero function. TTL high (or open connection) allows normal control operation.

VALVE TEST (OVERRIDE): The valve voltage may be monitored during normal operation using a high input impedance DVM. Connecting this pin to common or the +15VDC supply will override the control signal and open the valve. (A maximum current of 75 milliamps is required).

ZENER TEST: The internal negative reference voltage (-5VDC) may be monitored for troubleshooting purposes using a high impedance DVM.

AUTO-ZERO INHIBIT: The auto-zero function may be inhibited (deactivated) by applying a TTL low signal. This pin may also be used as an output, as it goes high during the 2.5 second adjustment cycle.

AUTO-ZERO STORE: Momentary application of a TTL low signal stores the latest zero correction in memory. This is automatically recalled on power up. This feature is not available on MFMs or MFCs with a "D" connector.

AUTO-ZERO TRIGGER: The auto-zero function may be triggered by applying a TTL low signal to pin L. This will override the setpoint signal and close the valve.

NOTE: Shorting to common may be substituted for TTL low, and open connection substituted for TTL high.

3-3 Environmental Requirements

Refer to the specifications.

TEMPERATURE: The instrument may be operated at any temperature between 0°C and 50°C, provided the gas and ambient temperatures are maintained equally. Temperatures up to 100°C are possible with an optional remote electronics package. Since the indicated flow rate has a temperature coefficient of ±0.05% per °C, the user

may want to calibrate the instrument at the actual operating temperature to maximize the measurement accuracy.

PRESSURE: Vapor controllers may be operated at any gas pressure up to 1135 kPa (150 psig). Since the indicated flow rate varies in direct proportion to specific heat (Cp), which varies differently with pressure and temperature depending upon the molecular structure of the gas, it is recommended that the instrument be calibrated at the actual operating pressure.

NOTE: The effect of the pressure coefficient is increasingly pronounced as the inlet pressure is decreased below 200 Torr (27 kPa).

The vapor controllers, which can be pressurized to 10,500 kPa (1500 psig) without damage, have a maximum operating pressure of 1135 kPa (150 psig) and the differential pressure (inlet to outlet) must be maintained within the specified range. Lower differential pressure ranges are available on special order.

The vapor controllers may be operated into a vacuum as long as the inlet pressure is sufficient to create an adequate pressure drop to allow a desired flow rate. See Appendix E for allowable flow-pressure-drop characteristic. Lower differential pressure ranges are available on special order.

3-4 Calibration

Each instrument is factory calibrated for the specific flow range and gas indicated on the nameplate. Standard factory calibration is within ±1.0% and is referenced to standard temperature and pressure.* The calibration for other gases can be approximated to ±5% using the Conversion Factor Charts. Factory calibration utilizes the test gases shown in Appendix A, Gas Flow Conversion Factors. Calibration checks with other gases can show discrepancies of up to ±5%. To obtain calibration accuracy of 1% after range change or for other gases, precision calibration equipment will be required. As detailed in the Adjustment and Calibration Procedures section, range changes can be made to within ±15% by removing the inlet fitting and replacing the bypass. Fine tuning to the desired accuracy level can then be accomplished by adjusting the potentiometers on the printed circuit board in conjunction with a reference flow standard.

**NOTE: In accordance with Semiconductor Equipment and Materials Institute Standard E12-91, Standard Pressure and Temperature are defined as 101.325 kPa (760mm Hg) and 0°C respectively.*

⚠ WARNING

An elastomer sealed instrument originally calibrated for a non-reactive, non-corrosive gas should not be converted for use with a reactive or corrosive gas unless all the seals are replaced with the suitable compound. Additionally, any instrument which has been in reactive or corrosive gas service should be thoroughly purged and cleaned prior to conversion to another gas. Instruments are factory assembled using Viton® for non-reactives, Neoprene for Ammonia, or Kalrez® for all other reactive and corrosive gases unless specified otherwise. The VC-4900M is assembled with metal seals compatible with all gases. Refer to spare parts O-ring Kits.

3-5 Mounting

Two 8-32 UNC tapped holes are provided for mounting. The instrument is essentially insensitive to mounting position. For mounting with optional integral heater, refer to Appendix D. Mount remote electronics unit (optional) with two 8-32 UNC screws at a cool, environmentally safe location.

4 OPERATING INSTRUCTIONS

4-1 Installation and Start-up

The interconnect cable should be tested separately for continuity, pin-to-pin shorts, and correct pin assignments per the electrical hook-up diagram. Attach the mating connector to the vapor controller and secure it to the cover with two 4-40 x 5/8 inch long screws. Do not over-torque.

After installation in the system and prior to operation, any reactive gas system should be thoroughly leak checked and then purged with dry nitrogen to eliminate the presence of air and moisture. If the mass vapor controller is equipped with a normally-closed control valve, it cannot be purged unless the valve is commanded to open. This can be done electrically in two ways. With ±15 volt power applied, apply either a full-scale (5 VDC) setpoint or ground the valve test point (pin D).

A "cycle" purging technique is more effective in removing atmospheric contaminants than a simple continuous purge gas flow. To cycle purge, alternate the flow of purge gas with a pumpdown of the gas system to vacuum for several cycles. If vacuum is not available, reducing the pressure to 101.325 kPa (zero psig) for several cycles should be adequate. Cycle purging helps remove contaminants from small, blind cavities in the system which constitute a virtual leak source. A more detailed procedure can be found in Appendix B.

Apply ±15 VDC power and allow a 30 minute warm-up time before pressurizing the system with process gas. If the instrument is equipped with an integral heater, activate the heater and stabilize at a normal operating temperature. Normal operating temperature is approximately 5°C higher than the source vapor (or gas) temperature. Refer to Appendix D for operating instructions.

If the indicated output does not settle to zero to within 1% full scale (or the level of zero desired), re-zero the instrument (see *Adjustment Procedures*) before proceeding. Once the zero has been verified, pressure may be applied. After establishing that no hazardous condition will be created by the venting of process gas, vapor controller operation may then be verified over the complete operating range. If the flow output voltage is within ten millivolts of the setpoint, the vapor controller is controlling properly. Check for this condition at the highest and lowest pressures anticipated at both the highest and lowest input.

4-2 Safety Features and Precautions

⚠ WARNING

THE FLOW BASE AND REMOTE ELECTRONICS MODULES MUST BE MATCHED BY SERIAL NUMBER FOR PROPER OPERATION AND WARRANTY COVERAGE.

Every effort has been made in the design of the instrument to provide safe, trouble-free operation. Key features include reverse power supply polarity protection, output over-voltage and short circuit protection, low component temperatures, and conformance to intrinsic-safety design criteria. Additionally, a built-in "threshold" circuit ensures that the valve is commanded closed at zero command independent of any existing output offset, and the valve automatically closes in case of a power failure (normally closed). The normally open valve automatically opens with power failure.

Two other features are provided for the operator's convenience during start-up, abnormal, or fault conditions. First, the valve command circuit can be overridden externally to either drive the valve fully open or fully closed. For normally closed valve, connecting pin D to 0 VDC or +15 VDC will drive the valve open, while connecting pin L to 0 VDC will drive the valve closed. For normally open valve, the opposite effect occurs.

The input to close the valve provided on pin L is active low and conforms to TTL Logic levels. Second, should there be a need to purge the system during a power failure or instrument malfunction prior to removing the instrument from the system for repair, the valve may be mechanically opened by first removing the instrument cover and then loosening the lock nut and turning the adjusting nut on top of the valve one or two turns counterclockwise. Re-adjustment of the valve after purging or repair is described in the *Adjustment Procedures*.

⚠ WARNING

PROPER LEAK CHECK EQUIPMENT AND SYSTEM PLUMBING MUST BE AVAILABLE TO LEAK CHECK THE CONTROLLER AFTER ANY MECHANICAL ADJUSTMENT HAS BEEN PERFORMED ON THE VALVE.

⚠ CAUTION ⚠

The following precautions should be taken to prevent damage, minimize safety hazards, and maximize performance.

- Use pre-cleaned tubing, free of particulate contamination. Ultraclean tubing is recommended for use with the VC-4900M.
- Thoroughly leak test the entire system prior to operation (recommended level for elastomer seals is $1x10^{-9}$ atm cc/sec of helium or less, $1x10^{-10}$ with metal seals).

- Whenever a condensable meduim is used, heat and maintain the temperature of the plumbing and vapor controller to avoid condensation.
- Purge only with dry nitrogen (or other inert gas) before and after breaking into the system. Connecting pin D to 0 VDC or +15VDC will readily allow for this by driving the valve open. (opposite for normally open valve).
- DO NOT purge reactive gas systems with inert gases between runs unless it is required by the process. Even "dry" gases contain some amount ofmoisture which will result in contamination build-up.

⚠ WARNING

NEVER INSERT OR UNPLUG THE CONNECTING CABLE OR THE CONTROL VALVE LEADS WITH POWER ON IF THERE IS A POSSIBILITY THAT THE AMBIENT ATMOSPHERE MIGHT BE EXPLOSIVE.

- ALWAYS command no flow or ground pin L when the gas supply is shut off. The command signal should be interlocked with a series shutoff valve to prevent unnecessary over-heating of the control valve during shutoff, and excessive flow surges after turn-on.
- Avoid installation of the instrument in close proximity to high sources of RF noise and/or mechanical vibration. If this is unavoidable, proven methods of instrumentation filtering, cable shielding, and/or shock mounting should be utilized.
- See *Caution Note* on page 7 before converting any elastomer sealed instrument for operation on a gas other than what it was originally calibrated for or previously used on.

4-3 Operating Modes

In general, the instruments may be operated at any pressure and temperature that falls within the limits stated in the specification. Optimum performance, however, can be achieved and will prevail if the operating pressure and temperature are pre-determined and controlled to a narrow range. Calibrating and "fine tuning" the instruments at the actual operating pressure, temperature and flow rates can significantly improve the performance characteristics.

The instruments are factory calibrated at an ambient temperature of 23°C (±3°C) and the inlet pressure set to the midpoint of the operating pressure range and corrected to standard conditions. Vapor controllers are adjusted to pass full rated flow at the minimum inlet pressure, with 101.325 kPa (0 psig) outlet pressure and shut down to less than 2% of full scale at the maximum inlet pressure. Response time is verified at both extremes.

In vacuum systems, vapor controllers maintain their calibration accuracy due to the pressure drop of the control valve downstream of the flow sensing section. The increased pressure drop of the valve due to the increased gas velocity reduces the full-scale flow rate and unless there is sufficient inlet pressure available to overcome the increased pressure drop required, increasing the range of the instrument and/or re-adjustment of the valve may be necessary.

If the control valve is normally closed, it is not necessary to provide an external time-delayed "soft-start" signal provided the command signal is maintained at zero during the "off" mode and is then applied to the instrument at the same time (or after) pressure is applied. Alternately, pin L connected momentarily to common prior to applying gas pressure also prevents excessive flow transients at turn-on. A slower ramp change may also be selected for vacuum systems which have small volumes and large flow rates or in other applications where a slower ramped change in flow rate is desirable.

Vapor controllers may be operated at inlet pressures of up to 1135 kPa (150 psig), provided the differential pressure is maintained within the limits where the calibration and adjustments are set, and the outlet pressure of the vapor controller is regulated to a relatively constant level. Vapor controllers can withstand pressure surges of up to 10,500 kPa (1500 psig) without damage, but are not designed to operate in a controlling mode above 1135 kPa (150 psig) inlet pressure.

5 Routine and Preventative Maintenance

It is recommended that a routine maintenance schedule be established on each instrument in order to maximize its useful service life. This would include, as a minimum, cleaning and recalibration. It is recommended that calibration be done at least once a year. The optimum (or necessary) service period is dependent on usage, environmental conditions, gas corrosiveness, etc., and must be established by the user based upon historical experience in that particular application.

The recommended steps for routine and preventative maintenance are as follows:

1. Purge the instrument with dry nitrogen for a minimum of 30 minutes prior to removal from the system *(See Appendix B for detailed purge procedure)*.
2. Verify the calibration of the flow metering section by comparison with a suitable reference standard or calibrator.
3. Operate the instrument in the control mode over its entire operating range (2 to 100% full scale) at the minimum and maximum inlet pressures of 175 kPa and 380 kPa (10 and 40 psig). Check response, stability and control resolution.
4. Remove the inlet and outlet fittings of elastomer sealed instruments and visually examine for signs of contamination. Examine the seals for any evidence of cracking, hardening, swelling or contaminant accumulation. Do not attempt to disassemble the VC-4900M unless replacement seals are available.
5. Based upon the results of steps 1 through 4 above, either reinstall in the system (followed by a nitrogen purge) or proceed to the applicable *Cleaning, Adjustment and/or Calibration Procedure* described in this manual.

6 MAINTENANCE, ADJUSTMENT AND RANGE CHANGE

⚠ CAUTION ⚠

The following information is provided as a reference for Millipore-trained and certified calibration and repair technicians ONLY. DO NOT attempt to disassemble, clean, or calibrate an MFC unless you are fully trained, certified and are working in a qualified calibration facility. Improper adjustments of your device may void all warranties. Consult your Millipore Service Center.

NOTE: The following instructions and procedures are intended for a laboratory bench top environment. Proper equipment and precautions should be used for any other system or environment.

6-1 **Cleaning** *(Elastomer Sealed Instruments)*

Should the instrument show symptoms of internal flow path contamination, it should be disassembled and cleaned. Elastomer seals on the fittings, sensor and valve should be examined for hardening, swelling, inflexibility, and/or contamination accumulation and should be replaced if any of these symptoms prevail relative to new and unused seals. The recommended sequence of solvents used for cleaning (either for flushing the assembled instrument or for soaking individual components in an ultrasonic cleaner) is as follows.

For instruments used with all non-reactive, non-corrosive gases:

- Distilled water (2 to 3 minutes)
- Alcohol (2 to 3 minutes)
- Blow dry with dry nitrogen or air.

For instruments used with all highly reactive and corrosive gases:

- A solution of 2% HF, 8% HNO_3, and 90% de-ionized H_2O (3 to 5 minutes)
- Distilled water (2 to 3 minutes)
- Alcohol (2 to 3 minutes)
- Blow dry with dry nitrogen or air.

Individual flow-path elements should be cleaned as follows:

Fittings

Remove the fittings from the base and clean individually.

Sensor

Remove the P.C. Board from the assembly, then remove the two screws which secure the sensor assembly to the base. Run a .18 mm (.007 inch) diameter wire (stainless steel or piano) through the full length of the sensor tube 3 or 4 times. Replace the sensor on the base, torque to 15 in-lb., flush with solvent during the *Bypass Cleaning Procedure* as described below.

Bypass

If it is desired to change the range of a flow meter or controller beyond the electronics adjustment capabilities, it

will be necessary to replace the bypass assembly to produce the nominal output of 5 ±0.6VDC at full scale flow. In addition, the valve may have to be adjusted and/or the orifice replaced.

The bypass is a preadjusted assembly located in the base, which can be removed and reinstalled with the use of a bypass torque wrench *(see Mass Flow Maintenance Kits)* or a screwdriver. To remove the bypass, hold the vapor controller in a vertical position (inlet down) and carefully remove the assembly. Since the discs are loose on the nut, be careful not to lose or damage them. The nut and discs should be cleaned in an ultrasonic cleaner and reassembled in the same order as originally installed (slots upstream, facing the shoulder of the nut).

New bypass assemblies may be installed with or without the Teflon retaining washer. Reinstall the bypass and torque to 25 in-lb.

NOTE: Installing the nut without the discs provides a means for thorough solvent flushing of the flow sensor. After purging with dry nitrogen, remove the nut and reinstall the discs.

After replacement or removal for cleaning of the bypass assembly, the flowmeter section should be recalibrated per the procedures outlined in the *Calibration* section, since a calibration shift of as much as 10% may occur during this operation depending on the level of contamination.

Valve

For minor contamination, the valve can be cleaned in place by mechanically opening the valve, flushing with solvent, purging with dry nitrogen and then resetting the valve during test as described in the *Valve Adjustment Procedure*. To mechanically open the valve, loosen the lock nut and turn the adjusting nut on top of the valve 2 to 3 turns counter-clockwise with a 5/16 inch open-end box wrench.

For severe contamination, the valve assembly and valve seat can be removed from the base and cleaned separately.

This is done as follows:

1. Unplug the valve from the P.C. Board.

   ⚠ **CAUTION** ⚠
   Always make sure power is off before disconnecting or reconnecting the valve to the P.C. Board.

2. Remove (or loosen) the P.C. Board from the base assembly if necessary to provide clearance for the removal of the valve assembly. For instruments with remote electronics option, disconnect the valve leads from the electrical junction board.
3. Remove the two screws which secure the valve flange to the base and pull the valve assembly out completely.
4. If further disassembly is necessary (due to the level of contamination), remove the plunger assembly (plunger, poppet, and spring) by holding the inner sleeve assembly at the top of the retaining nut with a 5/16 inch ring-wrench and removing the valve retaining nut with a ½ inch open-end wrench.
5. Thoroughly clean the plunger assembly and the inside of the inner sleeve assembly. Examine the poppet sealing surface and the valve O-ring and replace if necessary.

NOTE: Be sure to re-lubricate the O-ring with Halocarbon grease for Viton O-rings or Krytox grease for Kalrez O-rings prior to re-installation into the base.

6. Reinstall the plunger assembly making certain that the spider spring locates concentrically in the counter-bore of the inner sleeve assembly. Tighten the retaining nut with a torque of 20 in-lb. (±3%) and verify that the spring is positively held in place with no axial or rotational movement.
7. Remove the orifice from the base and clean separately. Be careful not to nick or damage sealing surface. Replace o-ring if required and re-grease before re-installing.
8. Replace the valve assembly by inserting it straight down into the base. Locate the valve coil leads towards the P.C. Board to provide maximum clearance for the valve adjustment wrench. Secure the valve in place by alternate tightening of the valve flange screws with 20 inch-pounds of torque.
9. Adjust the valve during test as described in the *Valve Adjustment Procedure*.

After cleaning or replacement of the sensor, bypass or valve assemblies, the instrument must be adjusted and recalibrated against a suitable reference standard or calibrator to re-establish the original calibration and performance characteristics.

6-2 **Cleaning** *(Metal Sealed Instruments)*

Should the instrument show symptoms of internal flow path contamination, it may be disassembled and cleaned. Contamination of the ultraclean surface may cause irreparable damage depending on the severity of contamination. Metal seals should be replaced once the factory seal is broken. Before reassembling, inspect metal sealing surfaces carefully for nicks. Use of damaged metal seals will likely result in excess leakage after re-assembly.

Disassembly of the VC-4900M is accomplished as follows:

1. Remove the two screws which secure the cover to the base using a Phillips screwdriver.
2. Unplug the valve from the P.C. Board.

   ⚠ **CAUTION** ⚠
   Always make sure power is off before disconnecting or reconnecting the valve to the P.C. Board.

3. For instruments with remote electronics option, disconnect the valve leads from the electrical junction board.

4. Using an Allen wrench, remove the four screws which secure the valve to the base and pull the valve assembly out completely. Retain the metal centering ring for re-assembly and discard the nickel seal.
5. If Further disassembly of the valve is necessary (due to the level of contamination), remove the plunger assembly by removing the square headed retaining nut from the inner sleeve.
6. Remove the orifice from the base and retain. Discard the Teflon seal and replace with a new seal when reassembling.
7. Remove standoffs which support the cover.
8. Remove the P.C. Board from the assembly and, using an Allen wrench, remove the four screws which secure the sensor assembly to the base. Discard the Teflon centering rings and nickel seals.
9. Using an Allen wrench, remove four screws which secure the inlet fitting and outlet fitting end plates to the base. Retain the metal centering rings for re-assembly and discard the nickel seals.
10. To remove the bypass, hold the vapor controller in a vertical position (inlet down) and carefully remove the assembly. Since the discs are loose on the nut, be careful not to lose or damage them. Note the order of the installed discs for re-assembly.

Cleaning of all gas wetted parts is accomplished as follows:

1. Run a heated ultrasonic cleaner with D.I. water for a minimum of 5 minutes. Hand clean each part with clean room approved wipes. Reclean using fresh D.I. water.

   NOTE: Do not submerge electronics, sensor or valve coil. Use of harsh solvents, chemicals or HF will likely cause irreparable damage to surface finishes.
2. Dry parts in a vacuum oven for 30 minutes. Maintain and observe clean room practices during the cleaning process in preparation for re-assembly.
3. Clean the sensor by running a .18 mm (.007 inch) diameter wire (stainless steel or piano) through the full length of the sensor tube 3 or 4 times. If possible, force DI water through the sensor then dry with ultra-pure nitrogen.

Re-assembly should be done in a Class 10 clean room environment which includes use of tools and fixtures.

1. Inspect all surfaces under high power magnification for surface degradation and replace suspect parts.

   NOTE: Carefully inspect all new nickel seal surfaces for nicks before installing.
2. Install outlet fitting plate using a new nickel seal. Note the orientation of the fitting. Torque Allen screws using a cross pattern to 25 in-lb.

   NOTE: Hand tighten Allen screws before torquing to be certain that each component is properly seated. Torque in 5 in-lb. increments until required torque is achieved.
3. The nut and discs should be reassembled in the same order as originally installed (slots upstream, facing the shoulder of the nut). Reinstall the bypass and torque to 15 in-lb. using the bypass adapter on the torque wrench.
4. Install the inlet fitting plate using a new nickel seal. Note the orientation of the fitting. Torque Allen screws using a cross pattern to 25 in-lb.
5. Install sensor using new nickel seals and new Teflon centering rings. Torque Allen screws to 15 in-lb. Reinstall the P.C. Board (or the junction board, if remote electronics option) to the sensor with the screw and spacer.
6. Install the orifice into the base with a new Teflon seal. Torque to 25 in-lb.
7. Install the valve with the "cut out" toward the sensor. Using a new nickel seal and the original centering ring, torque the Allen screws to 20 in-lb. using a cross pattern to tighten. It will also be necessary to readjust the valve (refer to the Valve Adjustment Procedure).
8. Secure cover support standoffs to the base.
9. Leak check to 1 x 10^{-10} atm cc/sec Helium.
10. Install the cover following recalibration.

After cleaning or replacement of the sensor, bypass or valve assemblies, the instrument must be adjusted and recalibrated against a suitable reference standard or calibrator to re-establish the original calibration and performance characteristics.

7 Adjustment and Calibration Procedures

In order to maintain the original factory calibration and performance characteristics of the instrument, the following adjustments may be necessary during routine maintenance and servicing and will definitely be required after disassembly for cleaning and/or parts replacement.

NOTE: To minimize errors due to pressure and temperature effects, it is recommended that calibration and adjustments be made at the same temperature and pressure conditions as the actual operating condition.

7-1 Calibration - Indicated Versus Actual Flow

Each controller is factory calibrated for the specific flow and gases indicated on the nameplate. Standard factory calibration is within ±1.0%. The calibration for other gases can be approximated to ±5% by using the conversion factors shown in Appendix A.

Factory adjustments should not be altered unless precision gas flow measuring equipment is available for calibration. Rotameters do not have sufficient accuracy for flow measurement calibration unless they have been specifically calibrated and the proper corrections are made for temperature and pressure. For access to the electronics, remove the two cover screws and carefully lift the cover from the assembly. If electrical adjustments are made with the cover removed and the PC board exposed, be very careful not to break wires or create short circuits while the

instrument is open.

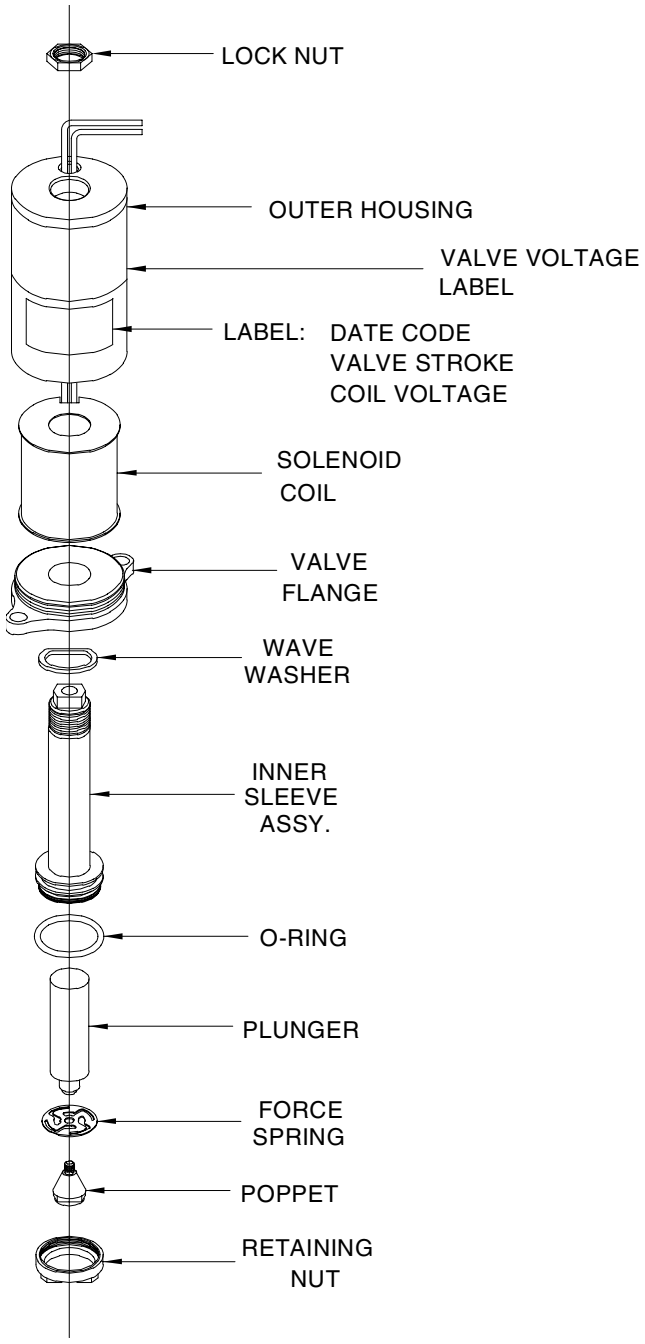


Figure 4: Solenoid Valve **(Elastomer Sealed Instruments)**

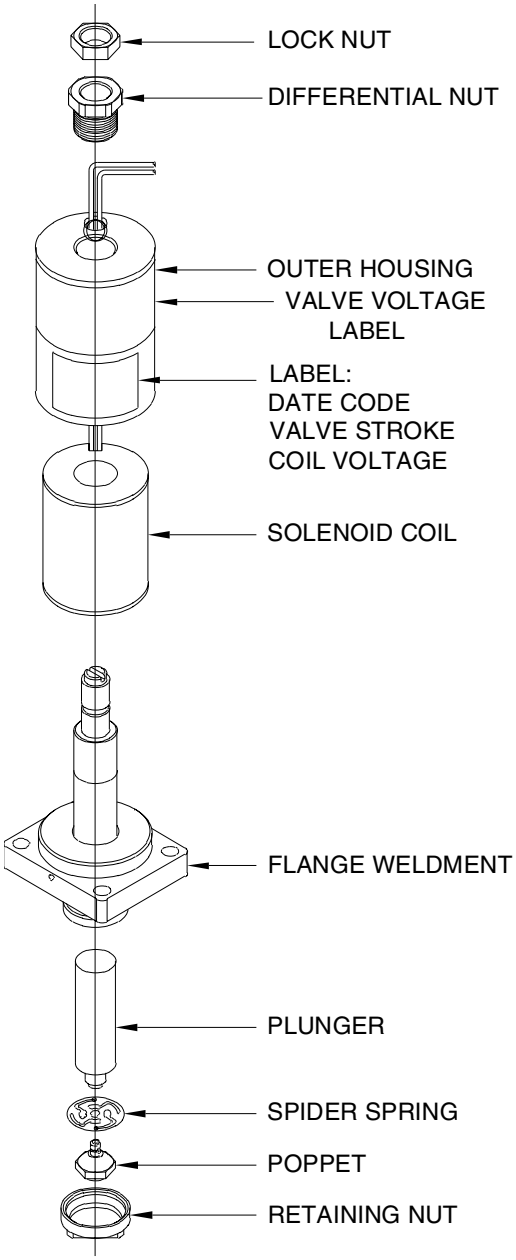


Figure 5: Solenoid Valve **(Metal Sealed Instruments)**

Recalibration may be accomplished as follows: (Refer to Figures 7 through 12).

1. Thoroughly flush and dry the instrument to remove contaminants (see Cleaning Procedures).
2. Connect a source of gas to the inlet and a suitable flow standard to the outlet. If a volumetric calibrator is used, be sure to apply the proper density corrections to maintain the mass flow calibration.
3. Connect the power and indicator wires *(see Electrical Hook-up Diagram*) and allow a 30 minute warm-up period.
4. Either mechanically open the valve by turning the adjusting nut on top of the valve 2 to 3 turns counter-clockwise, or electrically drive the valve open by connecting pin D to pin 4 (+15VDC). This will override the control loop, allowing flowmeter operation. Command >10% flow to deactivate autozero during calibration.
5. Remove the outlet gas line and cap off the instrument to assure zero flow through the sensor. Adjust ZERO potentiometer RP1 to make the indicator read zero (±5mV).
6. Reconnect the outlet gas line and adjust the flow to 40% full-scale value. Set the output to read 2.00 VDC (±5mV) at 40% full-scale flow rate using the GAIN potentiometer RP2.
7. Recheck zero as described in step 5.
8. Linearity adjustments are not normally required. After achieving calibration at zero and 40% maximum flow, the full scale calibration may be checked by setting the flow to full-scale. If the indicator does not read 5.00 ±0.025 VDC, adjust the output to 5.00 VDC using the LINEARITY potentiometer RP4. Although this adjustment is essentially independent, steps 5 and 6 should be repeated until all three points are within the desired calibration.
9. The flowmeter section of the vapor controllers can be calibrated with the instrument operating in the controller mode and using the setpoint control to dial in the desired flow rate. Adjustments should be made as in steps 5 through 8. When adjusting the gain and linearity potentiometers, the actual flow will change rather than the output voltage since the controller acts to control the output voltage to the commanded setpoint voltage.
10. If the instrument cannot be brought into calibration within the adjustment range of RP2 or RP4, the flowmeter amplifier gain and/or bypass will have to be adjusted. This procedure is described in the *Range Change* section of this manual.
11. When using a test gas other than the intended usage gas, a correction factor equaling the ratio of the conversion factors of the two gases must be applied. See Appendix A, *Gas Flow Conversion Factors*, for further explanation.

7-2 Valve Adjustment (Mass Vapor controllers only)

⚠ WARNING

PROPER LEAK CHECK EQUIPMENT AND SYSTEM PLUMBING MUST BE AVAILABLE TO LEAK CHECK THE CONTROLLER AFTER ANY MECHANICAL ADJUSTMENT HAS BEEN PERFORMED ON THE VALVE.

Valve adjustment is accomplished through the following procedure:

1. Plumb the inlet of the instrument to a regulated supply of the appropriate gas. Connect a reference flowmeter in series, or monitor the flow as measured by the flow metering section of the instrument itself.
2. Remove the cover to permit access to the valve assembly. Plug the valve into the P.C. Board prior to applying power to the instrument. Starting with the valve mechanically open and the input command signal at zero, slowly apply inlet pressure to the controller to the maximum operating pressure (application specific). Mechanically close the valve by **SLOWLY** turning the adjusting nut clockwise until the flow is reduced to less than 2% of full scale. Cycle the valve from 0% to 100% then from 100% to 0% full scale to ensure consistent valve closure of less than 2% of full scale.

   ⚠ CAUTION ⚠
   The control valve is not designed for positive shut-off. Do not attempt to adjust closure to less than 1% as the poppet may be damaged.
3. Set the inlet pressure to the minimum operating pressure (application specific).
4. While monitoring the voltage applied to the valve (pin D to pin F), mechanically "fine-tune" the valve adjustment to achieve as close to the optimal 13 VDC control voltage as possible. Repeat this process until the valve controls from <2% to 100% full scale at both extremes of pressure.
5. After the valve is properly adjusted and tuned dynamically (see below), tighten the lock nut on the top of the valve with 10 to 20 inch-pounds of torque. This will lock the adjusted position in place.
6. Leak check the instrument.

7-3 Dynamic Response Adjustment

Each vapor controller is dynamically adjusted prior to shipment using a flow measuring device, in series, which is at least 5 times faster than the instrument under test (for experimental details, refer to SEMI Standard E17-91). This verifies that the tuned indicated response is indicative of the actual flow response and does not mask or filter-out overshoot or oscillatory flow conditions. It is recommended that the adjustments not be altered unless suitable equipment is available to adequately display the transient results. If it is found necessary to readjust the response characteristics following cleaning, re-assembly,

valve adjustment, or range change, the following steps may serve as a guideline.

1. Start with the previously set adjustment, or alternately center potentiometer RP3 and set R50 to 200K.

   NOTE: A resistance decade box is useful for finding the optimum value of R50.

2. Supply the instrument with the intended usage gas or a suitable substitute gas at the intended operating conditions including inlet pressure.
3. Generate step changes of the setpoint signal. For example, 50% to 100% and vice versa, and watch the output signal using a storage oscilloscope or a fast chart recorder.
4. Adjust RP3 to produce as near a square wave as possible. If a fast actual flow measuring device is used in series to view actual response, adjust RP3 to match the indicated response to the actual response.
5. Once RP3 has been optimized, reduce R50 to minimize the overshoot without causing oscillations or instability. R52 may also be varied if necessary to achieve optimal results. A high ratio of R52/R50 will provide the fastest response and minimal overshoot, but is more inclined to result in oscillation and instability. R50 should be minimized to prevent long delays at low setpoints.
6. Once the response has been optimized, the response characteristics should be checked at various step changes in setpoint over the expected operating pressure range. It is advisable that the value of R50 be increased by 50% as a last step to preclude the possibility of instability developing after installation.

Bypass Adjustment

Since the bypass is pre-assembled to a specific range, it is as such, non-adjustable. Minor adjustments can be made, however, by removing or adding discs to bring the calibration within range of the adjustment potentiometers. (Removing discs reduces the range proportionately, while adding discs increases the range). Bypass adjustment is not recommended by anyone other than a qualified service technician who has been factory trained in the serviceability of the instrument.

Range Change

Changing the range of the instrument is neither recommended nor warranted by anyone other than Tylan General authorized Service Centers or Maintenance Depots. The following information is provided only as a service to the OEM or user to assist them in an emergency situation. To change the range of the instrument it will be necessary to replace and readjust one or all of the following elements:

Valve

Five valve seats with different orifice sizes are available to accommodate full scale ranges of 10 sccm through 30 slm. See parts list for the flow ranges of each orifice. All five orifices are available in the General Spare Parts Kit.

When changing ranges, the valve seat may have to be changed accordingly. This can be accomplished by removing the valve assembly and replacing the valve seat as described in the Cleaning section. Readjustment of the valve is recommended (and in most cases is necessary) for optimal performance following any range change of 2:1 or more. Refer to the *Valve Adjustment Procedure* previously described.

Bypass:

Remove the bypass assembly as described in the Cleaning section and replace with an assembly which has been pre-assembled to the desired range. If the range is too high to bring within the range of the gain pot (RP2), either remove discs or decrease R21 (1.8K: minimum). If the range is too low to bring the calibration within the adjustment range of RP2, increase R21 (3.0K: maximum). Recalibrate per the Calibration Procedure previously described.

Electronics:

The following components need to be adjusted or re-selected during the calibration procedure or dynamic response optimization previously described:

- Potentiometer RP1: Zero Adjust
- Potentiometer RP2: Gain Adjust
- Potentiometer RP4: Linearity Adjust
- Potentiometer RP3: "DYN" Response Adjust
- Resistor R50 and/or R52: Proportional Band Adjust

NOTE: Complete recalibration and dynamic response adjustment will also be required any time the sensor assembly or P.C. Board assemblies are replaced.

8 TROUBLESHOOTING PROCEDURES

8-1 **Initial Test**

1. Check setup and procedure against connection instructions given in the *Installation* section. Permanent damage to the instrument may result if purging procedures are not followed, or if line power is accidentally applied to the signal leads.
2. Test line cord for compliance with pin assignments and continuity from all wires to correct pins (see *Electrical Hook-up Diagram*). Use a hipot tester to check for pin-to-pin shorts; during the test, flex the cable coming out of the connector to find intermittent shorts.
3. Check insulation resistance from pin 2 to base. It should exceed 50 megohms at 50 VDC. Pin 1 to case should measure less than 1 ohm.
4. Connect a source of gas (same as that for which the instrument is calibrated or equivalent test gas) to the inlet fitting. Apply power and allow a 30 min. warm-up period. With the appropriate inlet pressure applied, the output signal of the controller should follow the command setting (i.e., 50% of full scale at 2.50 VDC commanded voltage). Actual flow (as measured by a suitable flow standard in series with the controller) should follow the command setting and agree with the indicated flow of the controller. If the instrument is malfunctioning or cannot be recalibrated as previously described in the *Adjustment and Calibration Procedure*, check the appropriate symptom in the Troubleshooting Chart.

Millipore has maintenance kits available which contain custom-designed tools that simplify the maintenance and repair of all Millipore mass flow equipment.

Table 1: VC-4900 Series Mass Flow Instrument

Maintenance Kit, Part No. 908605-001

DescriptionPart Number

Torque wrench, 10-inch-lb. (PC bd stndoff) 651780-001
Torque wrench, 15-inch-lb. (sensor) 200241-017
Torque wrench, 25-inch-lb. (bypass) 651780-002
Adapter, torque wrench (bypass) 907328-001
Adapter, torque wrench (bypass) 907328-002
Adapter, torque wrench (valve, sensor) 906278-001
Adapter, orifice (1/4") 906284-001
Adapter, use with orifice 200065-001
Pot adjustment tool 651784-001
Extended board 3780-280-0
Wire, mandrel 3505-122-0001A
Tool kit box 200557-001

Table 2: VC-4900 Series Additional Tools

Description Part Number

Screwdriver, 1/8" Phillips 200551-001
Wrench, open-end, 5/16" x ¼" 200552-006
Wrench, open-end, 7/16" x 3/8" 200552-007
Wrench, open-end, 11/16" x 13/16" 200552-001
Wrench, open-end, 7/8" x ¾" 200552-005
Wrench, adjustable, 1" 200553-001
Diagonal cutter 200554-001
Pliers, needle-nose 200555-001
X-acto knife NO-1

Table 3: Other Recommended Tools & Equipment

- Alcohol Dispenser
- Ultrasonic Cleaner
- Plastic Beakers (for use with cleaning solution)
- 25-10M Halocarbon Grease
- Soldering Equipment (for S.I.T. resistors)
- Suitable Power Supply and Readout with Interconnect Cable
- Tweezers
- Artist's brush #4
- Krytox Grease

Table 4: Table 4. Replaceable Spare Parts

DESCRIPTION PART NUMBER

O-Ring Kit: (contains all O-Rings to rebuild a vapor controller or flowmeter)
VC-4900/4901/4902
Viton908603-001
Orifice Kit (contains all 5 orifices)905491-001

Sensor:
Viton (10 sccm - 3slm) 902343-011
Viton (3.1 slm - 45slm) 902343-008
Metal (VC-4900M/4901M/4902M
10 sccm - 3 slm 909224-001
3.1slm - 45 slm 908858-001
Valve:
Viton 904149-019
Metal (VC-4900M/4901M/4902) (N.C.) 908778-003
Metal (VC-4900M/4901M/4902) (N.O.) 908778-006

P.C. Board Assembly
VC-4900/4900M 10sccm-3slm (N.C.) 909270-001
VC-4900/4900M 10sccm-3slm (N.O.) 909270-002
VC-4900/4900M 3.1 slm-30slm 908844-001
VC-4901/4901M 10sccm-3slm (N.C.) 909281-001
VC-4901/4901M 10sccm-3slm (N.O.) 909281-002
VC-4901/4901M 3slm-30slm 908854-001
VC-4902/4902M 10sccm-3slm 909364-001
VC-4902/4902M 3.1slm-30slm 909330-001

Table 5: General Troubleshooting

SYMPTOM	POSSIBLE CAUSE	REMEDY
No output	Faulty meter	Read output at pins 3 and 2 directly with alternate meter.
	No actual flow	Check pressures, valve positions, line or filter blockage.
	Sensor clogged	See Cleaning Procedures.
	Valve closed	See Valve section. Measure valve DC resistance (should be 410 ±20Ω). If coil is open, replace coil or entire valve assembly.
	Electronic Failure	See Electronics section.
	No input power	Check for line power between appropriate pins at mating connector.
	Faulty power supply	Check input/output voltages (±15 VDC, +5.00 VDC)
Maximum signal (approx. 200% of full scale): a. Indication correct, flow is high	Valve failed open	Check valve voltage as measured across valve wires. Valve should close when voltage decreases below 4.00 VDC. Higher voltage indicates lack of closing command or electronic failure; repair or replace electronics.
	Faulty power supply or command signal	Check input/output voltages (±15 VDC, +5.00 VDC)
b. Indication erroneous	Open resistance element on sensor	Replace sensor.
	Electronics failure	See Electronics section.

Table 6: Electrical Troubleshooting.

SYMPTOM	POSSIBLE CAUSE	REMEDY
General Failure or miscalculation	Power supply voltage off of nominal	Check ±15 VDC. Check P.C. Board interconnect J2.
Flow indication saturated (-0.7 or +12.0 VDC) regardless of flow	Bridge or sensor failure	Check sensor resistances, these should be 330 ±13Ω green to red and green to brown with power off. Voltage across BRN to RED should be 8.0 to 10.0 VDC and pin 6 to circuit common should be -5.0±0.3 VDC.
	Component failure	Check zero pot, gain pot, other components and solder joints.
Valve drive open or driven off (0VDC).	Valve drive transistor Q3 open or Q2 shorted	Check Q2, Q3, and other components; replace as required.
Valve drive saturated(>20VDC)	Q3 short, Op-amp (U1) failed.	Replace if necessary, or replace P.C. Board assembly 909002-001.
All circuits functional, but out of calibration	Contamination, or as a result of cleaning or repairing	Adjust.
Controls, but output voltage does not agree with control input voltage	Mismatched resistors	Check that R34=R37 and R35=R36 (±0.1%)
	Large input voltage offset in Op-amp(U1 of 909002-001)	Check U1. Replace as necessary, or replace P.C. Board 909002-001.

Table 7: Valve Troubleshooting

SYMPTOM	POSSIBLE CAUSE	REMEDY
Signal offset at zero flow	Electronics not adjusted	See Adjustment Procedures.
Valve fails to close	Contamination	See Cleaning Procedures.
	Electronics failure	See Electronics Section
	Mechanical damage from over-pressure or other cause	Adjust or replace valve.
	Operation on wrong gas(e.g., unit adjusted for argon may not shut off completely on hydrogen)	Test on proper gas or mechanically readjust valve.
	Valve failed open (normally open only)	Refer to General Troubleshooting Table on the previous page. Use the same remedy as the "Valve failed open" under Possible Cause.
Valve fails to open	Contamination	See Cleaning Procedures
	Electrically commanded closed or pot shorted	Check command signal (pins A and B) and pot. Check for Electronic failure.
Valve controls at flow rates, but not at minimum	Contamination	See Cleaning Procedures.
	Erosion or corrosion	Replace valve.
	Improper adjustment or inadequate drive	See Adjustment Procedures.
Valve Oscillates or hunts	Erratic pressure regulator	Replace regulator.
	Improper system dynamics due to excessive inlet pressure	Reduce upstream pressure regulator setting.
	Improper dynamics in electronics	Check for failed resistor or capacitor. See Dynamic Response Adjustment Procedure.

⚠ CAUTION ⚠

Always command zero flow when the gas supply is shut off. Failure to do so will result in excessive flow transients after the gas supply is turned "on" (See Electrical Hook-up Diagram.)

NOTE 1:Pin L may be connected to common prior to turning on the gas supply to achieve "soft start" performance.

NOTE 2:A threshold circuit in the controller ensures zero valve voltage whenever the commanded signal falls below 1.0%

NOTE 3:It is not recommended that a failed electronic component be replaced, as component failures are usually caused by another problem in the device or in the system. It is recommended instead, that the vapor controller be returned to the factory or other authorized Service Center for failure analysis and repair.

8-2 Sensor Replacement

If it is determined that either of the sensor elements is open or shorted to case, it will be necessary to replace the sensor assembly. This can be done by unsoldering the three sensor leads from the P.C. Board and removing the three screws which attach the sensor assembly to the base and the P.C. Board. The sensor assembly can then be removed and replaced. Before installing the new sensor element, resistance should be checked and measured as follows:

UpstreamRU=330±13 ohms at 24°C
(Brown to Green)
DownstreamRD=330±13 ohms at 24°C
(Red to Green)

Isolation>100 megohms
(All leads to sensor housing)

8-3 Solenoid Valve Replacement

If it is determined that the coil of the solenoid valve is open, shorted to case or outside the DC resistance range of 390 to 420 ohms, the valve assembly will need to be replaced. Be careful not to alter the mechanical adjustments of the valve when replacing the coil. Simply remove the locknut and valve housing to gain access to the coil.

9 APPENDIX A

9-1 Gas Conversion Factor Equations

This procedure is intended to help select a conversion factor relative to the test gas that closely matches the sample gas.

Example:

Sample Gas	Test Gas	Conversion Factor Relating to Test Gas
Ammonia (NH_3) C.F. = 0.719	Nitrous Oxide (N_2O) C.F. = 0.709	0.719/0.709 = 101.4%

Once a test gas conversion factor is selected (101.4%), divide the desired rate of flow by that percentage to obtain the adjusted flow rate for the standard unit decent (unit calibrated for the test gas).

Example 1:

Required Calibration: 1000sccm Bromine (BR_2) (C.F. = 0.808)

a) Using N_2 standard and N_2 test gas (C.F. = 100)

$$\frac{0.808}{1.00} = 0.808$$

so, for 1000sccm BR_2 you need:

$$\frac{1000}{0.808} = 1238 \quad N_2$$

Solution:
Use a 1500sccm standard, V_O of standard

$$\frac{1238}{1500} x5\,V = 4.13\,V \quad \text{or 82.5\% F.S.}$$

b) Using N_2O standard and N_2O test gas (C.F. = 0.709)

$$\frac{0.808}{0.709} = 1.140$$

so, for 1000sccm BR_2 you need:

$$\frac{1000}{1.140} = 877 \quad N_2O$$

Solution:
Use a 1000sccm standard, V_O of standard

$$\frac{877}{1000} x5\,V = 4.38\,V \quad \text{or 87.6\% F.S.}$$

Example 2:

Required Calibration: 1000sccm 10% Argon, 90% CO_2 (C.F. relative to N_2 = 0.777)

a) Using N_2O standard and N_2O test gas (C.F. = 0.709)

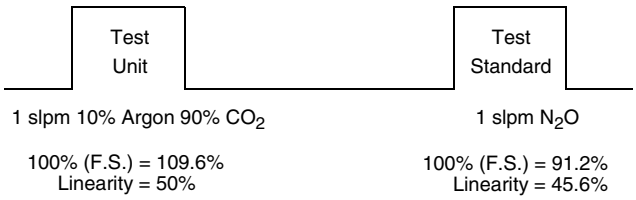
$$\frac{0.777}{0.709} = 1.096$$

so, for 1000sccm 10% Argon, 90% CO_2 you need:

$$\frac{1000}{1.096} = 912.4 \quad N_2O$$

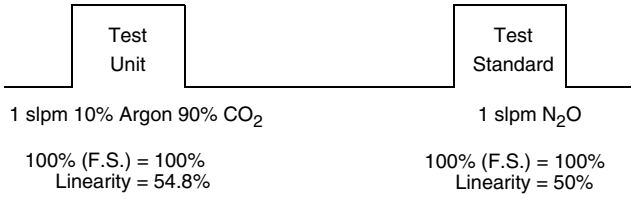
Solution:
Use a 1000sccm standard, V_O of standard

$$\frac{912.4}{1000} x5\,V = 4.56\,V \quad \text{or 91.2\% F.S. test standard}$$



b) Using N_2O standard and N_2O test gas (C.F. = 0.709)

$$\frac{0.777}{0.709} = 1.096 \text{ x } 100\% \text{ (F.S.)} = 109.6\%$$
$$= 1.096 \text{ x } 50\% \text{ (linearity)} = 54.8.\%$$



Note: Assuming actual flow of test standard per calibration sticker is 100% @ F.S. and 50% @ linearity.

9-2 Determining Mass Flow Conversion Factors

The ratio of a flow W_1 for a particular gas, to the flow W_2 of a different gas which will produce the same output voltage in a flowmeter or controller is equal to the ratio of their respective correction factors. This relationship is shown in equation 1 below:

$$\frac{C1}{C2} = \frac{W1}{W2} \qquad \text{(equation 1)}$$

Equation 2 shows the relationship between the properties of a gas and its rate of flow in standard cubic centimeters per minute for equal output voltages:

$$W = \frac{KN}{pCp} \qquad \text{(equation 2)}$$

- Cp is the specific heat in cal/g-C.
- p is the density of the gas at OC in g/liter
- N is a correction factor for the molecular structure of the gas. The values of N are listed in Table 1.
- For a particular flow meter of controller, K is a constant.

Substituting equation 2 into equation 1 yields the following relationship:

$$\frac{C1}{C2} = \frac{\frac{KN_1}{P_1 CP_1}}{\frac{KN_2}{P_2 CP_2}} \qquad \text{(equation 3)}$$

If we define both the conversion factor and the correction factor N, for the gas nitrogen to be 1.000, equation 3 can be reduced to the following:

$$C = \frac{(pN_2 CP_{N2})N_1}{p_1 Cp_1} \quad \text{(equation 4)}$$

By dropping the subscript 2 and replacing pN_2 and CpN_2, the density and specific heat respectively of nitrogen, with the actual values, we have an equation for calculating the flow conversion factors:

$$C = \frac{0.3108}{pCp} \text{ x N} \quad \text{(equation 5)}$$

Refer to the gas conversion factors table for conversion factors.

Substituting the flow range and conversion factor of the factory-calibrated gas and the conversion factor of a different gas into Equation 1 yields the flow range for the different gas.

Example: A flowmeter is calibrated for H_2 and the flow rate is 5000 sccm for 5.00 VDC output. The flow rate for nitrous oxide at 5.00 VDC output is:

$$\frac{1.01}{0.709} = \frac{5000}{W}$$

$$W = \frac{0.709x5000}{1.01} = 3510sccm$$

When calculating the conversion factor for a mixture of two or more gases, the following equations should be used:

The equivalent density is given by the relationship:

$$p = \frac{W_1}{W_T}p_1 + \frac{W_2}{W_T}p_2 \quad . \quad . \quad . \quad . + \quad \frac{W_n}{W_T}p_n \quad \text{(equation 6)}$$

Where:

- W_1 is the flow of gas #1
- W_2 is the flow of gas #2
- W_n is the flow of gas #n
- W_t is the total flow
- N_1 is the molecular C.F. of gas #1
- N_2 is the molecular C.F. of gas #2
- N_n is the molecular C.F. of gas #n
- p_1 is the density of gas #1
- p_2 is the density of gas #2
- p_n is the density of gas #n
- CP_1 is the specific heat of gas #1
- CP_2 is the specific heat of gas #2
- CP_n is the specific heat of gas #n

The equivalent specific heat is given by equation:

$$Cp = F_1 Cp_1 + F_2 Cp_2 \quad +. \; . \; . \; . + F_n Cp_n \quad \text{(equation 7)}$$

Where:

$$F1 = \frac{W_1 p_1}{W_T p}, \quad F2 \quad \frac{W_2 p_2}{W_T p} \quad + \; . \; . \; . \; . \quad Fn = \frac{W_n p_n}{W_T p} \quad \text{(equation 8)}$$

The equivalent value of N is:

$$N = \frac{W_1 N_1}{W_T} + \frac{W_2}{W_T} \quad + \; . \; . \; . \; . + \quad \frac{W_n}{W_T} \text{ N} \quad \text{(equation 9)}$$

For gas mixtures, the values p, Cp and N from equations 6, 7, and 9 are used in equation 5.

Combining numbers 5 through 9 results in the following equation:

$$C = \frac{0.3106\left(\frac{W_1}{W_T}N_1 + \frac{W_2}{W_T}N_2 + \ldots + \frac{W_n}{W_T}N_n\right)}{\frac{W_1}{W_T}p_1 Cp_1 + \frac{W_2}{W_T}p_2 Cp_2 + \ldots + \frac{W_n}{W_T}p_n Cp_n} \quad \text{(equation 10)}$$

or

$$C = \frac{\frac{W_1}{W_T}N_1 + \frac{W_2}{W_T}N_2 + \ldots + \frac{W_n}{W_T}N_n}{\frac{W_1}{W_T}x\frac{N_1}{C_T} + \frac{W_2}{W_T}x\frac{N_2}{C_T} + \ldots + \frac{W_n}{W_T}X\frac{N_n}{C_T}} \quad \text{(equation 11)}$$

Example : 10% Argon 90% CO_2

Let Argon be gas #1 and CO_2 be gas #2

$$CF = \frac{0.3106\left(\frac{10}{100}X1.01 + \frac{90}{100}X0.94\right)}{\left(\frac{10}{100}1.782X0.1245\right) + \left(\frac{90}{100}1.964X0.2017\right)}$$

$$= \frac{0.3106\ (0.101 + 0.846)}{0.022186 + 0.356525} = \frac{.3106\ (0.947)}{0.378711} = \frac{0.2941382}{0.378711}$$

C.F. = 0.777 Relative to N_2

9-3 Measurement Conversion Table

psi (lbs/in^2)	x	51.7149	=	mmHg (0°C)
	x	2.03602	=	inches of Hg
	x	51.7149	=	torr of mmHg
	x	0.068948	=	bar
1 torr	x	0.0193368	=	psi (lbs/in^2)
Hg	x	0.491154	=	
Inches of H_2O (4°C)	x	0.03612628	=	
mmHg @ 0°C	x	0.0193368	=	inches of Hg
STD Pressure in absolute unit = 14.696 PSI				
Atmosphere = 760 mmHg = 29.92 in. of mercury				
Atmospheric pressure (sea level, 0°C) = one atmosphere				
cubic feet per hour	x	0.4719342	=	slpm (liters/min.)
cubic feet per minute (cfm)	x	28.316052	=	
slpm (liters/min.)	x	0.0353157	=	cubic feet per minute (cfm)
cubic centimeter	x	0.001	=	liters
liters	x	1000	=	cubic centimeters
cubic feet/minute	x	60	=	cubic feet/hour
1 torr = 1 mmHg @ 0°C = 0.0013157895 atmosphere				
LB/hour	x	6.0533	=	l/minute
inch	x	25.4	=	mm
C° = 5/9 (F-32°)				
F° = 9/5C° + 32				

9-4 Values for the Molecular Correction Factor

Gas Type	Examples	Correction Factor
Monotamic gases	argon, helium, xenon	1.01
Diatomic gases	carbon monoxide, nitrogen, oxygen, nitric oxide	1.00
Triamtomic gases	carbon dioxide, nitrous oxide, sulfur dioxide	0.94
Polyatomic gases	ammonia, arsine, diborane, ethane, methane, phosphine	0.88

Note: Standard pressure is defined as 760mmHg (14.7 psig).
Standard temperature is defined as 0°C.

9-5 Applicable Documents

- PS-1033, Calibration Procedure for MFC's & MFM
- PS-1042 & PS-1183, Bypass Selection Charts

Sources of Data

- Matheson Gas Data Book; Braker, William & Mossman, Allen.; 6th edition 1980
- Janaf Thermochemical Tables; Chase, M.W., et.al.;3rd edition 1985
- Lange's Handbook of Chemistry; 13th edition; Dean, John A.; McGraw Hill 1985
- Touloukian, Y.S. et.al.; Viscosity, Nonmetallic Liquids & Gases, IFI/Plenum Data Corp., 1975
- Handbook of Chemistry & Physics; 70th edition; CRC Press, 1989-90
- Touloukian, Y. S. et. al.; Thermal Conductivity, Nonmetallic Liquids & Gases, IFI/Phenum Data Corp., 1975
- Chemical Resistance Chart, DuPont, E-88462
- Fluid Resistance of Viton, DuPont 2/89, E-52084-2
- Fluid Compatibility of Greene, Tweed Chemraz
- Gask-O-Seal Handbook, Parker Seal Group, 1986
- Technical Information for the Semiconductor Industry, DuPont, Kalrez, date unknown, E-86438
- Kalrez Chemical Resistance & Fluid Compatibility, DuPont, 9/93, E-42-789-2
- Viton Engineering Properties Manual, Chapter 2
- Calculated from Experimental Data
- Schumacher Trans-LC data Sheet 5

9-6 Conversion Factors Table

Code	Gas	Symbol	Cal Test Gas	Conversion Factor Cal Test Gas	N2	Dynamic Response Test Gas	Specific Heat @ 25°C Cp(cal/g°C)	Density	Suggested Seal Material	STD Cal Press (PSID)
25	Acetylene	C2H2	C2H4	0.973	0.581	C2H4	0.4049	1.1620	V	10 to 40
1	Air		N2	1.006	1.006	N2	0.2389	1.2930	V	10 to 40
32	Allene (Propadlene)	C3H4	C2H6	0.877	0.421	Ar	0.3633	1.7870	V	10 to 40
125	Ammonia	NH3	N2O	1.014	0.719	N2	0.5005	0.7600	N	10 to 40
2	Argon	Ar	Ar	1.000	1.415	Ar	0.1245	1.7820	V	10 to 40
4	Arsine	AsH3	N2O	0.949	0.673	N2O	0.1168	3.4780	V	10 to 40
7	Boron Tribromide	BBr3	C2H6	0.787	0.378	SF6	0.0647	11.1800	KZ	3 to 12
8	Boron Tricloride	BC13	C2H6	0.895	0.430	SF6	0.1217	5.2270	KZ	3 to 12
9	Boron Trifluoride	BF3	C2H6	1.057	0.508	N2O	0.1779	3.0250	KZ	10 to 40
10	Bromine	Br2	N2O	1.140	0.808	SF6	0.0539	7.1300	V	10 to 40
12	Bromine Pentafluoride	BrF5	SF6	0.956	0.253	SF6	0.1387	7.8030	KZ	3 to 12
11	Bromine Trifluoride	BrF3	C2H6	0.802	0.385	SF6	0.1162	6.1080	KZ	10 to 40
74	Bromotrifluoromethane (Freon-13B1)	CBrF3	SF6	1.399	0.370	SF6	0.1113	6.6440	V	3 to 12
63	1.3-Butadiene	C4H6	SF6	1.181	0.312	N2O	0.3632	2.4130	V	6 to 24
61	n-Butane	n-C4H10	SF6	0.966	0.255	N2O	0.4130	2.5930	V	6 to 24
67	1-Butene	C4H8	SF6	1.110	0.294	N2O	0.3723	2.5030	V	10 to 40
161	2-Butene CIS	C4H8	SF6	1.070	0.283	N2O	0.3863	2.5030	V	6 to 24
162	2-Butene TRANS	C4H8	SF6	1.187	0.314	N2O	0.3483	2.5030	V	6 to 24
93	Carbon Dioxide	CO2	N2O	1.040	0.737	N2O	0.2017	1.9640	V	10 to 40
97	Carbon Disulfide	CS2	C2H4	1.003	0.600	N2O	0.1434	3.3970	V	10 to 40
92	Carbon Monoxide	CO	N2	1.000	1.000	N2	0.2488	1.2500	V	10 to 40
77	CarbonTetrachloride	CCl4	SF6	1.163	0.307	SF6	0.1297	6.8600	V	3 to 12
79	Carbon Tetrafluoride (Freon-14)	CF4	CF4	1.000	0.428	CF4	0.1659	3.9260	V	10 to 40
95	Carbonyl Fluoride	COF2	C2H4	0.908	0.542	N2O	0.1712	2.9450		10 to 40
96	Carbonyl Sulfide	COS	N2O	0.931	0.660	N2O	0.1652	2.6800		10 to 40
13	Chlorine	Cl2	N2O	1.210	0.858	N2O	0.1145	3.1630	V	10 to 40
91	Chlorine Trifluoride	ClF3	C2H6	0.835	0.401	N2O	0.1651	4.1250	KZ	3 to 12
89	Chlorodifluoromethane (Freon-22)	CHClF2	C2H6	0.934	0.449	N2O	0.1580	3.8580	KZ	10 to 40
88	Chloroform	CHCl3	C2H6	0.816	0.392	SF6	0.1310	5.3260	V	3 to 12
22	Chloropentafluoroethane (Freon-115)	C2ClF5	SF6	0.915	0.242	SF6	0.1640	6.8959	V	10 to 40
78	Chlorotrifluormenthane (Freon-13)	CClF3	SF6	1.243	0.329	SF6	0.1786	4.6600	V	10 to 40
42	Cyanogen	C2N2	C2H6	0.940	0.452	N2O	0.2608	2.3220	V	10 to 40
16	Cyanogen Chloride	ClCN	C2H4	1.012	0.605	N2O	0.1762	2.7420	V	10 to 40
48	Cyclopropane	C3H6	C2H6	0.927	0.445	N2O	0.3272	1.8770	V	10 to 40
98	Deuterium*	D2	N2	0.998	0.998	He	1.7325	0.1798	V	10 to 40
5	Diborane	B2H6	C2H6	0.918	0.441	N2	0.5020	1.2350	V	10 to 40
163	Dibromodifluoromethane	CBr2F2	SF6	1.210	0.320	SF6	0.0913	9.3620	V	3 to 12
164	Dibromomethane	CH2Br2	C2H6	0.978	0.470	SF6	0.0750	7.7600	V	10 to 40
75	Dichlorodifluoromethane (Freon-12)	CCl2F2	SF6	1.339	0.354	SF6	0.1432	5.3950	V	10 to 40
87	Dichlorofluoromethane (Freon-21)	CHCl2F	C2H6	0.875	0.420	SF6	0.1417	4.5920	V	10 to 40
165	Dichloromethylsilane	(CH3)2SiCl2	SF6	0.955	0.252	SF6	0.1882	5.7580	KZ	3 to 12
143	Dichlorosilane	SiH2Cl2	C2H6	0.858	0.412	SF6	0.1472	4.5060	KZ	3 to 12
20	1,2-Dichlorotetrafluoroethane (Freon-114)	C2CL2F4	SF6	0.858	0.227	SF6	0.1581	7.6260	V	10 to 40
166	Trans 1,2-Dichloroethylene	C2H2Cl2	SF6	0.885	0.234	SF6	0.2700	4.3280	V	10 to 40
167	Difluoromethane	CH2F2	C2H4	1.000	0.060	C2H4	0.1971	2.3210	V	10 to 40
26	1,1-Difluoroethylene	C2H2F2	C2H6	0.887	0.426	N2O	0.2245	2.8570	V	10 to 40
144	Dimethylamine	(CH3)2NH	C2H6	1.346	0.356	N2O	0.3822	2.0110	KZ	3 to 12
168	Dimethyl Cadmium	(CH3)2Cd	SF6	0.736	0.194	SF6	0.2211	6.3607		
38	Dimethyl Ether	(CH3)2O	C2H6	0.812	0.390	N2O	0.3411	2.0550	KZ	10 to 40
70	2,2-Dimethylpropane	C5H12	SF6	0.821	0.217	N2O	0.3918	3.2190	V	3 to 12
140	Disilane	Si2H6	SF6	1.200	0.317	N20	0.3105	2.7760	V	10 to 40
37	Ethane	C2H6	C2H6	1.000	0.481	C2H6	0.4241	1.3420	V	10 to 40
36	Ethanol	C2H6O	C2H6	0.815	0.392	N2O	0.3398	2.0550	V	3 to 12
64	Ethyl Acetylene (1-Butyne)	C4H6	SF6	1.220	0.322	N2O	0.3515	2.4130	V	3 to 12

Code	Gas	Symbol	Cal Test Gas	Conversion Factor Cal Test Gas	N2	Dynamic Response Test Gas	Specific Heat @25°C Cp(cal/g°C)	Density	Suggested Seal Material	STD Cal Press (PSID)
169	Ethylamine	C2H5NH2	SF6	1.335	0.353	N2O	0.3854	2.0110	V	10 to 40
35	Ethyl Chloride	C2H5Cl	SF6	1.475	0.390	N2O	0.2436	2.8790	V	3 to 12
31	Ethylene	C2H4	C2H4	1.000	0.598	C2H4	0.3658	1.2510	V	10 to 40
34	Ethylene Oxide	C2H4O	C2H6	1.114	0.535	N2O	0.2601	1.9650	KZ	3 to 12
99	Fluorine	F2	N2	0.931	0.931	Ar	0.1970	1.6950	V	10 to 40
90	Fluroform (Freon-23)	CHF3	C2H6	1.045	0.502	N2O	0.1742	3.1270	V	10 to 40
170	Freon-11	CCl3F	SF6	1.163	0.307	SF6	0.1452	6.1290	V	3 to 12
171	Freon-12	CCl2F2	SF6	1.339	0.354	SF6	0.1432	5.3950	V	10 to 40
172	Freon-13	CClF3	SF6	1.243	0.329	SF6	0.1786	4.6600	V	10 to 40
173	Freon-13B1	CBrF3	SF6	1.044	0.370	SF6	0.1113	6.6440	V	10 to 40
174	Freon-14	CF4	CF4	1.000	0.428	CF4	0.1659	3.9260	V	10 to 40
175	Freon-21	CHCl2F	C2H6	0.875	0.420	SF6	0.1417	4.5920	KZ	3 to 12
176	Freon-22	CHClF2	C2H6	0.934	0.449	N2O	0.1580	3.8580	KZ	10 to 40
177	Freon-113	CCl2FCClF2	SF6	0.858	0.227	SF6	0.1442	8.3600	V	3 to 12
178	Freon-114	C2Cl2F4	SF6	0.858	0.227	SF6	0.1581	7.6260	V	6 to 24
179	Freon-115	C2ClF5	SF6	0.915	0.242	SF6	0.1640	6.8959	V	10 to 40
180	Freon-C318	C4F8	SF6	0.610	0.161	SF6	0.2021	8.3970	V	3 to 12
181	Freon-152A	C2H4F2	SF6	1.430	0.377	SF6	0.0570	12.6800	N	10 to 40
104	Germane	GeH4	C2H4	0.953	0.569	N2O	0.1405	3.4180	V	10 to 40
102	Germanium Tetrachloride	GeCl4	SF6	1.009	0.267	SF6	0.1072	9.5650	V	3 to 12
182	Hexamethyl Disiloxane	(CH3)3Si-O-Si(CH3)3	SF6	0.312	0.082	SF6	0.4600	7.2500	KZ	1 to 5
112	Helium*	He	He	1.000	1.415	He	1.2418	0.1786	V	10 to 40
24	Hexafluoroethane (Freon-116)	C2F6	SF6	**0.942	0.241	SF6	0.1844	6.1570	KZ	10 to 40
71	n-Hexane	C6H14	SF6	0.678	0.179	N2O	0.3971	3.8450	V	3 to 12
105	Hydrogen*	H2	H2	1.000	1.010	H2	3.4224	0.0899	V	10 to 40
109	Hydrogen Bromide	HBr	N2	1.000	1.000	N2O	0.0861	3.6100	KZ	10 to 40
110	Hydrogen Chloride	HCl	N2	1.000	1.000	N2O	0.1911	1.6270	KZ	10 to 40
111	Hydrogen Cyanide	HCN	N2O	1.077	0.764	N2	0.3172	1.2060	KZ	10 to 40
113	Hydrogen Fluoride	HF	N2	1.000	1.000	N2	0.3482	0.8930	KZ	3 to 12
114	Hydrogen Iodide	HI	N2	0.999	0.999	SF6	0.0545	5.7070	KZ	10 to 40
108	Hydrogen Selenide	H2Se	N2O	1.112	0.788	N2O	0.1026	3.6130	KZ	10 to 40
107	Hydrogen Sulfide	H2S	N2O	1.190	0.844	Ar	0.2278	1.5200	KZ	10 to 40
115	Iodine Pentafluoride	IF5	SF6	0.943	0.249	SF6	0.1109	9.9000	KZ	3 to 12
66	Isobutane	CH(CH3)3	SF6	0.997	0.264	N2O	0.3998	2.5950	V	6 to 24
183	Isobutylene	C4H6	SF6	1.081	0.288	N2O	0.3824	2.5030	V	6 to 24
184	Isopropanol	C3H7OH	SF6	1.093	0.289	N2O	0.3529	2.6830	V	3 to 12
116	Krypton	Kr	Ar	1.000	1.415	SF6	0.0593	3.7390	V	10 to 40
84	Methane	CH4	N2O	1.014	0.719	N2	0.5318	0.7150	V	10 to 40
185	Methanol	CH3OH	C2H4	0.977	0.584	C2H6	0.3277	1.4290	V	10 to 40
46	Methylacetylene (Propyne)	C3H4	C2H6	0.867	0.417	Ar	0.3672	1.7870	V	10 to 40
186	Methylamine	CH3NH2	C2H6	1.065	0.512	C2H6	0.3856	1.3860	KZ	10 to 40
81	Methyl Bromide	CH3Br	C2H4	0.953	0.569	N2O	0.1134	4.2360	KZ	6 to 24
80	Methyl Chloride	CH3Cl	C2H4	1.053	0.629	N2O	0.1929	2.2530	V	10 to 40
82	Methyl Fluoride	CH3F	N2O	0.964	0.684	C2H6	0.2636	1.5180	V	10 to 40
83	Methyl Mercaptan	CH3SH	C2H6	1.118	0.502	N2O	0.2541	2.1460	V	6 to 24
187	Methyl Trichlorosilane	(CH3)SiCl3	SF6	0.947	0.250	SF6	0.1638	6.6690	KZ	3 to 12
117	Molybdenum Hexafluoride	MoF6	SF6	0.571	0.151	SF6	0.1933	9.3719	KZ	3 to 12
123	Neon	Ne	Ar	1.000	1.415	N2	0.2464	0.9000	V	10 to 40
127	Nitric Oxide	NO	N2	0.976	0.976	N2	0.2378	1.3390	V	10 to 40
118	Nitrogen	N2	N2	1.000	1.000	N2	0.2486	1.2500	V	10 to 40
128	Nitrogen Dioxide	NO2	N2O	1.044	0.741	N2O	0.1923	2.0520	KZ	10 to 40
124	Nitrogen Trifluoride	NF3	C2H6	0.999	0.480	N2O	0.1798	3.1680	V	10 to 40
119	Nitrogen Trioxide	N2O3	C2H6	0.813	0.391	N2O	0.2063	3.3930	V	10 to 40
129	Nitrosyl Chloride	NOCl	C2H4	1.027	0.614	N2O	0.1629	2.9200	V	10 to 40
122	Nitrous Oxide	N2O	N2O	1.000	0.709	N2O	0.2098	1.9640	V	10 to 40
60	Octafluorocyclobutane (Freon-C318)	C4F8	SF6	0.610	0.161	SF6	0.1899	8.9370	V	10 to 40
130	Oxygen	O2	N2	0.992	0.992	N2	0.2196	1.4270	V	10 to 40
132	Oxygen Difluoride	OF2	C2H4	1.058	0.632	N2O	0.1918	2.4090	KZ	10 to 40
131	Ozone	O3	N2O	0.984	0.698	N2O	0.1954	2.1428	V	10 to 40
6	Pentaborane	B5H9	SF6	1.034	0.273	N2O	0.3555	2.8160	V	3 to 12
188	Pentafluoroethane	C2HF5	SF6	1.000	0.264	SF6	0.1933	5.3590	V	3 to 12
189	n-Pentane	n-C5H12	SF6	0.807	0.213	N2O	0.3984	3.2190	V	3 to 12
17	Perchloryl Fluoride	ClO3F	C2H6	0.822	0.395	SF6	0.1515	4.5710	V	10 to 40

Code	Gas	Symbol	Cal Test Gas	Conversion Factor Cal Test Gas	N2	Dynamic Response Test Gas	Specific Heat @25°C Cp(cal/g°C)	Density	Suggested Seal Material	STD Cal Press (PSID)
44	Perfluoropropane	C3F8	SF6	0.635	0.168	SF6	0.1944	8.3880	V	10 to 40
94	Phosgene	COCl2	C2H6	0.925	0.444	SF2	0.1393	4.4180	V	3 to 12
135	Phosphine	PH3	N2O	0.974	0.691	C2H6	0.2610	1.5170	V	10 to 40
136	Phosphorous Oxychloride	POCl	SF6	1.142	0.302	SF6	0.1324	6.8452	V	3 to 12
134	Phosphorous Pentafluoride	PF5	SF6	1.143	0.302	SF6	0.1611	5.6200	KZ	10 to 40
133	Phosphorous Tribromide	PBr3	SF6	1.275	0.337	SF6	0.0671	12.0842	V	3 to 12
190	Phosphorous Trichloride	PCl3	SF6	1.355	0.358	SF6	0.1247	6.1270	V	3 to 12
50	Propane	C3H8	C2H6	0.723	0.348	C2H6	0.3991	1.9670	V	10 to 40
47	Propylene	C3H6	C2H6	0.829	0.398	N2O	0.3659	1.8770	V	10 to 40
145	Silane	SiH4	C2H4	1.001	0.599	C2H4	0.3189	1.4330	V	10 to 40
141	Silicon Tetrachloride	SiCl4	SF6	1.074	0.284	SF6	0.1270	7.5847	KZ	3 to 12
142	Silicon Tetrafluoride	SiF4	SF6	1.317	0.348	SF6	0.1692	4.6430	KZ	10 to 40
148	Sulfur Dioxide	SO2	N2O	0.968	0.687	N2O	0.1489	2.8580	V	10 to 40
139	Sulfur Hexafluoride	SF6	SF6	1.000	0.264	SF6	0.1588	6.5160	V	10 to 40
138	Sulfur Tetrafluoride	SF4	SF6	1.250	0.330	SF6	0.1717	4.8210	KZ	10 to 40
149	Sulfuryl Fluoride	SO2F2	C2H6	0.808	0.388	SF6	0.1545	4.5620	V	3 to 12
73	Tetraethoxysilane (TEOS)	Si(OC2H5)4	SF6	0.295	0.078	SF6	0.3770	9.3004	KZ	1 to 5
191	Tetrafluorahydrazine	N2F4	SF6	1.225	0.324	CCl2f2	0.1821	4.6400	V	3 to 12
192	Tetrafluorethane (F134A)	C2H2F4	SF6	1.090	0.288	SF6	0.2088	4.5540	V	3 to 12
159	1,3,5,7-Tetramethylcyclotetrasiloxane (TMCTS)	(-HSi(CH3)O-)4	SF6			SF6		10.7366	KZ	1 to 5
150	Titanium Tetrachloride	TiCl4	SF6	0.778	0.206	SF6	0.1572	8.4650	V	10 to 40
28	Trichlorethane (TCA)	C2H3Cl3	SF6	1.051	0.278	SF6	0.1654	5.9500	V	10 to 40
193	Trichloroethylene (TCE)	C2HCl3	SF6	1.210	0.320	SF6	0.1459	5.8620	V	10 to 40
76	Trichlorofluoromethane (Freon 11)	CCl3F	SF6	1.163	0.307	SF6	0.1452	6.1290	V	10 to 40
146	Trichlorosilane	SiHCl3	SF6	1.285	0.340	SF6	0.1332	6.0430	KZ	3 to 12
21	Trichloro-Trifluoroethane (Freon-113)	CCl2FCClF2	SF6	0.858	0.227	SF6	0.1442	8.3600	V	3 to 12
194	Trilsobutyl Aluminum	(C4H9)3Al	SF6	0.230	0.061	SF6	0.5080	8.8480	V	3 to 12
56	Trimethylamine	(CH3)3N	SF6	1.055	0.279	N2O	0.3717	2.6390	V	6 to 24
195	Trimethylborate (TMB)	Br(OCH3)3	SF6	0.769	0.203	SF2	0.2900	4.6388	V	1 to 5
58	Trimethylphosphite (TMP)	P(OCH3)3	SF6	0.599	0.158	SF2	0.3116	5.5393	V	1 to 5
196	Tritium*	T2	N2	0.986	0.986	He	1.1709	0.2693		10 to 40
152	Tungsten Hexafluoride	WF6	SF6	0.815	0.215	SF6	0.0956	13.2900	KZ	3 to 12
151	Uranium Hexafluoride	UF6	SF6	0.748	0.198	SF6	0.0881	15.7000	KZ	3 to 12
27	Vinyl Bromide	CH2CHBr	C2H6	0.960	0.462	SF2	0.1242	4.7720	V	10 to 40
30	Vinyl Chloride	CH2CHCl	C2H6	0.995	0.478	N2O	0.2052	2.7880	V	10 to 40
106	Water Vapor	H2O	N2	**0.876	0.876	N2	0.4485	0.8040	V	3 to 12
153	Xenon	Xe	Ar	1.000	1.415	SF2	0.0379	5.8580	V	10 to 40

Note:
Converstion of controller to or from thse gases may alter dynamic response or stability.
In accordance with Semiconductor Equipment and Materials Institute Standard E12-91, Standard Pressure and Temperature are defined as 101.325 kPa (760mm Hg) and 0°C respectively.

1. Matheson Gas Data Book; Braker, William and Mossman, Allen L.; Sixth Edition, 1980
2. JANAF Thermochemical Tables; Chase, M.W., et. al.; Third Edition, 1985
3. Lange's Handbook of Chemistry, Thirteenth Edition; Dean, John A., McGraw Hill, 1985
4. Touloukian, Y.S., et. al.; Viscosity, Nonmetallic Liquids and Gases, IFI/Plenum Data Corp., 1975
5. Handbook of Chemistry and Physics, 70th Edition, CRC Press, 1989-90

10 APPENDIX B

10-1 Recommended Procedures to Avoid Contamination of Highly Reactive Gas Systems

Gas systems for silane and other highly reactive gases are extremely vulnerable to contamination. When oxygen, water vapor or other gases combine with highly reactive molecules, solid contaminants, such as silicon dioxide, form in the system and can cause numerous problems with measurement and control equipment. These particles can be transported in sub-micron sizes that pass through filters, or, can be formed by reactions in the plumbing downstream of the filter. Although proper use of filters reduces contamination, this potential problem exists throughout the entire system.

The three primary causes of contamination are leaks, impure purge gases, and improper purging procedures. These problems and their solutions are discussed below.

Leaks

Plumbing leaks cannot be tolerated in a pure gas system. It is commonly believed that if a gas line pressure is above that of the ambient, the surrounding atmosphere will be prevented from entering the system. However, for any flow through an orifice or leak path, back diffusion from the surrounding gas (air) takes place into the gas stream. The system can then become contaminated with oxygen or moisture. THEREFORE, AVOID ALL LEAKS. Check the system when new, after replacing any equipment in the plumbing circuit, and on a periodic schedule. A leak detector capable of detecting leaks in the range of less than 1 x 10^{-10}atm cc/sec. of helium, is recommended.

Impure Purging Gases

Before and after a highly reactive gas system has been exposed to air, it is necessary to purge the system with an inert gas, for example, N_2 or Argon with less the 10ppm O_2 and water vapor.

Each time a transition is made from purge gas to process gas or process gas to purge gas, there is mixing of the two gases throughout the plumbing; any oxygen or moisture in the purge gas reacts and can be left behind as contamination. The practice of purging process lines between runs gives two potential mixing events per run, and can cause a cumulative buildup or contamination. With leak-tight plumbing, it is not necessary to remove process gas from the system. Buildup resulting from repetitive purging can be avoided by not purging between runs.

In some installations, process gas is fed into a reaction chamber that can be exposed to air, thereby causing oxidation of residual gas in the gas supply line. As a preventative measure, installation of a shutoff valve in the process line, close to the reaction chamber, is recommended.

Proper Purge Procedure

The most effective method for removing process gases from process tubing is cycle purging. Cycle purging alternates evacuating the gas system and pressurizing the gas system with an inert purge gas. This procedure causes absorbed molecules and trapped gases to be removed much more quickly than straight purging. Contaminants trapped in plumbing dead space and micro cavities can communicate with the process stream to cause virtual leaks. Cycle purging helps to purge these cavities. Although the application of vacuum to the gas system is very effective, a similar procedure can be adapted for atmospheric systems.

Vacuum Systems

The illustration below shows a typical reactive gas flow controller installation.

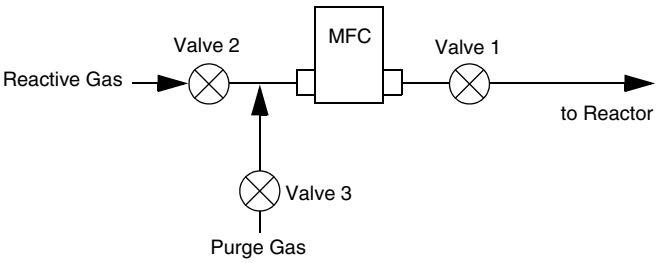


Figure 6: Purge plumbing

To initiate purge procedure:

1. Close Valves 2 and 3, and open Valve 1.
2. Evacuate the line to base pressure.
3. Close Valve 1.
4. Open Valve 3 for one or two minutes to pressurize the controller with purge gas.
5. Close Valve 3 and open Valve 1 to evacuate the controller back down to base pressure.
6. Repeat the alternating application of evacuation and pressurization at least 20 times.
7. When removing the flow controller, pressurize it with the purge gas and then close all 3 valves.

Atmospheric Systems

Although a vacuum pump is highly desirable, a similar procedure can be performed without a pump. An aspirator powered by a high rate of purge gas flow to exhaust can be used to create a subatmospheric pressure in the plumbing system. If an aspirator is not available, cycling between atmospheric pressure and purge gas line pressure is better than simply flowing purge gas. Pressurize and depressurize the controller for about 5 minutes, and repeat the procedure at least 40 times, rather than the 20 used for vacuum systems.

⚠ CAUTION ⚠
When highly reactive gases are being evacuated by pumping, the pump should contain a nitrogen blanket above the oil level to dilute the gases and prevent air from being absorbed into the pump. Take extreme precautions to dispose of any un-reacted process gas. CONSULT YOU PLANT SAFETY ENGINEER.

11 APPENDIX C

11-1 FC2900 Series Auto-Zero Feature

What it is

How it works

How to use it

An automatic re-zeroing circuit is a standard feature on all FC2900 series mass flow controllers. FC2900 Auto-Zero helps compensate for small changes in electronic components and the environment which result in calibration changes commonly referred to as “drift”.

In most applications, FC2900 Auto-Zero will operate automatically with no change in the plumbing or control system of the process tool. The only requirement is that there is no gas flowing through the MFC during the Auto-Zero procedure. Because this action also ensures that the MFC will start without overshoot when gas flow begins, it does not represent an additional control requirement.

Why Auto-Zero Is Useful

Millipore has developed the most stable flow sensor technology currently available in the marketplace. Our products routinely come out on top in competitive evaluations of MFC stability. Nevertheless, no sensor is absolutely stable. In critical applications, even a few tenths of a percent drift between MFC re-calibrations may be objectionable.

FC2900 Auto-Zero adds one more level of stability enhancement to answer this requirement. In less demanding applications, using a FC2900 series MFC may still improve process control due to the more consistent, repeatable flows they produce. Users may also find that equipment stays in spec longer so that downtime for re-calibration is reduced.

FC2900 Auto-Zeroing also cancels out several small environmental effects on the MFC. Like all Millipore MFC’s, the FC2900s can be considered essentially insensitive to mounting attitude, exhibiting a zero shift of less than 0.1 percent with any change in mounting position. Even these small changes can be cancelled out with FC2900 Auto-Zero, which will resolve errors as small as 0.05%.

FC2900 MFCs also have enhanced temperature stability which, by itself, reduces the effects of ambient temperature change. A 10°C change in ambient temperature will affect MFC zero less than 0.5%. FC2900 Auto-Zero can cancel this residual effect as well.

What Auto-Zero Cannot Do

MFCs can be affected in ways which change their full scale sensitivity, or span calibration, independently from zero calibration. An example of such a phenomenon is contamination or corrosion of the internal components of the MFC. FC2900 Auto-Zero cannot completely compensate for these effects because they do not necessarily involve any zero error. Fortunately, in the FC2900 series, most span effects have been stabilized or compensated. FC2900 Auto-Zero provides significant improvements in the remaining zero effects which by their nature are larger in magnitude.

How Auto-Zero Works

In normal operation the electrical output of the mass flowmeter which is part of every MFC will slowly drift away from its calibrated setting. After some time, this output will no longer be zero volts under no-flow conditions. When this happens, the entire calibration of the MFC is shifted by a constant inversely equivalent to the shift in the zero point. For example, if the flowmeter zero were to drift high by 1% (50 mV) a setpoint of 50% would produce a 49% flow. Adjusting the flowmeter back to a zero output in the absence of flow shifts the entire range back into calibration. FC2900 Auto-Zero performs these corrections automatically, without the need for removing the cover and manually adjusting the zero potentiometer.

FC2900 Auto-Zeroing is an intermittent process which is triggered by the equipment process control system under conditions where there should be no gas flow through the MFC. The process starts after the setpoint to the MFC has been commanded to less than 1% for 80 seconds or more. The actual zeroing process takes about 2-1/2 seconds and repeats itself every 80 seconds as long as the triggering condition continues to be met. This continuous re-zeroing prevents drift in the zero point over long idle periods. In short-cycle processes where a gas loop may not be inactive for the 80 or 90 seconds which Auto-Zero requires, Auto-Zeroing may only occur at some interruption in the process cycle such as during the changing of cassettes.

The FC2900 Auto-Zero circuit looks at any net error which remains in the zero signal after previous corrections and creates a correction voltage which, when fed back to the flowmeter, cancels the error. The magnitude of this correction voltage is stored as a digital number. As the correction is stored digitally, it does not drift or change with time as would an analog value stored in a capacitor.

FC2900 Auto-Zero has a total correction range of 5% or ±2.5% with a resolution of ±0.05%. This correction is non-cumulative. It cannot offset the real or “natural” zero of the MFC by more than 5%. Successive zero corrections cannot accumulate.

This correction range is intentionally restricted. The flow sensor in the FC2900 is very stable by design and zero errors which fall outside the correction range can indicate a damaged MFC. Apparent zero errors caused by shutoff valve leaks will often be greater in magnitude than the correction range and are thereby also more readily detectable by the process control system.

FC2900 Auto-Zero Memory

The FC2900 Auto-Zero stores the Auto-Zero memory value in non-volatile EEROM. Upon power-up, the value in EEROM is transferred to the active Auto-Zero circuit. This protects your process from otherwise undetectable “drifts” that can be caused by power failures or other power interruptions.

Momentarily connecting Pin K to common stores the current Auto-Zero offset in non-volatile memory. For

maximum benefit EEROM memory should be updated in this way on a periodic basis. Consult your Millipore process engineer for details.

⚠ CAUTION ⚠
PIN K IS DESIGNATED PIN I ON UNIT® INSTRUMENT PRODUCTS. SEE NOTE BELOW.

Ensuring No Flow When Auto-Zeroing

You must ensure that there is NO-flow of gas through the device when adjusting the Auto-Zero. The FC2900 is very sensitive and may respond to room air currents if operated on a service bench without end caps. In a gas system, shutoff valves in series with the MFC should be used to ensure that gas does not flow when the gas loop is off.

Even in the presence of both up and downstream shutoff valves, it is possible for gas to flow through the MFC for some time after the shutoff valves have been closed. Gas can flow as long as there is a pressure difference across the MFC. This is an especially common problem in vacuum systems where flow rates are low. Some variation of the following control sequence can help in these cases:

1. Close the upstream gas valve and set the MFC for its maximum flow rate.
2. Pump the MFC and its plumbing to vacuum.
3. When evacuation of the system has been confirmed by measuring a very low flow value for some period of time, close the downstream shut-off valve. Wait again to ensure that any remaining pressure differential across the MFC has had the opportunity to discharge. Any non-zero reading from the MFC flow output at this point should be due to zero error or shutoff valve leakage.
4. Initiate the Auto-Zero process by taking the MFC setpoint to zero or by connecting pin L to common. The control valve will close. If no shutoff valve leakage exists, the flow output reading should not change. The FC2900 will recompute its zero setting after 80 seconds.

The normal rate of zero drift is low enough that run-to-run zeroing is not required in most cases. Consequently, the above sequence can be run as part of a regular weekly maintenance routine. Auto-Zero memory can be updated as part of the same procedure. As noted below, Auto-Zero operation which would normally take place at other times can be inhibited by using Pin J.

No mass flow controller, including the FC2900, should be absolutely relied upon to be a positive shut off device. The FC2900 control valve with elastomeric poppet has been tested to shut off positively after over a million operations. Nevertheless, there are fundamental differences in the design of proportional control valves and shutoff valves such as those manufactured by Nupro®, Parker or Fujikin®.

The forces available to hold the valve poppet closed against the seat of a proportional control valve are much lower than those in a shutoff valve. The possibility that small leaks will develop as the valve materials age cannot be discounted. The direct effect of such a leak in the process may be undetectable. It may be their effect on the Auto-Zeroing process that brings them to attention. Consequently, Auto-Zeroing conditions should not rely on the seal of the MFC control valve for maximum system robustness and reliability.

Confirming Auto-Zero Operation

When the MFC actually Auto-Zeros, connector pin J goes high. This state lasts approximately 2.5 seconds. This signal can be used to alert a process controller that the MFC is Auto-Zeroing or it can be tied into an LED, giving a visual display of MFC Auto-Zeroing. It should be noted that Pin J functions as both an input and an output. Connecting the pin to common will inhibit Auto-Zero updating as discussed below.

Figure 6 shows the output configuration on Pin J and an example of how to drive an LED which will illuminate while the controller current is Auto-Zeroing. Note that the pin will not source enough in the high state to drive an LED directly. Within the FC2900, Pin J is pulled up to +5V through 10K. It is normally driven to common by a transistor. During the Auto-Zeroing process, the transistor turns off. The transistor will sink 500mA. Pin J must reach at least 2.8V for the Auto-Zeroing process to proceed.

⚠ CAUTION ⚠
PIN J IS DESIGNATED PIN H ON UNIT® INSTRUMENT PRODUCTS.

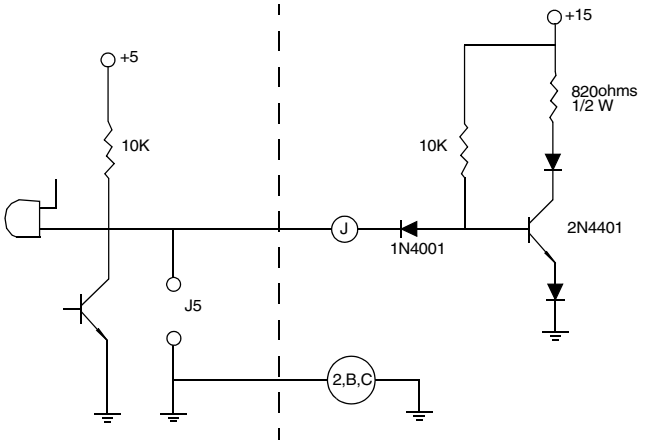


Figure 7: Auto-Zero pinouts

PC board jumper J2:
Removing this jumper disables the effect of the Auto-Zero circuit and permits the uncorrected “natural zero” of the flowmeter to be observed and adjusted if desired.

Connecting Pin J to common disables Auto-Zero updating. The current correction value stored will still be used to zero the MFC, but will not be recomputed under ordinary triggering conditions. This feature can be used to bring Auto-Zeroing under additional user control. For example, it may be desirable to re-zero only at routine maintenance intervals where some special condition can be set up. Such a condition might involve the closing of manual valves of the complete evacuation of the gas system to ensure that a no-flow condition exists when zero is recomputed. By linking this pin to a switch on an air actuated valve, the user can also prevent the MFC from Auto-Zeroing if the valve sticks open.

⚠ CAUTION ⚠
PIN J IS DESIGNATED PIN H ON UNIT® INSTRUMENT PRODUCTS. SEE NOTE BELOW.

⚠ CAUTION ⚠
THE SAME MFC PINS ARE NOT DESIGNATED THE SAME WAY BY ALL MANUFACTURES.

The 10 position bifurcated edge connector originally introduced by Millipore and currently used on many mass flow products references pins by numbers along one edge and letters along the other. Millipore, following the common practice of connector manufacturers, does not use the letters “G” and “I” in its pinout designations because they are too easily confused with “6” and “1” when molded almost illegibly into a plastic connector. Another manufacturer, Unit Instruments, does not follow this procedure. This can lead to confusion. The system is as follows:

Numbered side of connector	1	2	3	4	5	6	7	8	9	10
Lettered side of connector:										
Industry Standard (Millipore)	A	B	C	D	E	F	H	J	K	L
Unit Instruments	A	B	C	D	E	F	G	H	I	J

The difference is in the last four positions on the lettered side. The functions commonly found on these pins are as follows:

Function	Millipore Pin	Unit Pin	Function
Keyway	H	G	Keyway
Auto-Zero output/disable	J	H	none
Auto-Zero memory store	K	I	none
Valve OFF/Auto-Zero trigger	L	J	Valve OFF

As can be seen, the pin letters may be different but the same functions appear in the same position. The Millipore FC2900 can therefore be used with confidence to upgrade a Unit flow controller, although the advanced Auto-Zero feature pins found on the FC2900 will not necessarily be available in the Unit cable as-wired.

12 Returning Products for Service

Products requiring service may be shipped to any one of our Service Centers located worldwide. Repaired products are typically returned within 5 working days. Emergency service is also available. For more information, please contact the service center nearest you.

When returning mass flow products for service, please be sure to specify the type of service required, the product’s failure mode, return shipment information, a purchase order to cover non-warranty charges and the name and telephone number of a person to contact if questions should arise.

In addition, **you must complete** an appropriate Certificate of Non-Hazardous Containment and attach it to the outside of the shipping container of the product being returned. Disclosure of all chemical exposed to the equipment is required by federal common carrier transportation laws. This will help us to protect our personnel and environment, and also help us to determine if special handling is required to process your repair. For example, California Hazardous Communication Regulation (General Industry Safety Orders Sec. 5194 Title 8, California Code CCR Title 22) defines the regulations that must be met for products returned to California, U.S.A. for service. Certificates of Non-Hazardous Contamination vary from state to state, so we recommend that you contact your nearest service center to determine what certificates are required. They can provide you with the specific documents needed to comply with state and federal laws.

Omission of the information or required Non-Hazardous Contamination form may result in a delay in processing your order or return of the material. This information will help us to avoid unnecessary delays in processing your request for service.

Mass Flow Controller/Mass Flow Meter
1 Year Product Warranty

Millipore Corporation warrants its Mass Flow Controllers and Mass Flow Meter products will meet their applicable published specifications when used in accordance with their applicable instructions 1 year from shipment of the products.

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CERTIFICATE OF NON-HAZARDOUS CONTAMINATION

Return Acceptance Policy

In accordance with California Hazard Communication Regulation (General Industry Safety Orders Sec. 5194 Title 8, California Code CCR Title 22, California Hazardous Substances Information and Training Law and Department of Transportation requirements) Millipore requires this Certificate of Non-Hazardous Contamination to be completed for all products received for service or repair. Complete and affix to the outside of the shipping container.

This form must be completed by a person with knowledge of all types of processes in which the equipment has been used. Non-completion of this form will cause delays and possible rejection of your equipment.

Sec. 1

Model _____ Serial Number_____

Has the equipment been used? Y N If Yes, go to section 2
If No, go to section 6

Sec. 2

List all substances, gases or by-products which have come in contact with the equipment.

Chemical/Substance:

_____

_____

_____

Has the equipment been purged on-site? Y N If Yes, go to section 3
If no, go to section 4.

Sec. 3

Substance used in purge/flush process:

_____

Sec. 4

Please attach all required Material Safety Data Sheets (MSDS) for all substances listed in Sec.2. Exposed equipment cannot be transported without the above safety information. Please contact your carrier for more specific instructions.

Sec. 5

The undersigned certifies that the composition of residue on the equipment listed above is of a non-hazardous nature and/or that the equipment has been purged or flushed on-site. All exposed equipment will be cleaned. Millipore reserves the right to reject any equipment based on contamination resulting from exposure to severely toxic substances.

Sec. 6

Signed: _____

Print Name: _____

Title: _____

Company: _____

Telephone: _____

Date of Signature:_____

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