Instruction Manual

FC-280 and FM-380 SERIES MASS FLOW CONTROLLERS and MASS FLOW METERS

Tylan General

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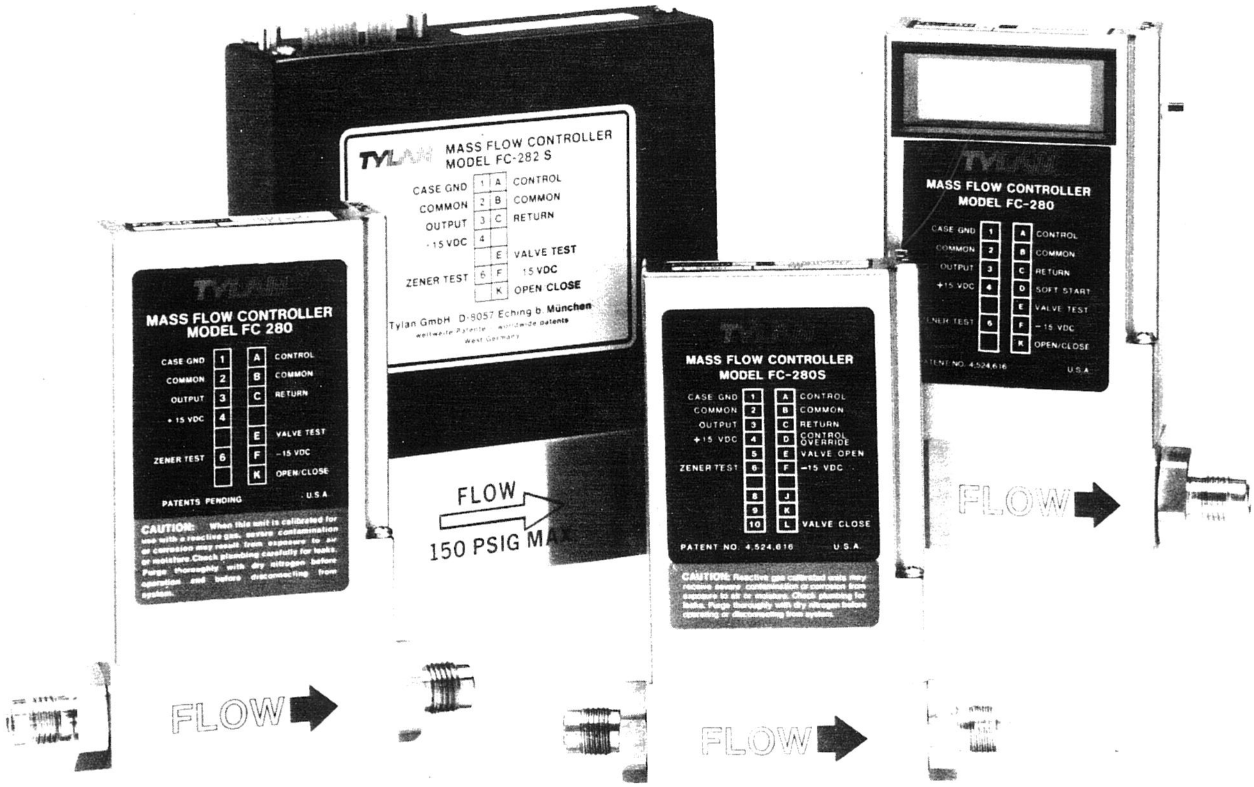

FC-280A, FC-280AD, FC-280SA, FC-282S
MASS FLOW CONTROLLERS

FM-380A, FM-380AD
MASS FLOWMETERS

MAY 1991

Tylan General

A Note to Our Customers

The Tylan General instrument you have just purchased is the finest mass flow controller available. It includes significant advantages in the state-of-the-art as measured against leading competitive instruments. It offers increased stability and inherent linearity, tightly controlled response and maximum applications flexibility. Furthermore, it is backed by the strongest commitment to quality, service and support in the industry.

Should you need additional information concerning your new purchase, please contact Tylan General Customer Service at (213) 212-5512.

We exist to serve your needs. We appreciate your business.

TYLAN GENERAL

WARRANTY

Tylan General warrants that, for a period of one year after shipment, products manufactured by it shall be free from defects in material and workmanship when installed, serviced and operated within the specifications for which they were designed. Tylan General will replace or repair any equipment or parts returned to it provided that investigation and factory inspection discloses that such defect developed under normal and proper use by the original user. Tylan General's liability under this warranty is limited to such replacement or repair and it shall not be held liable in any form of action for incidental or consequential damages to property or person. The foregoing is in lieu of all other warranties, express or implied, including the warranties of merchantability and fitness for particular purpose. Representations and warranties made by any person, including dealers and representatives of seller, which are inconsistent or conflict with the terms of this warranty (including but not limited to limitations of liability as set forth above), shall not be binding upon Tylan General unless reduced to writing and approved by an expressly authorized representative of Tylan General.

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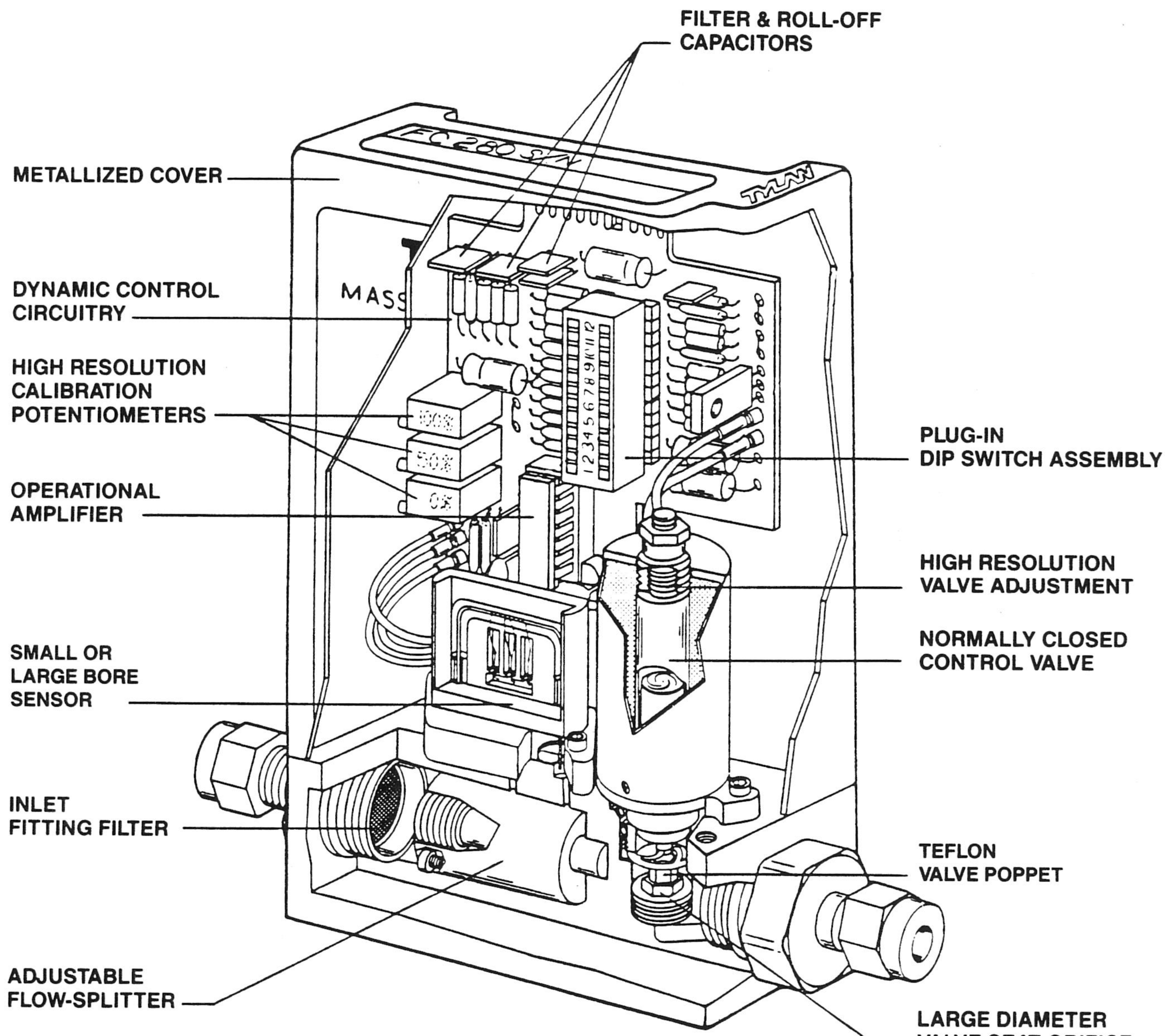

Figure 1
FC-280A Cutaway View

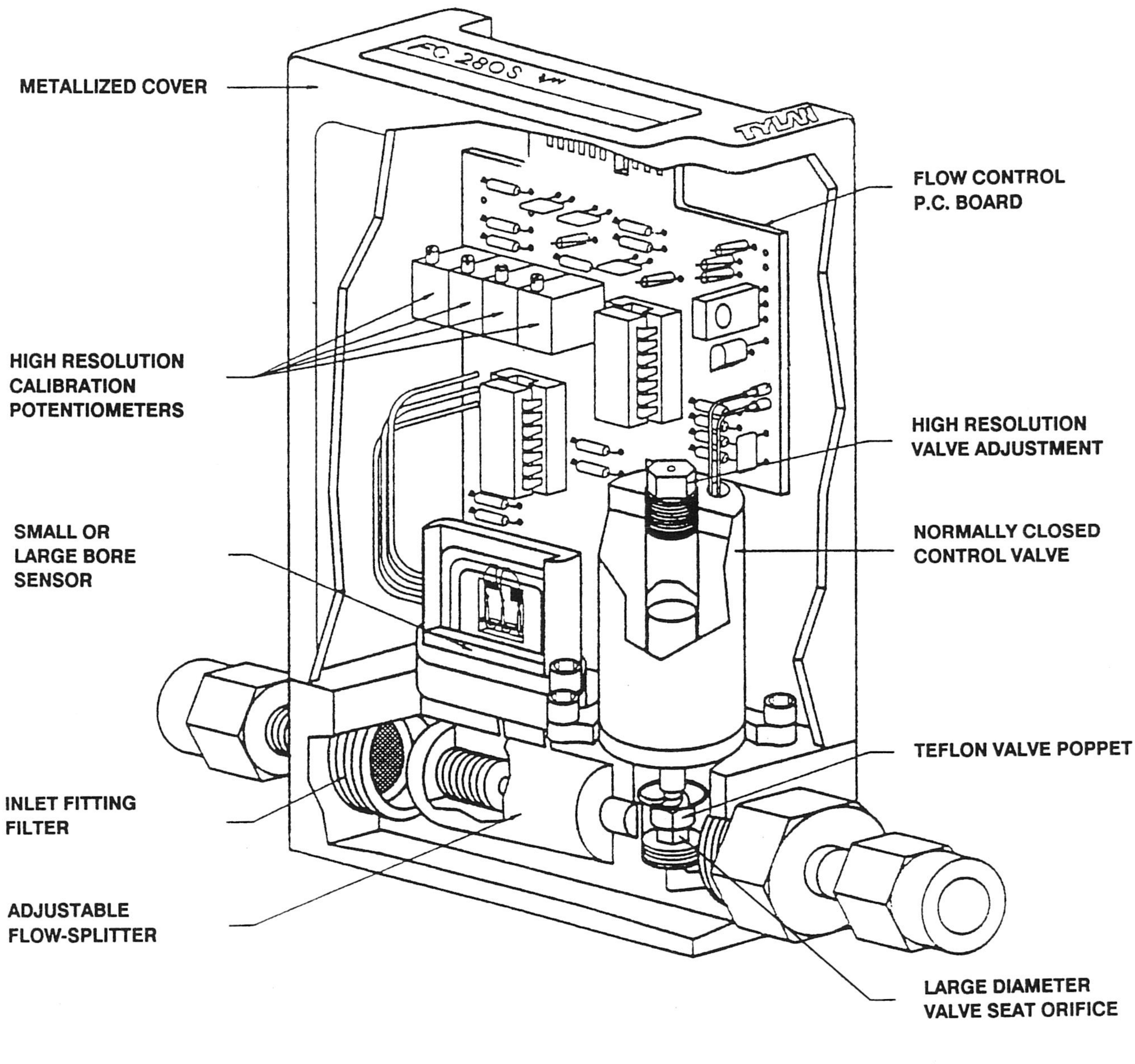

Figure 1A
FC-280SA Cutaway View

GENERAL DESCRIPTION

Tylan General Model FC-280 Series Mass Flow Controllers accurately and reliably measure and control the mass flow rate of gases. They have been specifically designed to allow operation on any gas having a known molar specific heat (ρC_p).

The FC-280 series of mass flow controllers and flowmeters include:

Mass Flow Controllers
Low Flow (10 sccm to 30 slm full-scale)

FC-280A	Fast response of less than 2 seconds
FC-280AD	Integral 3-1/2 digit display
FC-280AJ	4-20 MA input and output
FC-280SA	Ultra-fast response of 400-800 ms
FC-280SA-P	Ultra-fast response with valve drive signal on Pin D

Medium Flow (50 slm to 200 slm full-scale)

FC-282S	3 second response

Mass Flowmeters

FM-380A	10 sccm to 30 slm
FM-380AD	Integral 3-1/2 digit display

The low flow instruments have a user-adjustable range from 10 SCCM to 30 SLM full-scale flow rate. This is accomplished in the flowmeter section by adjusting the bypass. In the controller section, many changes in flow range can be accomplished by an external adjustment of the control valve alone. Very large range changes may involve replacing of the valve orifice.

The instruments operate on ±15.0 VDC power, provide a 0 to 5.0 VDC indicated output signal linearly proportional to the flow rate, are RFI/EMI protected and are both mechanically and electrically interchangeable with the Tylan General FC-260 series flow controllers. The "J" option provides 4-20 MA control and output and is available when specified at time of order. An adaptor fitting is available for interchangeability with the Tylan General FC-261 series instruments. Other inherent design features include:

- Enhanced stability of both zero and span
- Insensitive to mounting position
- Fast response with minimal overshoot
- External electrical valve override
- Normally closed solenoid valve with both mechanical and electrical "purge" capability
- Ease of maintenance

PRINCIPLE OF OPERATION

The flow 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 flow 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

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 ±10 ohms at 20°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.

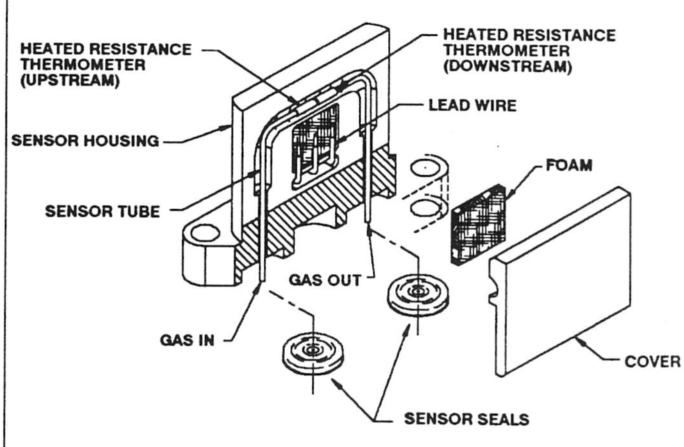

Figure 2 - Flow Sensor

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 operation range. The optional large bore sensor tube is designed for low vapor pressure gas applications where minimal pressure drop is required, but is limited to full scale flow rates of 3 slm or less.

The housing which encases the sensor tube is precisely configured to minimize 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 flow controller response can therefore be dynamically controlled to eliminate overshoot.

Bypass (Flow-splitter)

The FC-280A/FC-280SA/FM-380A 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 tapered flow restrictor concentrically located in the tapered bore of the base. The resulting annular flow path develops the required pressure drop versus flow rate relationship necessary to drive the sensor flow through its full operating range. Axial adjustment of the restrictor in relation to the bore varies the thickness of the annular gap and thus provides a means for continuous adjustment of the full-scale range of the instrument from 10 sccm to 30 slm.

The advantages of this patented configuration are as follows:

- Excellent agreement between actual and theoretical gas conversion factors is achieved, allowing the instrument to be used with any gas by simply varying the electrical gain in direct proportion to the theoretical conversion factor.
- A wide adjustment range is provided within the same instrument eliminating the need for parts replacement in order to change the flow range.
- Accuracy degradation due to contamination build-up is greatly reduced due to the large surface area of the restrictor and bore.
- The restrictor can be easily removed and cleaned during routine maintenance procedures.

The FC-282S bypass consists of a variable area, cylindrical screen bypass which produces the necessary linear pressure drop to drive the sensor through its operating range. This configuration is necessarily different from the annular FC-280A/FC-280SA bypass to accommodate the higher flow rates of the FC-282S.

Valve

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 316 stainless steel. The plunger is 446 stainless steel.

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 316 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 poppet is uniquely designed to provide a relatively constant control range (stroke) for each size of the valve seat. 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.

Electronics

To ensure intrinsically safe operation, the circuit has been designed in accordance with the basic requirements of ISA-RP12.2, in that there is no inductance (except in the solenoid valve itself) and the capacitance values are below the level which will provide enough energy to create a spark under foreseeable fault conditions. The higher capacitance elements are in series with large resistance values, which provide the necessary current limiting protection.

The circuit consists of three interrelated sections: The bridge supply circuit consists of an operational amplifier which supplies the flow sensor bridge with a constant current of 13.0 milliamps as determined by the reference voltage. The bridge current may be increased to the 15.0 milliamp level required for operation with the large bore sensor. Linearity results are fed back from the flowmeter output to alter the bridge current as a function of the output with linearity adjustment potentiometer adjusting the magnitude and sign (positive or negative) of this feedback. This linearity control has its maximum effect at 50% output and little or no effect at 0% and 100% output, resulting in virtually independent zero, gain and linearity adjustments.

The flowmeter amplifier circuit amplifies the bridge output to give a 0 to 5.0 VDC output signal linearly proportional to flow rate. The gain adjustment pot provides a 20% gain adjustment, and the zero adjustment pot provides a ±30% zero adjustment.

The speed-up circuit (FC-280SA/FC-282S only) provides the necessary frequency response correction for the output signal. This results in expanding the sensor cutoff frequency by about one decade, which is equivalent to "speeding-up" the sensor response time. P4 allows for tuning to the original sensor cutoff frequency.

The setpoint signal conditioning circuit limits the speed of setpoint changes. A step change of setpoint is converted to a signal with tapered edges enabling the controller to follow the setpoint without large control deviations at any time.

The controller circuit generates the valve drive signal as a function of output and setpoint signal. First, the control deviation is computed. This signal is then processed by the true P-I-D controller in order to drive the control valve using a transistor. Control parameters are influenced by proportional band, integral action, and differential action. The valve protection circuit disables the valve driver at setpoints below a threshold voltage of 50 mV. Additionally, there is an external setpoint override capability through pins D and L. Pin D is internally pulled low to -14V . Grounding this pin to common overrides the setpoint and closes the valve. Similarly, TTL input 'low' at pin L effectively disables the setpoint and closes the valve.

NOTE: With "P" option (FC-280SA/FC-282S only), grounding pin D opens the valve to maximum, *see Figure 13*.

Cover

The cover on the instrument is designed to accept both round and flat cable mating connectors in a single configuration. The cover is made of high strength plastic and is copper-nickel-chrome plated to provide 60db (minimum) attenuation of RF noise. This, in conjunction with the eight roll-off and filter capacitors in the electronics, provides excellent EMI protection.

INSTALLATION

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 dust caps should not be removed from the instrument until installation.

Gas Connections

The various types of fittings available are shown in Figures 3 and 4. 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. Since the control valve in the instrument is not guaranteed 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).

When the FC-280A/FC-280SA is used to replace the FC-261, an outlet adaptor kit (Tylan General P/N 905516-001) is available to extend the overall length of the flow controller, matching the length of the FC-261.

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 flow controller is 1 megohm (minimum). 4-20 mA current option is also available. Contact factory for details.

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 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 1 ohm. The FC-280AD/FM-380AD contains a built-in display which may be used to read the output and control signals.

NOTE: Exercise caution when connecting the instrument to currently available readout boxes and calibrators which are manufactured by Unit Instruments, Inc. This equipment applies 15 VDC to pin E (FC-280SA/FC-282S valve test point). With jumper option "P", (*see Figure 13*) the valve test point is moved to pin D, which makes it compatible with Unit Instruments' test sets but no longer retrofittable with the TYLAN GENERAL FC-260 series soft-start function.

Integral Display *(FC-280AD/FM-380AD only)*

The FC-280AD/FM-380AD features a 3-1/2 digit liquid crystal display mounted in the side of an otherwise standard FC-280A/FM-380A. Additional power consumption for the 1.25" x 0.5" display with 1/2" high is negligible.

During normal operation the display shows the indicated flow rate. Depressing a momentary push button on the side of the instrument switches the display to read the commanded setpoint. The display may be set to read in engineering units (sccm or slm) or as a percentage of full scale.

Environmental Requirements

Refer to *Figure 9 - 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. Since the indicated flow rate has a temperature coefficient of ±0.1% per °C, the user may want to calibrate the instrument at the actual operating temperature to maximize the measurement accuracy.

PRESSURE: Flow controllers may be operated at any gas pressure up to 150 psig (1135 kPa). Since the indicated flow rate varies in direct proportion to specific heat (C_p), 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 pressure coefficient of ±0.007% per psi (±0.001% per kPa) generally applies to monatomic and diatomic gases only.

The flow controllers, which can be pressurized to 1500 psig (10,500 kPa) without damage, have a maximum operating pressure of 150 psig and the differential pressure (inlet to outlet) must be maintained within the specified 10 to 40 psid (70 to 275 kPa) range. Lower differential pressure ranges are available on special order.

The flow controllers may be operated into a vacuum as long as the inlet pressure is 15 psia or greater. Lower differential pressure ranges are available on special order.

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 gases on *Gas Flow Conversion Factor Charts.* 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 ±10% by removing the inlet fitting and adjusting 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 SEMI Standard E12-86, Standard Pressure and Temperature are defined as 760mm Hg and 0°C respectively.*

CAUTION: An instrument originally calibrated for a non-reactive gas should not be converted for use with a reactive gas unless all of the seals are replaced with a 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, and Kalrez for all other reactive and corrosive gases unless specified otherwise. Refer to spare parts O-ring Kits.

Mounting

Two 8-32 UNC tapped holes are provided for mounting. The instrument is essentially insensitive to mounting position. Refer to Figure 16 for mounting configuration.

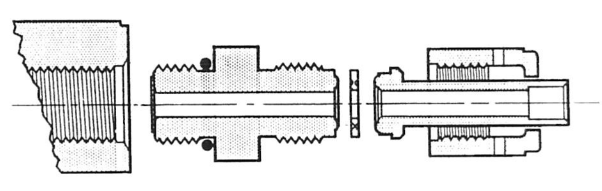

Figure 3
Vacuum Gas Fitting (With Flat Gasket)

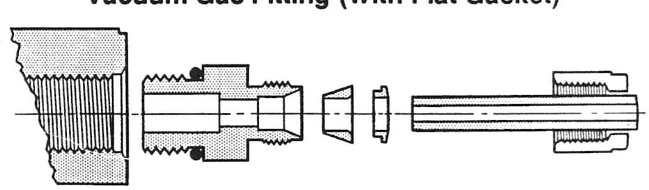

Figure 4
Compression Gas Fitting

OPERATING INSTRUCTIONS

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 shown in Figure 10. The insulation resistance between pin 2 and the base of the instrument should be verified to exceed 50 megohms at 50 VDC, and the ground connection between pin 1 and the base should be verified to be less than 1 ohm. After engaging the mating connector, secure it to the cover with two 4-40 x 3/4 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. Because the instrument 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 (normally pin E, with "P" option, 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 zero psig for several cycles is recommended. Cycle purging helps remove contaminants from small, blind cavities in the system which together 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 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, flow controller operation may then be verified over the complete operating range. If there is any question that gas system pressures may not be correct, verify operation with the following procedure: If the flow output voltage is within a few millivolts of the setpoint, the flow controller is controlling properly. Check for this condition at the highest and lowest flows anticipated at both the highest and lowest input-output pressure differentials anticipated.

Safety Features and Precautions

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.

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. Connecting pin E to 0 VDC will drive the valve open, while connecting pin D to 0 VDC will drive the valve closed. A second input to close the valve is provided on pin L. This input 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 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*.

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

1. Use pre-cleaned tubing, free of particulate contamination.
2. Thoroughly leak test the entire system prior to operation (recommended level is 1×10^{-9} cc/sec of helium or less).
3. Use only clean, moisture-free (dry) gases.
4. Purge only with dry nitrogen (or other inert gas) before and after breaking into the system. Connecting pin E to 0 VDC will readily allow for this by driving the valve open.
5. DO NOT purge reactive gas systems with inert gases between runs unless it is required by the process. Even "dry" gases contain some amount of moisture which will result in contamination build-up.
6. 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.
7. ALWAYS command no flow or ground pin D or pin L when the gas supply is shut off. The command signal should be interlocked with a series shutoff valve (as shown in Figure 10) to prevent unnecessary over-heating of the control valve during shutoff, and excessive flow surges after turn-on.
8. 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.

9. See *Caution Note* on page 6 before converting any instrument for operation on a gas other than what it was originally calibrated for or previously used on.

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 30 psig ±10 psig (315 kPa ±70 kPa) inlet pressure and corrected to standard conditions. Flow controllers are adjusted to pass full rated flow at 8 psig (160 kPa) inlet pressure (with 0 psig outlet pressure) and shut down to less that 2% of full scale at 40 psig (380 kPa) inlet pressure. Response time is verified at both extremes.

In vacuum systems, flow 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 and/or the valve voltage may be necessary.

Since 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 D connected momentarily to ground 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.

Flow controllers may be operated at inlet pressures of up to 150 psig (1135 kPa), provided the differential pressure is maintained within the specified range for the full scale flow rate (*see Figure 9 Specifications*) and the outlet pressure of the flow controller is regulated to a relatively constant level. Flow controllers can withstand pressure surges of up to 1500 psig (10,500 kPa) without damage, but are not designed to operate in a controlling mode above 150 psig (1135 kPa) inlet pressure.

MAINTENANCE, ADJUSTMENT AND RANGE CHANGE

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. The optimum (or necessary) service period being dependent on usage, environmental conditions, gas corrosiveness, etc., 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.
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 10 and 40 psig (380 kPa). Check response, stability and control resolution.
4. Remove the inlet and outlet fittings and visually examine for signs of contamination. Examine the seals for any evidence of hardening, swelling or contaminant accumulation.
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.

Cleaning

Should the instrument show symptoms of internal flow path contamination, it should be disassembled and cleaned. The 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 gases except those containing silicon or germanium compounds:

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

For instruments used with gases containing silicon or germanium compounds:

a. A solution of 2% HF:90% H_2O and 8% HNO_3 (3 to 5 minutes).
b. Distilled water (2 to 3 minutes)
c. Alcohol (2 to 3 minutes)
d. 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 .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 and flush with solvent during the *Bypass Cleaning Procedure* as described below.

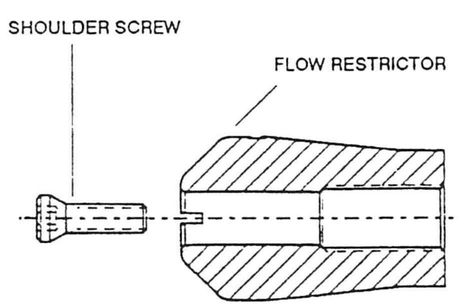

Figure 5
FC-280A/FC-280SA/FM-380A Bypass

Bypass FC-280A/FC-280SA/FM-380A *(see Figure 5)*
Loosen center locking shoulder screw one turn using a 7/64 inch Allen wrench. With a 1/4 inch flat head screwdriver, turn the bypass clockwise fully into the bore of the base. IMPORTANT: Count the exact number of turns it takes to hit bottom (N) and do not over-torque once the stop is reached. At this point, the bypass is closed and the sensor passageway can be solvent flushed and nitrogen purged through the inlet and outlet ports of the base. (Note: The valve will have to be mechanically opened or removed from the base during the operation.)

To clean the bypass, back it out of the bore by turning the bypass counter-clockwise. Either flush in place or, in the case of severe contamination build-up, remove and clean separately by screwing the bypass fully off of the shaft.

After cleaning, reinstall the bypass as follows:

1. Screw the bypass fully into the bore (clockwise) until it bottoms out in the bore. Do not over-torque once the stop is reached.
2. Turn the bypass exactly (N) turns counter-clockwise (as previously noted during disassembly) thereby moving the bypass back out to its original axial position.
3. Tighten the shoulder screw into the threaded shaft with a torque of 15 to 20 inch-pounds. CAUTION! Do not over-torque.

If this operation is performed carefully, no further bypass adjustment should be required to re-establish the original calibration within the adjustment range of the potentiometer in the electronics.

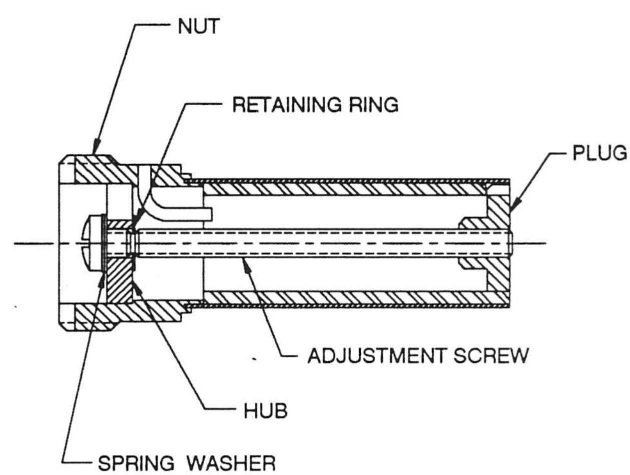

Figure 6
FC-282S Bypass

Bypass FC-282S *(see Figure 6)*
Remove the inlet fitting. Using a 3/4-inch wide flat blade screwdriver, turn bypass assembly counter clockwise until it becomes loose and can be removed. Note: Be careful not to turn the center adjustment screw. After cleaning, thread the bypass back into the flow body and firmly tighten against shoulder.

Valve FC-280A/FC-280SA *(see Figure 7)*
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, turn the

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). Remove (or loosen) the P.C. board from the base assembly to provide clearance for the removal of the valve assembly.
2. Remove the two screws which secure the valve flange to the base and pull the valve assembly out completely.
3. 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 valve with a 5/16 inch ring-wrench and removing the valve retaining nut with a 1/2 inch open-end wrench.
4. 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).
5. 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 (±3) inch-pounds and verify that the spring is positively held in place with no axial or rotational movement.
6. 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 15 inch-pounds of torque.
7. Adjust the valve during test as described in the *Valve Adjustment Procedure*.

Valve FC-282S

Due to the complexity of the high flow valve with its necessary sequence of internal assembly, mechanical adjustments and/or disassembly should not be attempted by other than qualified Tylan General service personnel. To clean, do not disassemble the instrument. Energize the valve, solvent flush then purge with dry nitrogen for 1 hour.

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.

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.

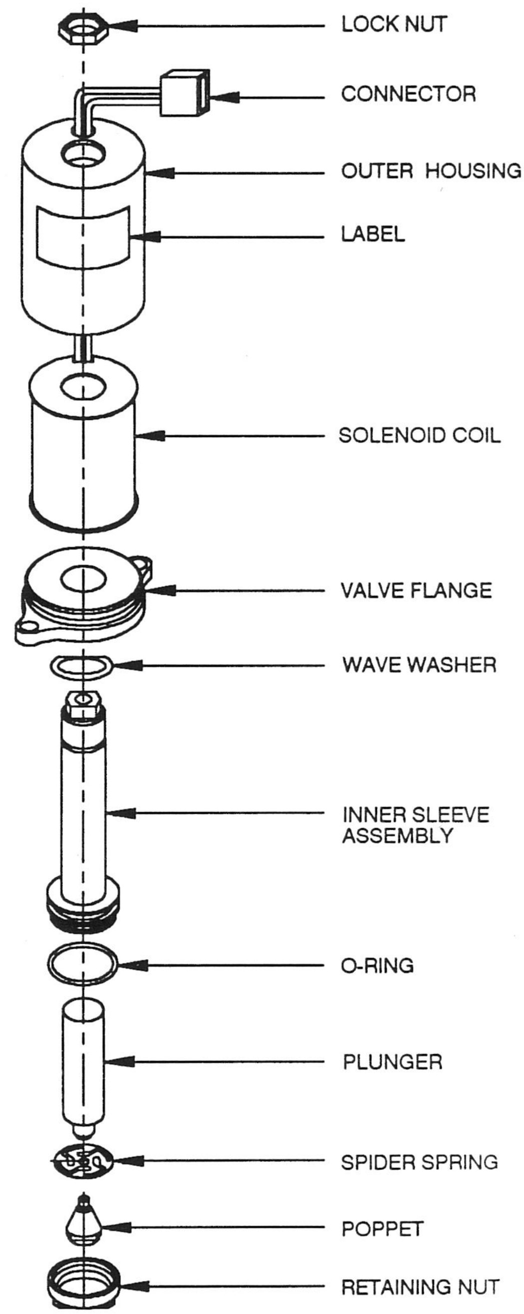

Figure 7
FC-280A/FC-280SA Solenoid Valve

Calibration - Indicated Versus Actual Flow Rate

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 the *Conversion Factor Tables*.

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.

Recalibration FC-280SA/FC-282S

This may be accomplished as follows:

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 Figure 10A Electrical Hook-up Diagram*).
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 E to pin C (0 VDC). This will override the control loop, allowing flowmeter operation.
5. Remove the outlet gas line and cap off the instrument to assure zero flow through the sensor. Adjust ZERO potentiometer P1 to make the indicator read zero.
6. Reconnect the outlet gas line and adjust the flow to the full-scale value. Set the output to read 5.00 VDC at the full-scale flow rate using the GAIN potentiometer P2.
7. Recheck zero as described in step 5.
8. Linearity adjustments are not normally required. After achieving calibration at zero and maximum flow, the midpoint calibration may be checked by setting the flow to one-half of full-scale. If the indicator does not read 2.50 ±0.025 VDC, adjust the output to 2.50 VDC using the LINEARITY potentiometer P3. 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 flow 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 P2 or P3, the 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 equalling the ratio of the conversion factors of the two gases must be applied. See the *Conversion Factors* section, Appendix A for further explanation.

Dynamic Response Adjustment(FC-280SA/FC-282S only)

Potentiometer P4 provides the means for tuning the speed-up circuit, and R29 is to be changed for optimizing stability and dynamic response characteristics of the control loop. While these adjustments are factory set to give repeatable response characteristics independent of gas density and inlet pressure, the user may want to alter the settings for optimized performance under the particular operating conditions. This optimizing may also be required after range changes or after replacement of sensor or control valve. When doing any readjustment the following procedure should be followed:

1. The first step is to verify the calibration of the mass flow controller. The procedure for this is detailed in the calibration section of this manual.
2. Start with the previously set adjustment or alternately center potentiometer P4, and set R29 to 750kΩ.

   NOTE: *A resistance decade box is useful for finding the optimum value of R29.*
3. Supply the instrument with the intended usage gas or a suitable substitute gas at the intended operating conditions including inlet pressure.
4. 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.
5. Adjust potentiometer P4 and resistor R29 subsequently, until the instrument shows optimum response characteristics.

   NOTE: *Speeding-up is accomplished by adjusting P4 clockwise. If instability occurs before the desired speed is* *established, adjust P4 counter-clockwise until stability is achieved. Too low resistance values of R29 results in oscillation.*

Recalibration FC-280A/FM-380A

This may be accomplished as follows:

1. Thoroughly flush and dry 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 Figure 10 Electrical Hook-up Diagram)*.
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 K to pin F (-15 VDC). This will override the control loop allowing flowmeter operation.
5. Remove the outlet gas line and cap-off the instrument to assure zero flow through the sensor. Adjust zero potentiometer R3 to make the indicator read zero.
6. Reconnect the outlet gas line and adjust the flow to the full-scale value. Set the output to read 5.00 VDC at the full-scale flow rate using the GAIN potentiometer R9.
7. Recheck zero as described in step 5.
8. Linearity adjustments are not normally required. After achieving calibration at zero and maximum flow, the midpoint calibration may be checked by setting the flow to make the indicator read 2.50 VDC. The calibrator should then measure half of the full-range flow rate within ±0.5% of full-scale. If not, set the flow rate at one-half of the full-scale value, and adjust the output to 2.50 VDC using the LINEARITY potentiometer R19. Although this adjustment is essentially independent of the zero and full-scale adjustments, steps 5 and 6 should be repeated until all three points are within the desired calibration.
9. The flowmeter section of the flow 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 then 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 R9, the bypass will have to be adjusted. This procedure is described in the *Range Change section* of this manual.
11. If it is desired to calibrate the flow metering section for a gas other than that of the original factory calibration, determine the gas conversion factor relative to N_2 from the *Conversion Factor Tables* and then activate the appropriate positions (1 through 7) of Dip Switch SW1 in accordance with Figure 15. *Note: Factory calibration is done with the dip switch set to the conversion factor relative to N_2 for the nameplate gas. If the conversion factor of the nameplate gas is less than 0.50, the dip switch is set to 1.00.*
12. 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 the *Conversion Factors section* for further explanation.

Dynamic Response Adjustment (FC-280A only)

Dip Switch SW1, positions 10, 11, and 12 provide the means for optimizing the stability and dynamic response characteristics of the control loop. While these switch positions are factory set to give repeatable response characteristics independent of gas density and inlet pressure, the user may want to alter the settings for optimized performance under his particular set of conditions (operating pressure, gas, and flow rates). To assist in doing so, the following explanation of these switch functions are presented *(refer to Figure 14, FC-280A Schematic)*.

1. SW1 positions 10 and 11 provide four separate selections of the dynamic feedback resistance of the control loop. The higher the value of this resistance (positions 10 and 11 "off"), the higher the A.C. gain. This produces the best response and overshoot characteristics, but is prone to control instability. Switching positions 10 and/or 11 "on" reduces the resistance, thereby improving the stability at the expense of optimal response characteristics.
2. SW1 position 12 provides selection of the setpoint ramp rate from 1/2 second (first order time constant) in the "on" position, to 1 second in the "off" position. The longer time constant typically gives better over and undershoot characteristics in response to a step change in setpoint and provides a smoother transition in actual flow rate. The shorter time constant may be desirable when process runs are very short and the time to reach setpoint is critical to the process.

3 The optimal switch settings for full-scale flow rates of 20 SCCM and below are positions 10 and 11 "on" and position 12 is "off." For full-scale rates above 200 SCCM, best results have been achieved with positions 10 and 11 "off" and position 12 "on."

4. It should be noted that the required valve control voltage has some influence on the optimization of the dynamic response in that the higher voltages require a decrease in the dynamic feedback resistance to achieve stability (typically from 100K to 30K - i.e., SW1 position 11 "on").

Valve Adjustment (FC-280A/FC-280SA)
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 40 psig). Mechanically close the valve by turning the adjusting nut clockwise until the flow is reduced to less than 2% of full scale.
3. Set the inlet pressure to the minimum (10 psig for up to 5 SLM full scale, and 15 psig for 6 to 30 SLM full scale) and command 100% flow rate. Verify full-scale output. On the FC-280A/FM-380A, set SW1 position 9 to "off" for full-scale flow rates of 1 SLM or less or "on" for full-scale flow rates greater than 1 SLM before setting the inlet pressure.
4. While monitoring the voltage applied to the valve (pin E to pin F), mechanically "fine-tune" the valve adjustment to achieve as close to the optimal 8 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 15 inch-pounds of torque. This will lock the adjusted position in place.

Bypass Adjustment
If, during calibration, the desired calibration cannot be achieved within the range of the potentiometers, the bypass will have to be readjusted. The procedure for this is detailed in the *Bypass Adjustment Procedure* listed in the Range Change section below.

Range Change
Following are the procedures necessary to convert any instrument from one full scale flow range to another.

Sensor:
In order to change the range of a reactive gas instrument containing a large bore sensor (902343-009) to a full-scale flow higher than 3 slm, the sensor must be replaced with the small bore sensor (902343-008). This is done as follows:

1. Replace the sensor as detailed in the troubleshooting section.
2. *FC-280SA/FC-282S only*
   Install R37 (=3.48kΩ) for use with large bore sensor. Remove R37 for use with small bore sensor.
   FC-280A/FM-380A only
   Set Dip Switch SW1 position 8 to the proper sensor current (i.e., "off" for the small bore sensor to provide 13 milliamps or "on" for the large bore sensor to provide 15 milliamps).

   NOTE: Both steps are ultimately important since the increased current for the large bore sensor is necessary to compensate for additional heat loss to maintain the proper temperature rise, and is essential to achieve the specified accuracy and linearity of the flow signal.
3. Readjust the bypass as described in the *Bypass Adjustment Procedure* and recalibrate per the Calibration Procedure previously described.

Bypass FC-280A/FC-280SA/FM-380A:
The FC-280A, FC-280SA and FM-380A have been purposely designed to minimize the need to replace parts in order to change the full scale flow range of the instrument. The continuously adjustable bypass is the key to the wide range of the instrument. For conversion factors of less than 0.50 on the FC-280A/FM-380A only, set Dip Switch S1 positions 2, 5, and 6 "off" (conversion factor equal to 1.00) prior to adjustment of the bypass. Full scale flow ranges of 10 SCCM to 30 SLM are easily achievable as follows:

1. Energize the instrument and adjust the flow rate to give 100% indicated output. Center the gain pot of the electronics by rotating the adjustment screw 12 turns from its point of non-influence on either the indicated output (flowmeter) or the actual flow rate (flow controller).

2. Measure the actual flow rate (ω_1) at 100% indicated flow rate using a suitable reference flow standard.
3. Remove the inlet fitting and loosen the bypass as explained in the Cleaning Section.
4. Loosen the center locking screw one turn and turn the entire bypass clockwise. For reference, count the exact number of turns it takes to solidly bottom out. Do not torque.
5. Refer to the graph in Figure 8 for the number of turns from full insertion.
6. Turn the adjusting screw N turns clockwise, backing the bypass out to its new location.
7. Measure the actual flow rate at 100% indicated flow rate and if within ±15% of the desired flow rate, adjust the gain potentiometer to bring it into calibration. If the actual flow is more than 15% different from the flow rate, refer to Figure 8 and readjust the bypass accordingly.

   Once the actual flow rate is within ±15% of the desired flow rate at 100% indicated flow rate (well within gain potentiometer adjustment range), tighten the center locking screw to 20 inch-pounds and recalibrate per the Calibration Procedure previously described.

8. An in-line adjustment tool (P/N T-900-454) is available to adjust the bypass with gas flowing through the instrument in lieu of steps 4 through 7. Contact TYLAN GENERAL for price and delivery.

Bypass FC-282S:
To change the range of the instrument, an adjustment may be made if the desired range is within the range of the installed bypass. Otherwise, it must be replaced. A three digit number etched on the bypass is used to identify its range as follows:

-001	25 to 75 slm
-002	76 to 150 slm
-003	151 to 300 slm

If the desired range is within the range of the installed bypass assembly, only a simple adjustment is necessary.

1. First, remove the bypass assembly as described in the cleaning section.
2. Using a phillips head screwdriver, adjust the center screw by turning counter-clockwise to locate the plug flush with the downstream end of the screen.
3. Thread the bypass back into the flow body and firmly tighten against shoulder.
4. Adjust the bypass by turning the adjusting screw clockwise to decrease the full scale flow rate.

Adjustment resolution for various high flow bypass sizes are approximately as follows:

-001	1.2 slm per turn
-002	2.5 slm per turn
-003	5.0 slm per turn

CAUTION: Press the screw firmly against the bypass nut during adjustment to insure that the threads only engage the plug and not the hub. Make sure that the screw does not thread out of the assembly during counter-clockwise adjustment.

Valve FC-280A/FC-280SA:
Five valve seats with different orifice sizes are available to accommodate full scale ranges of 10 SCCM through 30 SLM. See *Figure 17* for the flow ranges of each orifice. All five orifices are available in the Tylan 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.

Valve FC-282S:
The FC-282S valve has two adjustments which allow the user to optimize its performance for the actual operating pressure. These adjustments can be made while the flow controller is operating and without removing the valve assembly from the base.

To adjust the minimum flow (leak-through), set the inlet pressure to 50 psig or the maximum expected and command zero flow. Loosen the lower knurled nut and rotate the valve housing clockwise to reduce the flow to between 1% and 3% of full scale. Retighten the knurled nut to lock the valve in place.

To adjust the full scale flow, set the inlet pressure to 20 psig or the minimum expected and command 100% of range. Loosen the top lock nut and while monitoring the valve voltage (Pin E to Pin F) turn the top adjustment to give 100% flow at a valve voltage of 9 to 10 VDC. This will allow optimum response performance and provide adequate voltage margin to accommodate changes in operating conditions. Verify operation at 4%, 50% and 100% of the full scale range before and after tightening the lock nut.

After adjustments are made, it may be necessary to optimize dynamic response, refer to *Dynamic Response Adjustment (FC-280SA/FC-282S)* procedure.

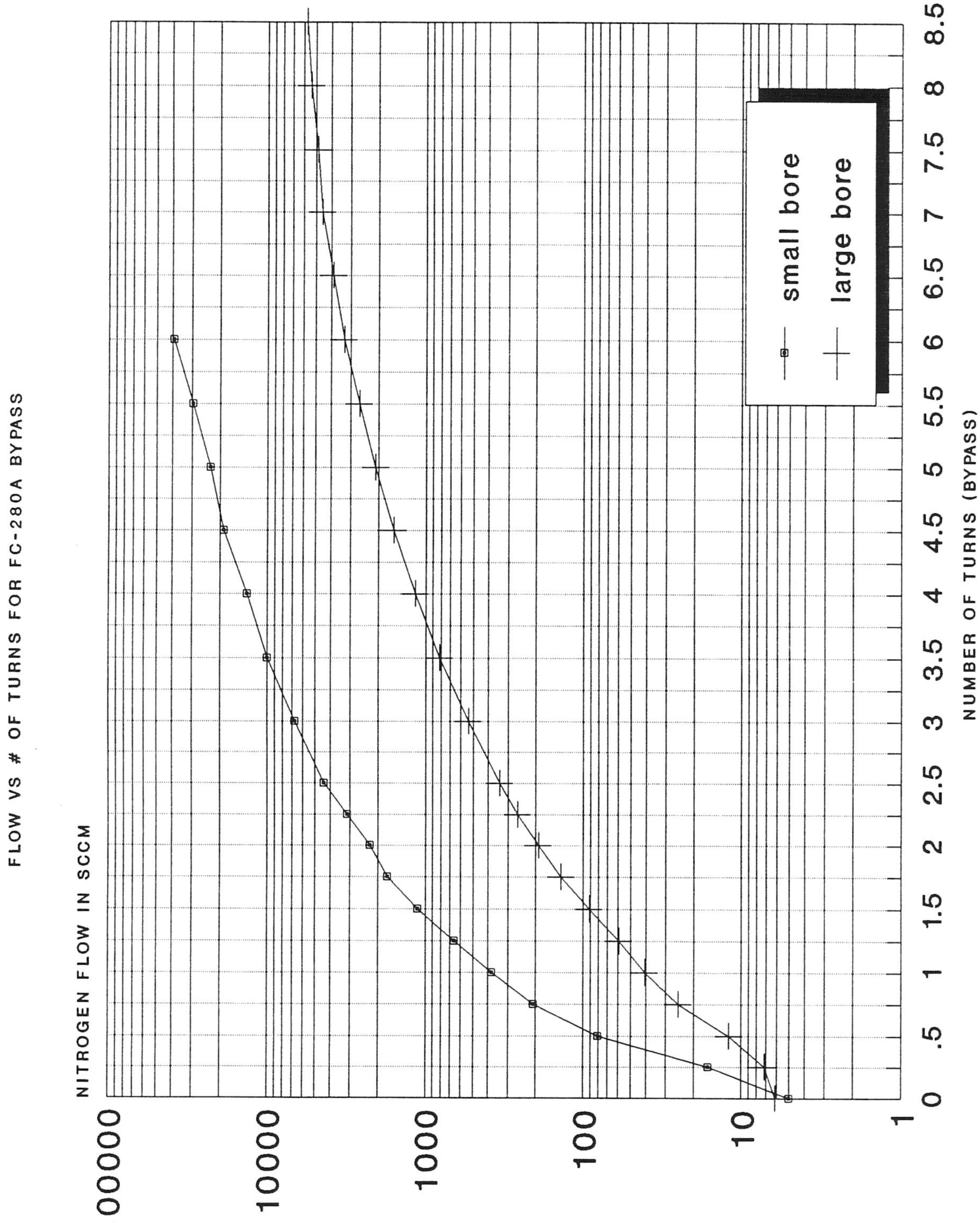

Figure 8
Flow vs. # of Turns for FC-280A/FC-280SA/FM-380A Bypass

Electronics FC-280SA/FC-282S:
The following components need to be adjusted or selected during the calibration procedure or dynamic response optimizing as previously described:

Potentiometer P1	Zero Adjustment
Potentiometer P2	Gain adjustment
Potentiometer P3	Linearity adjustment
Potentiometer P4	Dynamic response adjustment
Resistor R29	Proportional band adjustment
Resistor R37	Sensor current selection

Additionally, resistor R36 is to be re-selected in case of replacement of the reference diode D5. The following values should be chosen as a function of the reference voltage (to be accessed through pin 6 of the card edge connector, labeled "Zener Test Point", and measured against pin C, labeled "Return").

Voltage	Resistance (kΩ)
7.2 VDC	14.3
7.1 VDC	10.5
7.0 VDC	8.25
6.9 VDC	6.81
6.8 VDC	5.62
6.7 VDC	4.87
6.6 VDC	4.22

Note: After replacement of the reference diode D5 or the quad operational amplifier IC1, recalibration of the instrument is required.

Electronics FC-280A/FM-380A:
Only those changes concerning the Dip Switch (SW1) as previously described need be made during a range change. To reiterate, positions 1 through 7 accomodate different gases by conversion factor selection, position 8 is used when converting from the large bore sensor to the small bore sensor or vice-versa. Position 9 allows for the increasing of the maximum available valve voltage or low differential pressure and/or higher flow applications. Positions 10 and 11 provide optimization of the response characteristics via the dynamic feedback resistor in the control loop. Position 12 allows selection of the setpoint ramp-rate-time constant.

Integral Display (FC-280AD/FM-380AD):
The numeric display is factory set for the namplate range in engineering units (sccm or slm) The display may also be set to read as a percentage of full scale. If it becomes necessary to re-range the display, it is recommended that this service be performed by a factory authorized service center or contact Tylan General Technical Support for information.

TROUBLESHOOTING PROCEDURES

Initial Test

1. Check setup and procedure against the 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 Figures 10 and 10A Electrical Hook-up Diagram*). Use a hipot tester to check for any 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 10 minute warmup period. With the inlet pressure between the specified range for the full scale flow rate, the output signal of the controller should follow the command setting (i.e., 50% of full scale at 2.50 VDC commanded voltage). The 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.

Tylan General has maintenance kits available which contain custom-designed tools that simplify the repair of all Tylan General's mass flow equipment.

Tylan General

REPLACEABLE SPARE PARTS

Description	Part Number
O-Ring Kit:	
(contains all O-Rings to rebuild a flow controller)	
FC-280A/FC-280SA/FM-380A:	
▪ Viton	907971-001
▪ Neoprene	907971-002
▪ Kalrez	907971-003
FC-282S:	
▪ Viton	908801-001
▪ Neoprene	908801-003
▪ Kalrez	908801-002
Orifice Kit (contains all 5 orifices): (FC-280A/FC-280SA/FM-380A):	905491-001
Sensor:	
▪ Viton	902343-008
▪ Kalrez (small bore)	908543-001
▪ Neoprene	902343-010
Valve:	
FC-280A/FC-280SA/FM-380A:	
▪ Viton	904149-001
▪ Kalrez	904149-003
▪ Neoprene	904149-005
FC-282S:	
▪ Viton, 25 to 75 slm	908734-001
▪ Viton, 50 to 150 slm	908734-002
▪ Viton, 100 to 300 slm	908734-003
▪ Neoprene, 25 to 75 slm	908734-004
▪ Neoprene, 50 to 150 slm	908734-005
▪ Kalrez, 25 to 75 slm	908734-007
▪ Kalrez, 50 to 150 slm	908734-008
P.C. Board Assembly	
FC-280A/FM-380A	907214-001
FC-280SA/FC-282S	908210-001

OTHER RECOMMENDED TOOLS & EQUIPMENT

1. Alcohol Dispenser
2. Ultrasonic Cleaner
3. Plastic Beakers (for use with cleaning solution)
4. 25-10M Halocarbon Grease
5. Soldering Equipment (for P.C. board repair)
6. Suitable Power Supply and Readout with Interconnect Cable (Tylan General RO-28 recommended)
7. Tweezers
8. Artist's brush #4
9. Kryox Grease

FC-280 SERIES MASS FLOW INSTRUMENT MAINTENANCE KIT Part No. 908464-001

Description	Part Number
Torque wrench, 6-inch-lb.	200241-016
Torque wrench, 10-inch-lb.	651780-001
Torque wrench, 15-inch-lb.	200241-017
Adaptor, torque wrench (bypass)	906279-001
Adaptor, torque wrench (valve, sensor)	906278-001
Bypass extractor	T-900-555
Adaptor, orifice	906284-001
Adaptor, use with orifice	200065-001
Adjusting wrench, 1/4" Allen hex (flow restrictor)	200558-001
Pot adjustment tool	651784-001
Extender board	3780-280-0
Calibration cover, metallized (not for use with FC-282S)	907326-001
Wire, mandrel	3505-122-0001A
Tool kit box	200557-001
OPTIONAL	
In-situ bypass adjusting tool	T-900-454

FC-280/FC-260 SERIES ADDITIONAL TOOL KIT Part No. 908466-001

Description	Part Number
Screwdriver, 1/8" Phillips	200551-001
Screwdriver, 1/4" flat	200556-001
Wrench, open-end, 1/2" x 9/16"	200552-003
Wrench, open-end, 3/4" x 5/8"	200552-002
Wrench, open-end, 11/16" x 13/16"	200552-001
Wrench, open-end, 15/16" x 1"	200552-004
Wrench, adjustable, 1"	200553-001
Diagonal cutter	200554-001
Pliers, needle-nose	200555-001
X-acto knife	NO-1

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.
	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.
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 electronics. Measure valve DC resistance (should be 120 ±5 ohms). If coil is open, replace coil or entire valve assembly.
	Faulty power supply or command signal	Check ±5.00 VDC reference for the control input.
b. Indication erroneous	Open resistance element on sensor	Replace sensor.
	Electronics failure	See Electronics section.

ELECTRONICS TROUBLESHOOTING

(See Figure 10 and 10A Electrical Schematic and Notes 1 through 3 listed below)

SYMPTOM	POSSIBLE CAUSE	REMEDY
General Failure or miscalibration	Power supply voltage off of nominal	Check ±15 VDC.
Flow indication saturated (-0.7 or +12.0 VDC) regardless of flow	Bridge or sensor failure	Check sensor resistances, these should be 330Ω (±10Ω) green to red and green to brown with power off. Voltage across BRN to circuit common should be 8.0 to 10.0 VDC and Ez to circuit common should be -6.9 ±0.3 VDC.
	Component failure	Check zero pot, gain pot, other components and solder joints.
Valve drive open or saturated (FC-280SA only) (0 or 12 to 15 VDC)	Valve drive transistor open or short, Op-amp failed.	Check these and other components and solder joints. Replace if necessary.
All circuits functional, but out of calibration	Contamination, or as a result of cleaning or repairing	Adjust.
Instrument controls, but output voltage does not agree with control input pot setting	±5.00 VDC supply of the control input off nominal	Check +5.00 VDC input reference supply. Readjust as necessary.
	Large input voltage offset in Op-amp	Check and replace as necessary.

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., instrument adjusted for argon may not shut off completely on hydrogen)	Test on proper gas or mechanically readjust valve.
Valve fails to open	Contamination	See Cleaning Procedures
	Open valve coil	Verify by removing case and measuring DC resistance of valve with power shut off; should be approximately 120 ohms; if coil is open, replace valve coil or entire assembly.
	Electrically commanded closed or pot shorted	Check command signal (pins A and B) and pot. Check for Electronic failure.
	Clogged inlet screen appearing as closed valve	Clean inlet filter fitting.
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.
	Erratic pressure regulator	Replace regulator.
Valve Oscillates or hunts	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.

NOTE 1: *CAUTION: Always command zero flow when the gas supply is shut off. Failure to do so will result in the valve overheating and in excessive flow transients after the gas supply is turned "on" (see Figures 10 and 10A Electrical Hook-Up Diagram).*

NOTE 2: *Pin D may be connected to common prior to turning on the gas supply to achieve "soft-start" performance.*

NOTE 3: *A threshold circuit in the controller ensures zero valve voltage whenever the commanded signal falls below 1.0% full scale.*

Sensor Replacement

If it is determined that either of the sensor elements is open or shorted to case, it will be necessary to replace 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:

Upstream .... Ru=330 ±10 ohms
(Brown to Green)

Downstream .... Rd=330 ±10 ohms
(Red to Green)

Isolation .... >100 megohms
(All leads to sensor housing)

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 115 to 125 ohms, the valve assembly will need to be replaced.

Figure 9 - Specifications

Specifications	Mass Flowmeters	Mass Flow Controllers	
	FM-380A / FM-380AD	FC-280SA/FC-280A/FC-280AD	FC-282S
PERFORMANCE			
Full-scale range* (N_2 equivalent)	10 sccm to 30 slm	10 sccm to 30 slm	31 slm to 200 slm
Turndown ratio	50:1	50:1	25:1
Accuracy	±1.0% of full scale	±1.0% of full scale	±2% of full scale
Repeatability	±0.2%	±0.2%	±0.2%
Linearity	±0.5%	±0.5%	±0.5%
Step Response Time (0 to 100%)	2 seconds	FC-280S: 400 to 800 ms FC-280A: 2 seconds	3 seconds
OPERATING			
Maximum Operating Pressure	500 psig	150 psig	150 psig
Proof Pressure	1500 psig	1500 psig	1500 psig
Differential Pressure	0.5 psid maximum	10-40 psid (to 5 slm) 15-40 psid (6 to 30 slm)	20-50 psid (to 100 slm) 30-60 psid (101 to 200 slm)
Pressure Coefficient	±0.007%/psi (typical)	±0.007%/psi (typical)	±0.007%/psi (typical)
Temperature Range	0 - 50°C	0 - 50°C	0 - 50°C
Temperature Coefficient	±0.05%/°C	±0.05%/°C	±0.05%/°C
Warm-up Time	30 minutes	30 minutes	30 minutes
Attitude Sensitivity	< 0.25% @ 90°	< 0.25% @ 90°	< 0.25% @ 90°
ENVIRONMENTAL			
Pressure	> 100 Torr	> 100 Torr	> 100 Torr
Temperature Range	0 - 50°C	0 - 50°C	0 - 50°C
Humidity	0-95% relative humidity, non-condensing		
ELECTRICAL			
Supply Voltage:	+15 VDC ±4%, 25 mA -15 VDC ±4%, 25 mA	+15 VDC ±4%, 35 mA - 15 VDC ±4%, 150 mA	+15 VDC ±4%, 40 mA - 15 VDC ±2%, 300 mA
Power	3 watts max.	3 watts max.	5 watts max.
Output Voltage	0 - 5 VDC (into 2000 Ohms, shortcircuit protected)		
Control Voltage	0 - 5 VDC (Controller only from voltage source with maximum of 5000 Ohms)		
MECHANICAL			
Valve (> 1 million cycles)	High Speed Electromagnetic Normally Closed Solenoid		
Materials	Type 316 & 446 stainless steel, PFA teflon		
Seals	Viton®, Kalrez® or Neoprene®		
Leak Integrity	1 x 10^{-9} atm cc/sec Helium		
Valve Through-Leak (Teflon Poppet)	< 2% full scale	< 2% full scale	< 4% full scale
Fittings Available	1/8", 1/4", 3/8" VCR™ or Swagelok™	1/8", 1/4", 3/8" VCR™ or Swagelok™	3/8" Swagelok™ or VCR™
DIMENSIONAL	see Figure 16	see Figure 16	see Figure 16A

*Note: Standard Pressure is defined as 760 mm Hg (14.7 psia). Standard Temperature is defined as 0°C.

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VCR and Swagelok are trademarks of Crawford Fitting Co.

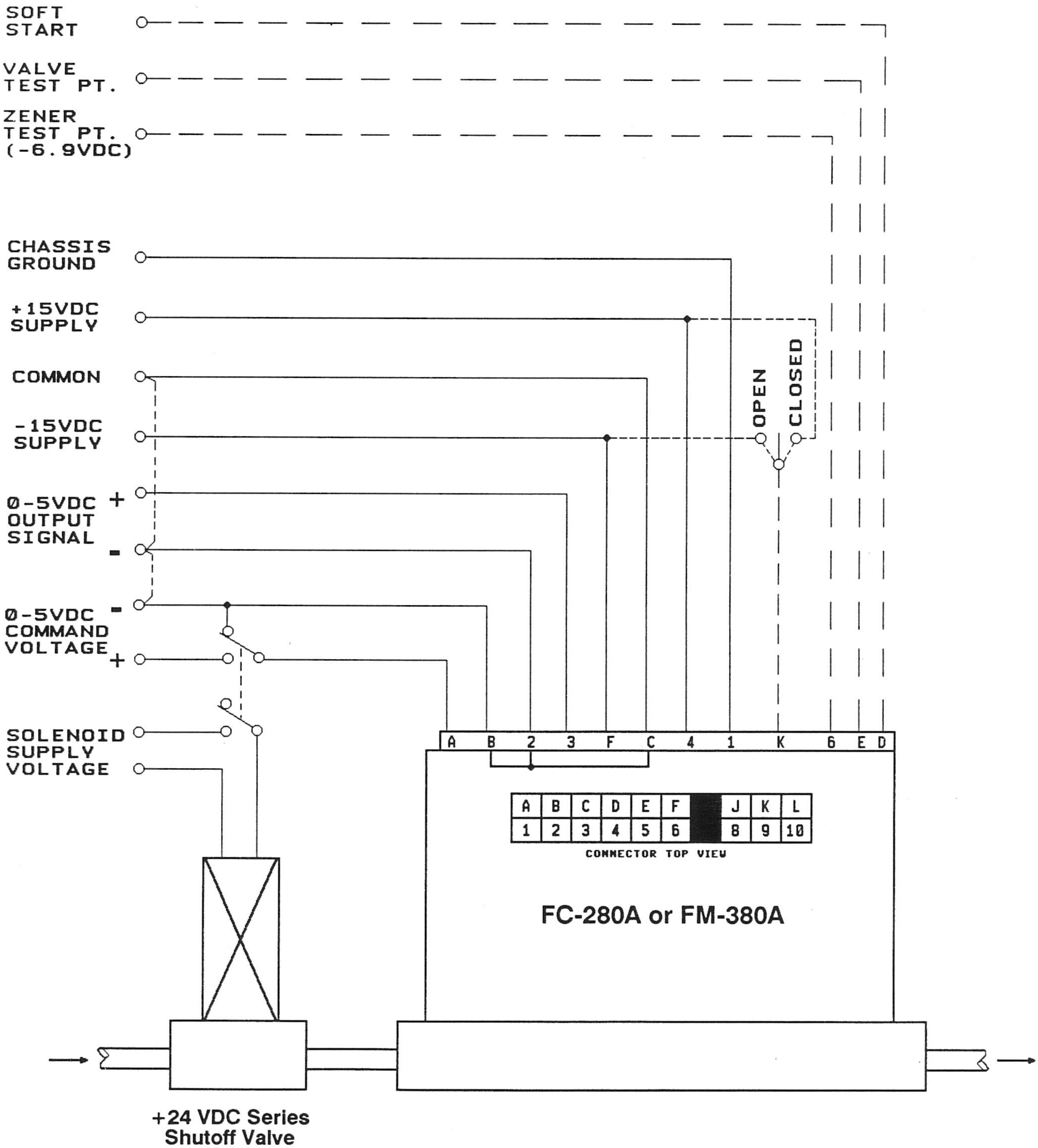


Figure 10
FC-280A / FM-380A Electrical Hook-Up Diagram

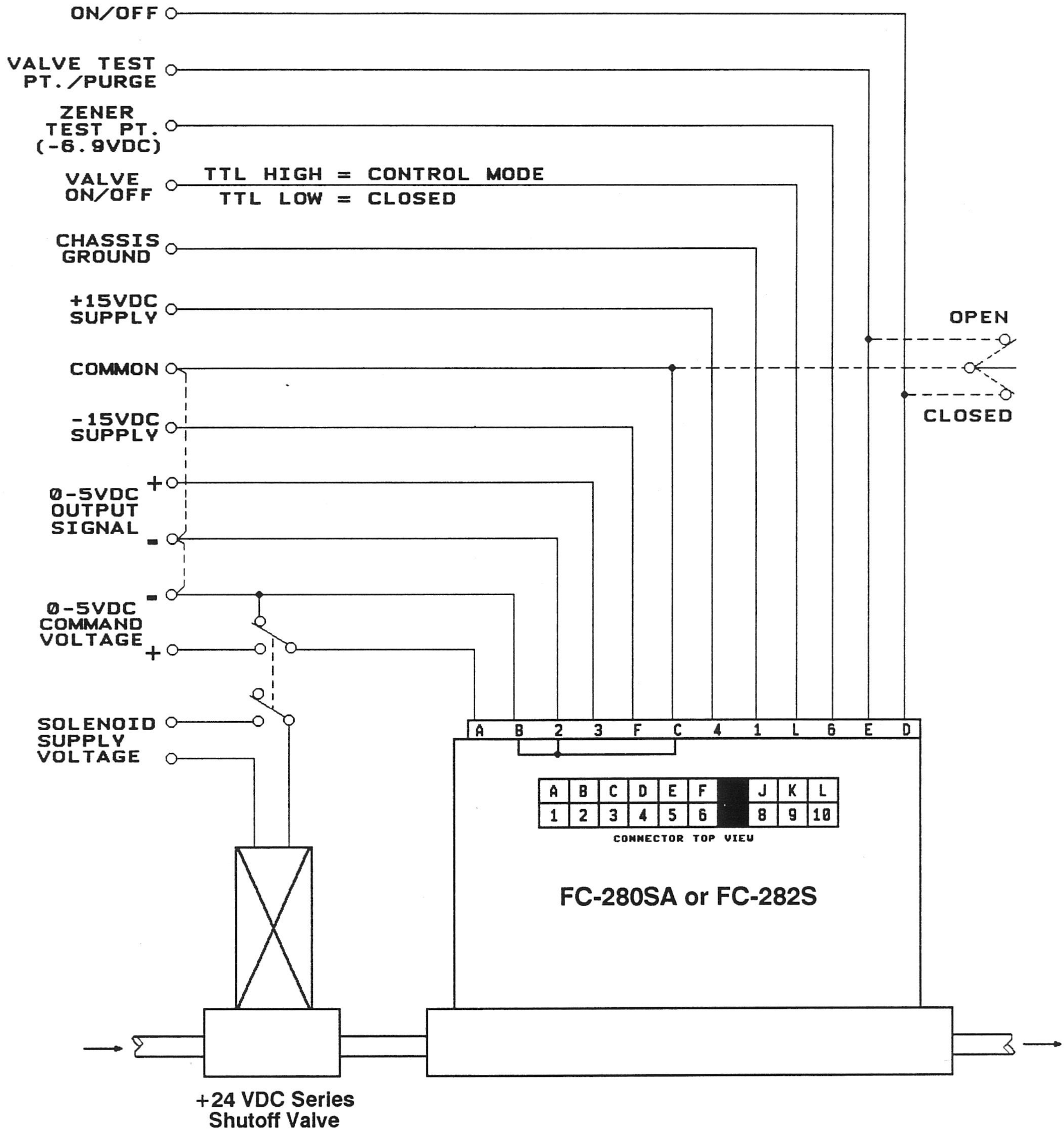
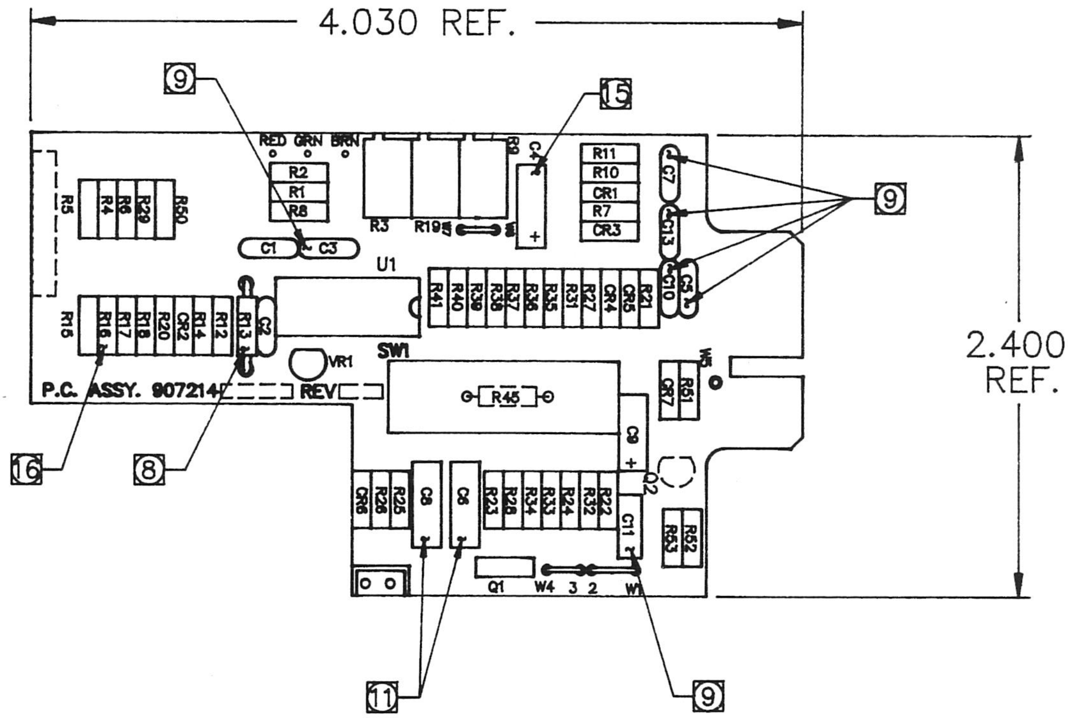


Figure 10A
FC-280SA / FC-282S Electrical Hook-Up Diagram



COMPONENT SIDE

NOTES:

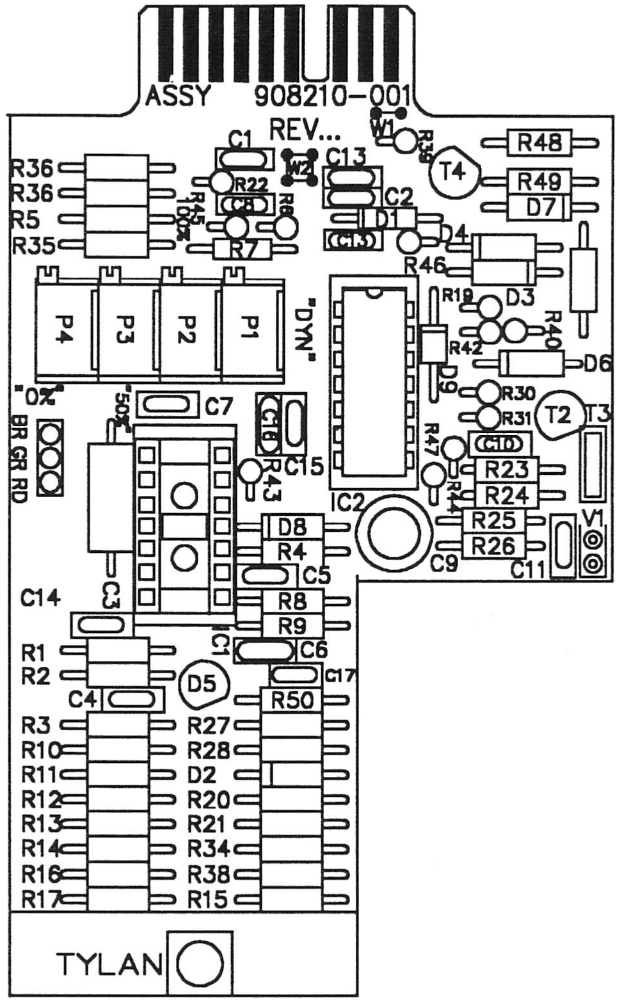
- 16 Alternate part: 200345-003
- 15 Alternate parts: 200345-002 or 3073DA1S1T6P3JPA (Mepco)
- 11 Alternate part: 200345-001
- 9 Alternate part: Kemet C330C154M5UICA and Erie 8131-050-651-154M
- 8 Select R13 in initial test per Table I

TABLE I

VZ	R13 (KΩ)
7.2	14.3
7.1	10.5
7.0	8.25
6.8	5.62
6.7	4.87
6.6	4.22

Figure 11

907214-001, Rev. M
P.C. B. Assembly
FC-280A/FM-380A Mass Flow Controller/Flowmeter



NOTES:

13. Install R50 at final test only as required to minimize delay at low setpoints

10. R37 used with large bore sensor only

9. A -002 is made from a -001 assembly. See Figure 13 and Note 8 for modifications.

8. If "P" option is required, remark dash no. to -002 using permanent ink on avery label.

TABLE I

Ez	R36 (KΩ)
6.6	4.22
6.7	4.87
6.8	5.62
6.9	6.81
7.0	8.25
7.1	10.50
7.2	14.30

Figure 11A

908210-001, Rev. P
P.C. B. Assembly
FC-280SA/FC-282S Mass Flow Controller

Figure 12 - FC-280A/FM-380A P.C. Board Assembly Parts List

ITEM NO.	QTY	PART NUMBER	DESCRIPTION	REMARKS
1	1	907213-001	P.C. Board (Tylan General)	
2	1	LM324AN/A+	I.C. (Quad Op. Amp)	U1,LM324AN-3 (T.I.)
3	1	LM329CZ	Voltage Regulator	VR1,6.9V 5%
4	1	2N4918	Transistor	Q1
5	4	1N4002	Diode	CR1, CR2, CR3, CR7
6	3	1N4002	Diode	CR4, CR5, CR6
7	1	2N4401	Transistor	Q2
8	1	200349-001	Dip Switch, 12 Pos.	SW1, Alt 1012-692-2 (SAE)
10	2	200476-001	Capacitor .0047μF, 100V	C1, C2
11	6	200476-002	Capacitor, .15μF, 100V	C3, 5, 7, 10, 11, 13 (Note 9)
12	1	200630-001	Capacitor, 220μF, 6.3V	C4, Nichicon (Note 15)
13	2	3070BA220T025ASF	Capacitor, 22μF, 25V	C6, C8 (Note 11)
14	1	3070BA470T025ASF	Capacitor, 47μF, 25V	C9 (Note 16)
16	1	3299X-1-201	Potentiometer, 200Ω	R3, Bourns
17	2	3299X-1-202	Potentiometer, 2000Ω	R9, R19
18	2	RN55E2002B	Resistor, 20.0KΩ, 1/8 W, 0.1%	R1, R2
19	1	RN55C3092F	Resistor, 30.9KΩ, 1/8W, 1%	R4
20	2	RN55C1004F	Resistor, 1.00M, 1/8W, 1%	R5, R6
21	1	RC07GF122J	Resistor, 1.2KΩ, 1/4W, 5%	R7, R28
22	1	RN55C2102F	Resistor, 21.0KΩ, 1/8W, 1%	R8
23	1	RN55C4221F	Resistor, 4.22KΩ, 1/8W, 1%	R10
24	1	RC07GF103J	Resistor, 10KΩ, 1/4W, 5%	R11
25	1	RN55E5760B(F Alt)	Resistor, 576Ω, 1/8W, .1%	R12 (1% Alt.)
26	1	RN55CXXXXF	Resistor, 4.22-14.3KΩ,1/8W,1%	R13 S.I.T. (Note 8)
27	1	RC07GF391J	Resistor, 390Ω, 1/4W, 5%	R14
28	3	RN55C1002F	Resistor, 10.0KΩ, 1/8W, 1%	R15, 16, 17
29	1	RN55C1372F	Resistor, 13.7KΩ, 1/8W, 1%	R18
30	1	RN55C4022F	Resistor, 40.2KΩ, 1/8W, 1%	R20
31	1	RN55C1002F	Resistor, 10.0KΩ, 1/8W, 1%	R21
32	1	RN55C2002F	Resistor, 20.0KΩ, 1/8W, 1%	R22
33	1	RC07GF242J	Resistor, 2.4KΩ, 1/4W, 5%	R23
34	1	RC07GF104J	Resistor, 100KΩ, 1/4W, 5%	R24
35	2	RC07GF620J	Resistor, 62Ω, 1/4W, 5%	R25, R26
36	1	RC07GF304J	Resistor 300KΩ, 1/4W, 5%	R27
38	1	RL07S621G	Resistor, 620Ω, 1/4W, 2%	R29
39	1	RN55C3481F	Resistor, 3.48KΩ, 1/8W, 1%	R31
40	1	RN55C4022F	Resistor, 40.2KΩ, 1/8W, 1%	R32
41	1	RC07GF433J	Resistor, 43KΩ, 1/4W, 5%	R33
42	1	RC07GF273J	Resistor, 27KΩ, 1/4W, 5%	R34
43	2	RN55C4001B	Resistor, 4.00KΩ, 1/8W, 0.1%	R35, R36
44	2	RN55C2001F	Resistor, 2.00KΩ, 1/8W, 1%	R37, R51
45	1	RN55C1001F	Resistor, 1.00KΩ, 1/8W, 1%	R38
46	1	RN55C4990F	Resistor, 499Ω, 1/8W, 1%	R39
47	1	RN55C2490F	Resistor, 249Ω, 1/8W, 1%	R40
48	1	RN55C1240F	Resistor, 124Ω, 1/8W, 1%	R41
49	1	RN55C6041F	Resistor, 6.04KΩ, 1/8W, 1%	R50
50	1	RN55C3011F	Resistor, 3.01KΩ, 1/8W, 1%	R53
51	1	RN55C1000F	Resistor. 100Ω, 1/8W, 1%	R52
52	1	706-14-11	Socket, Dip	14 pin
53	1.2	SS-120-G-2	Pin, Socket	24 pin
54	1	200593-002	Header, P.C.B., 2 Pos.	Ref. V1, V2
55	2	2000B-5.5	Terminal, Bifurcated	Useco
56	A/R	BU22-19/34-9	Wire, 22 AWG	Storm or equivalent
57	.05	652005-001	Sleeving, 22 GA, Type SW	Clear Teflon
58	1	RN55C9001B	Resistor, 9.0KΩ, 1/8W, 0.1%	R45

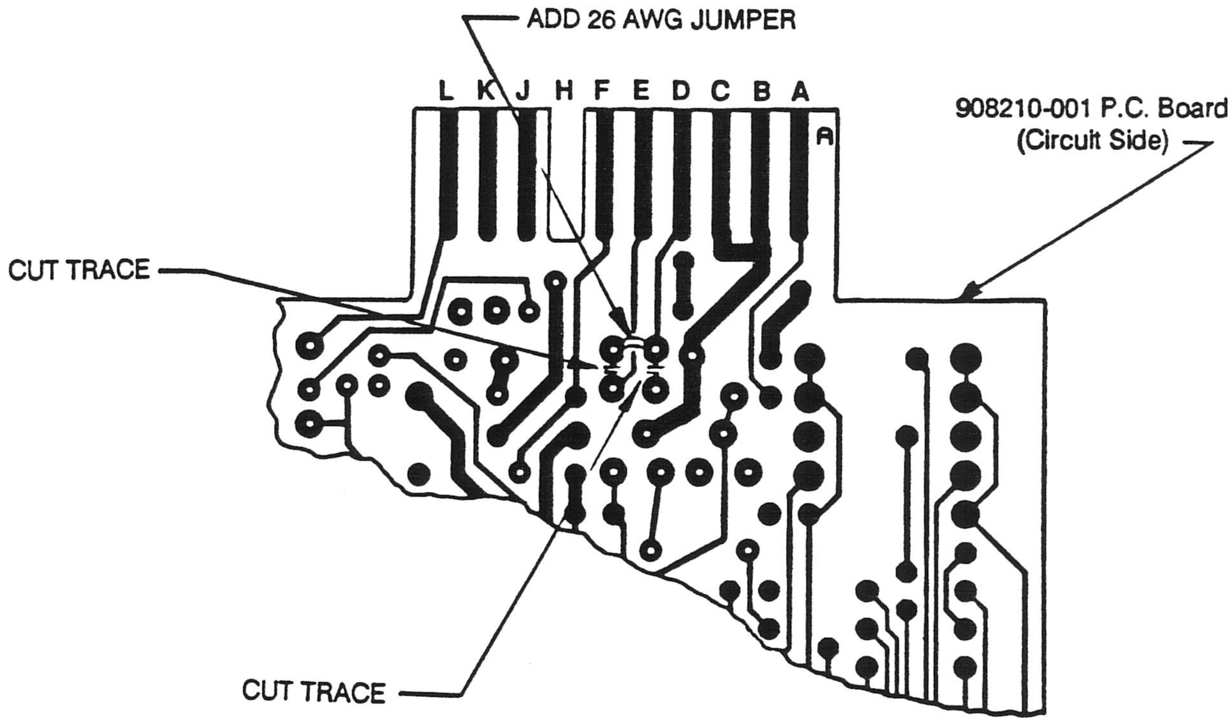
Figure 12A - FC-280SA/FC-282S P.C. Board Assembly Parts List

ITEM NO.	QTY	PART NUMBER	DESCRIPTION	REMARKS
1	1	908211-001	P.C. Board (Tylan General)	
2	2	706-14-11	Socket, Dip	Ref. IC1, IC2
4	1	2N4401	Transistor, NPN	T3
5	1	BD140-16	Transistor	T2 (Phillips)
6	1	3299X-1-204	Potentiometer, 200KΩ	P4 (Bourns) "DYN"
7	2	3299X-1-202	Potentiometer, 2KΩ	P2,P3 (Bourns) "100", "50"
8	1	3299X-1-201	Potentiometer, 200Ω	P1 (Bourns) "0"
9	9	RPE122X7R104K100V	Capacitor, 0.1μF, 100V	C1,2,4,7,8,10,12,13,14 (Murata)
10	2	SR305A153FAA	Capacitor, 0.015μF, 50V	C5,6 (AVX)
11	1	3070BA220T025ASF	Capacitor, 22μF, 25V	C3
12	1	196D475X9050JA1	Capacitor, 4.7μF, 50V	C9 (Sprague)
13	3	RPE122X7R474K100V	Capacitor, 0.47μF, 50V	C11, 16, 17 (Murata)
14	1	RPE122X7R101K100V	Capacitor, 100pF, 100V	C15 (Murata)
15	7	1N4002	Diode	D1-4, D6-8
16	1	LM329CZ	Diode, Zener	D5
17	1	RN55C1211F	Resistor, 1.21KΩ, 1%	R1
18	2	RN55C1001F	Resistor, 1KΩ, 1%	R2, 39
19	2	RN55C2001F	Resistor, 2KΩ, 1%	R3, 47
20	1	RN55C4221F	Resistor, 4.22KΩ, 1%	R4
21	1	RN55C2001F	Resistor, 2KΩ, 1%	R5
22	2	RN55C1004F	Resistor, 1MΩ, 1%	R6, 9
23	1	RN55C1022F	Resistor, 10.2KΩ, 1%	R7
24	1	RN55C2002F	Resistor, 20KΩ, 1%	R8
25	1	RN55C6190F	Resistor, 619Ω, 1%	R11
26	1	RN55C6041F	Resistor, 6.04KΩ, 1%	R12
27	7	RN55C1002F	Resistor, 10KΩ, 1%	R14,15,17,22,24,42,44
28	2	RN55C1002B	Resistor, 10KΩ, 0.1%	R25, 26
29	1	RN55C4022F	Resistor, 40.2KΩ, 1%	R16
30	1	RN55C3321F	Resistor, 3.32KΩ, 1%	R19
31	1	RN55C1000F	Resistor, 100Ω, 1%	R20
32	1	RN55C3012F	Resistor, 30.1KΩ, 1%	R21
33	1	RN55C3323F	Resistor, 332KΩ, 1%	R23
34	1	RN55C7503F	Resistor, 750KΩ, 1%	R29
35	1	RN55C2000F	Resistor, 200Ω, 1%	R30
36	2	RN55C2003F	Resistor, 200KΩ, 1%	R31, 50, Note 13
37	1	RN55C4751F	Resistor, 4.75KΩ, 1%	R32
38	1	RC07GF391J	Resistor, 390Ω, 1/4W, 5%	R34
39	1	RN55E5760F	Resistor, 576Ω, 1%	R35
40	1	RN55CXXXXF	Resistor, 4.22KΩ to 14.3k:	R36 (S.I.T.)
41	1	RN55C3481F	Resistor, 3.48KΩ, 1%	R37 Note 10
42	1	RN55C1372F	Resistor, 13.7KΩ, 1%	R38
43	2	RN55C1003F	Resistor, 100KΩ, 1%	R40, 48
44	1	RN55C4753F	Resistor, 475KΩ, 1%	R43
45	1	RN55C9001B	Resistor, 9.00KΩ, 0.1%	R45
46	1	2N3906	Transistor, PNP	T4
47	1	1N746A	Diode, Zener, 3.3V	D9
48	2	RN55C4991F	Resistor, 4.99KΩ, 1%	R46, 49
49	1	200593-002	Header, P.C.B., 2 Pos.	Ref. V1, V2
50	2	2000B-5.5	Terminal Bifurcated	(Useco) Note 5
51	2	RN55E2002B	Resistor, 20KΩ, 0.1%	R10, 13
52	2	200574-001	I.C., Op Amp	IC1, IC2
53	2	RN55C4992F	Resistor, 49.9KΩ, 1%	R27, 28

"P" JUMPER MODIFICATION

For compatibility with Unit Instruments and other MFCs which bring a normally closed control valve drive signal out on Pin D.

1. Cut (2) traces to Pins D and E
2. Jumper W2 using 26 AWG wire as shown
3. Add the letter "P" to the MFC label as in "FC-280SA-P" or "FC-282S-P"



NOTES:

1. Once modification is complete, connecting Pin D to common will OPEN the valve instead of CLOSE it.
2. Pin E becomes inoperative.
3. Enables compatibility with Unit Instruments mass flow controllers and will no longer retrofit Tylan General FC-260 series MFCs which use Pin D for "soft-start" function.
4. The "P" Jumper Modification is available on FC-280SA PCB assemblies identified with Part No. 908210-XXX. This option was not available on older PCB assemblies identified with Part No. E76P000401.

Figure 13

"P" Jumper Modification
for Moving Valve Drive to Pin D (FC-280SA/FC-282S only)

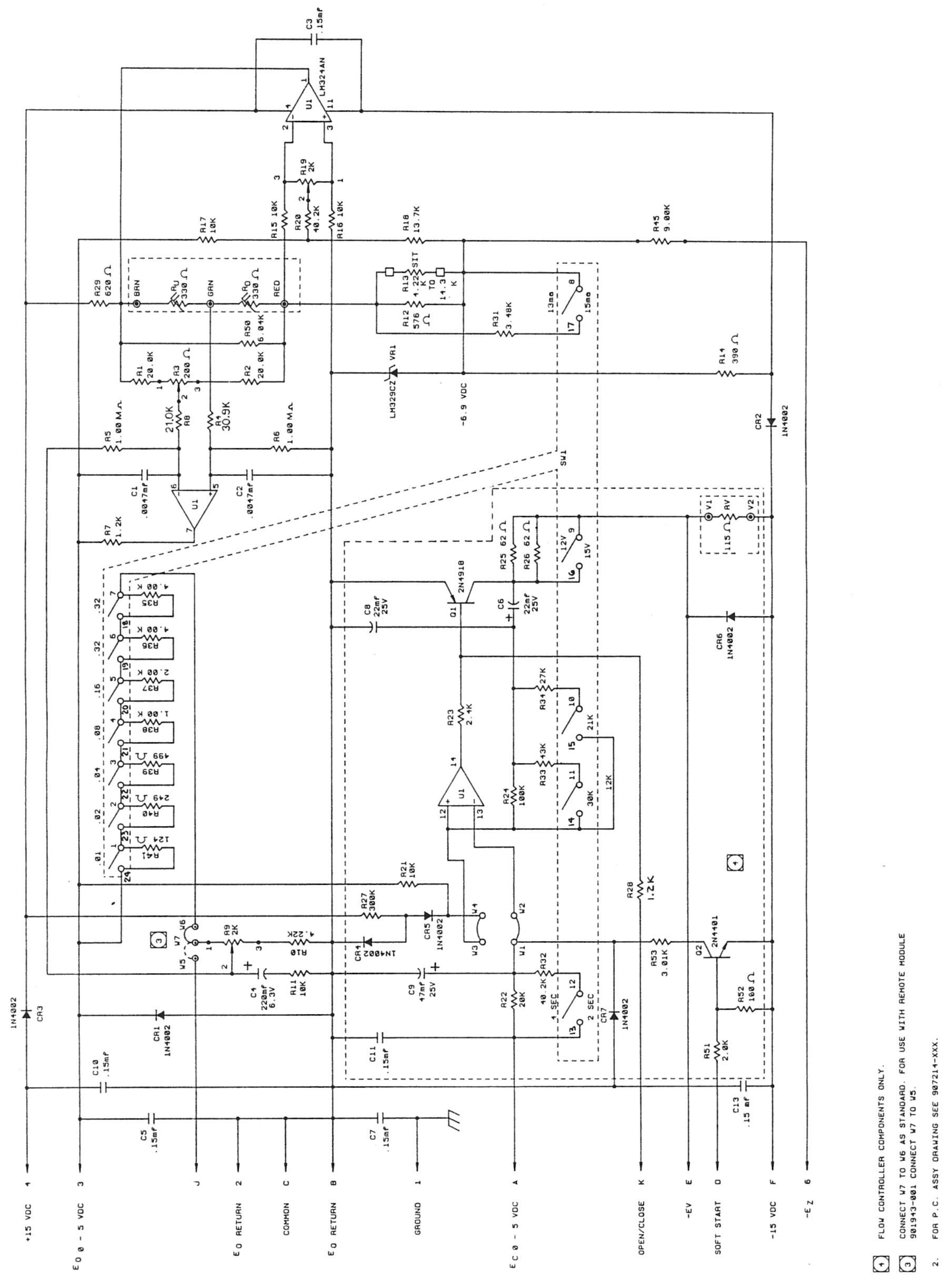


Figure 14

907215-001 Rev. G
FC-280A/FM-380A Mass Flow Controller/Flowmeter Schematic

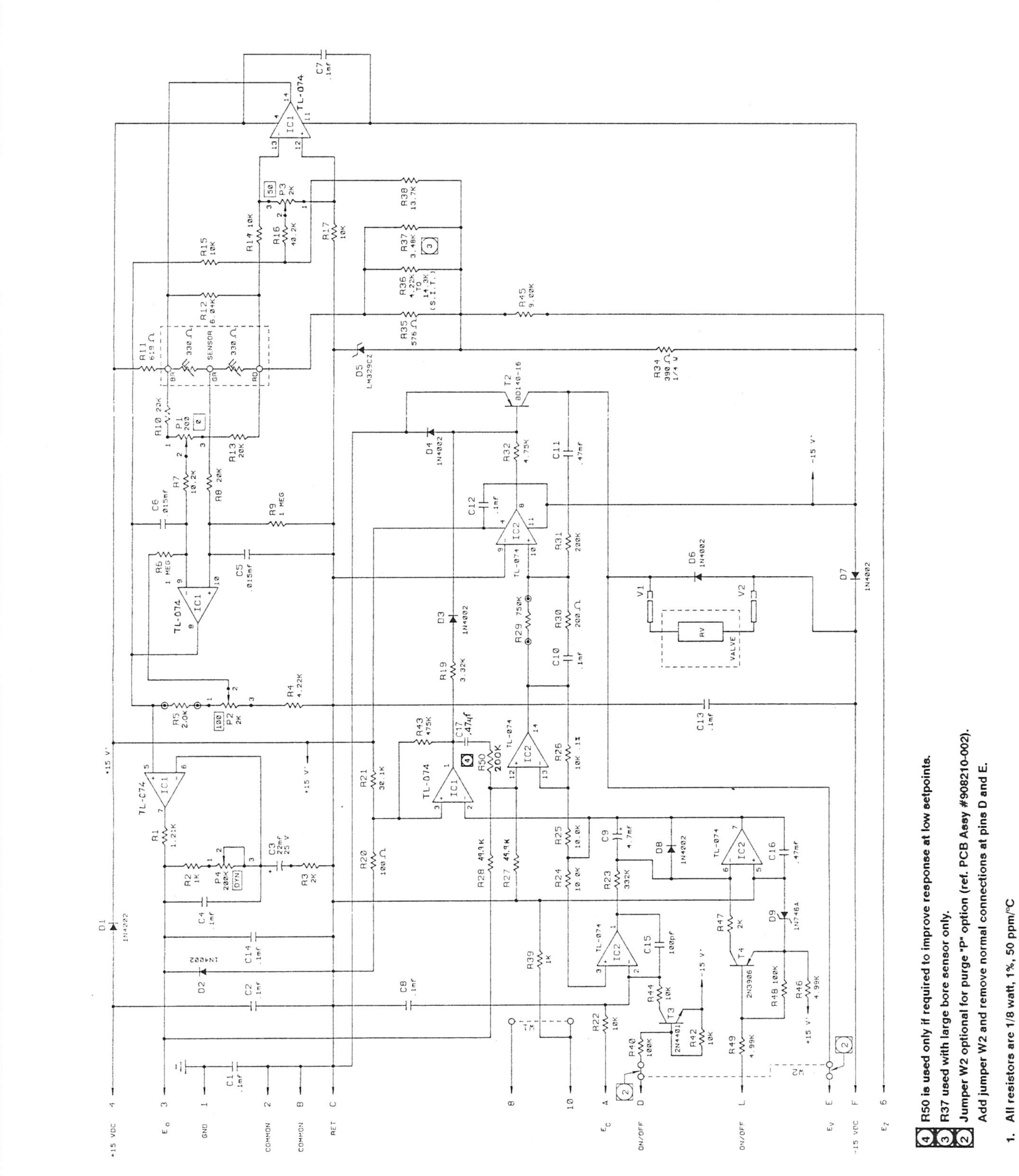


Figure 14A

908206-001 Rev. K

FC-280SA/FC-282S/FM-380A Mass Flow Controller/Flowmeter Schematic

Figure 15 (FC-280A/FM-380A only) - Gas Conversion Selector Switch (SW1) Settings

Conversion Factor (CF) = 0.50 + Σx - See Note (2)

GAS CONVERSION FACTOR	1	2	3	4	5	6	7
	☐	⬚	☐	☐	⬚	⬚	☐
X=	.01	.02	.04	.08	.16	.32	.32
.10		●			●	●	
↓		●			●	●	
↓ (1)		●			●	●	
.49		●			●	●	
.50							
.51	●						
.52		●					
.53	●	●					
.54			●				
.55	●		●				
.56		●	●				
.57	●	●	●				
.58				●			
.59	●			●			
.60		●		●			
.61	●	●		●			
.62			●	●			
.63	●		●	●			
.64		●	●	●			
.65	●	●	●	●			
.66					●		
.67	●				●		
.68		●			●		
.69	●	●			●		
.70			●		●		
.71	●		●		●		
.72		●	●		●		
.73	●	●	●		●		
.74				●	●		
.75	●			●	●		
.76		●		●	●		
.77	●	●		●	●		
.78			●	●	●		
.79	●		●	●	●		
.80		●	●	●	●		

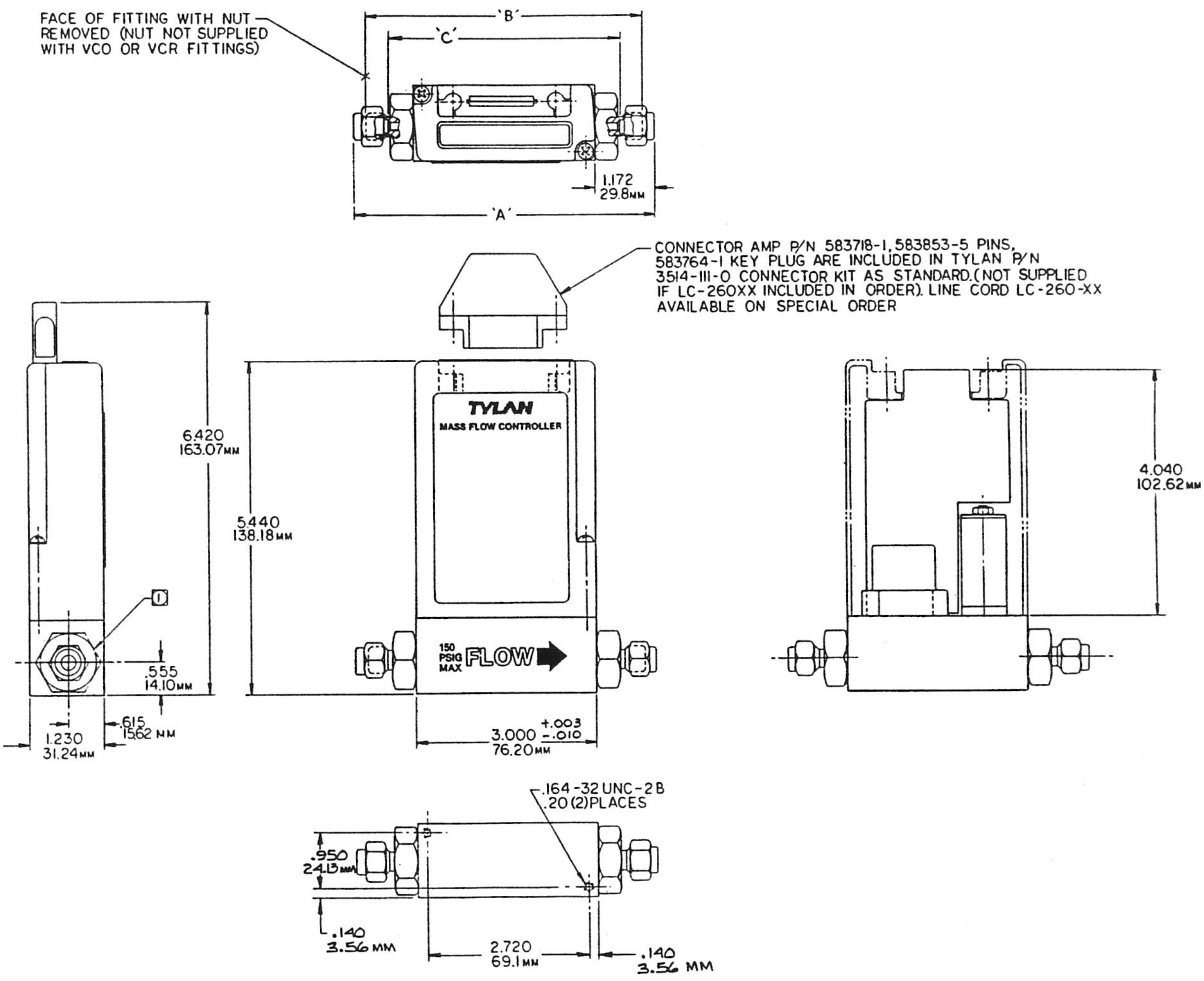
GAS CONVERSION FACTOR	1	2	3	4	5	6	7
	⬚	⬚	⬚	⬚	⬚	☐	☐
X=	.01	.02	.04	.08	.16	.32	.32
.81	●	●	●	●	●		
.82						●	
.83	●					●	
.84		●				●	
.85	●	●				●	
.86			●			●	
.87	●		●			●	
.88		●	●			●	
.89	●	●	●			●	
.90				●		●	
.91	●			●		●	
.92		●		●		●	
.93	●	●		●		●	
.94			●	●		●	
.95	●		●	●		●	
.96		●	●	●		●	
.97	●	●	●	●		●	
.98					●	●	
.99	●				●	●	
1.00		●			●	●	
1.01	●	●			●	●	
1.02			●		●	●	
1.03	●		●		●	●	
1.04		●	●		●	●	
1.05	●	●	●		●	●	
1.10			●	●	●	●	
1.15	●					●	●
1.20		●	●			●	●
1.25	●	●		●		●	●
1.30					●	●	●
1.32		●			●	●	●
1.35	●		●		●	●	●
1.40		●		●	●	●	●
1.41	●	●		●	●	●	●
1.42			●	●	●	●	●
1.45			●	●	●	●	●

(1) For gases having a conversion factor of less than 0.50, set conversion factor to 1.00 and:

Using the actual gas (or equivalent test gas as given in Table 2) adjust the bypass to give an indicated output of 100% at the desired full scale flow rate.

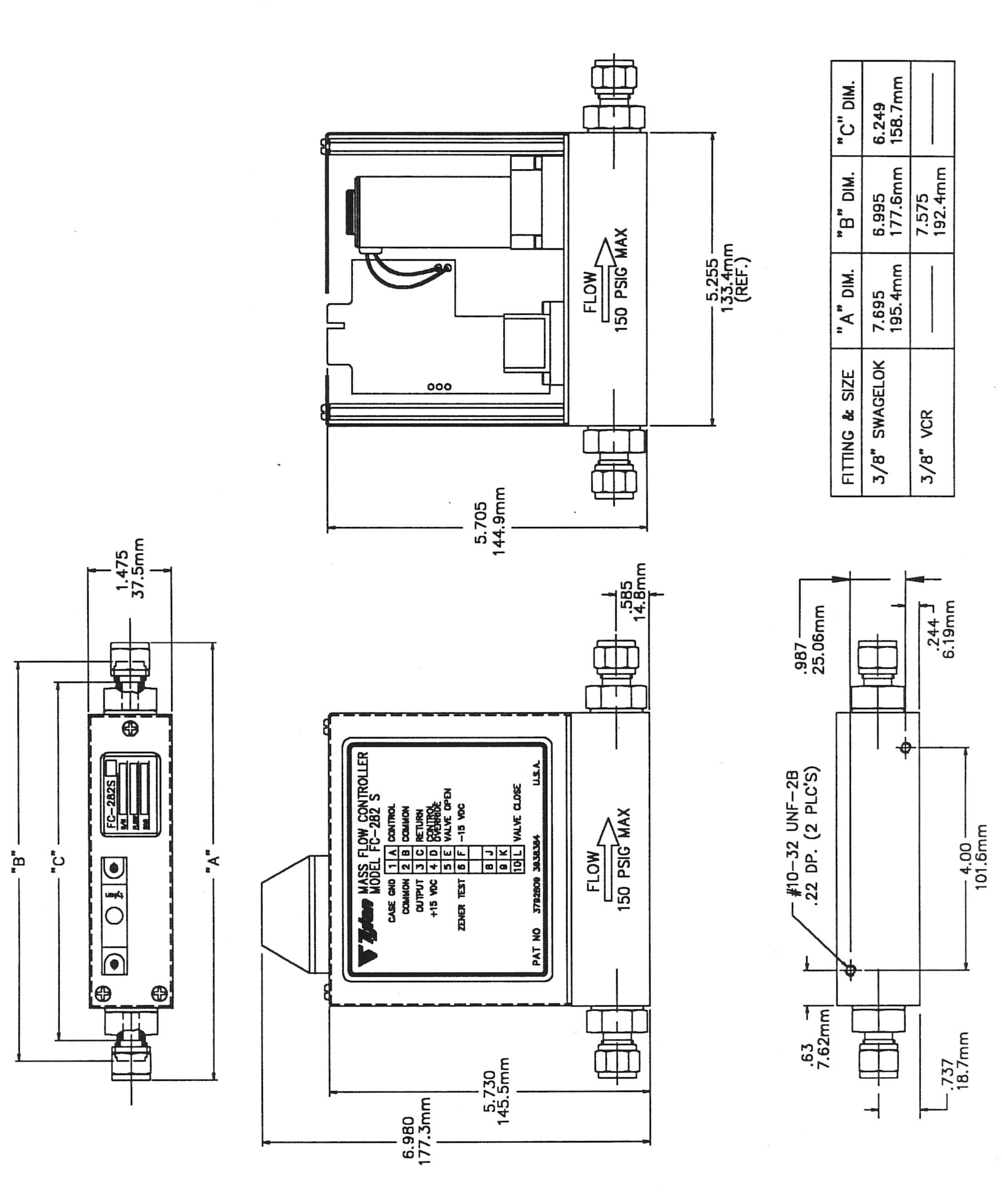
(2) ● indicates open position (depressed on the right-hand side).

Example: Flow controller is calibrated for nitrogen. To use it with methane, conversion factor with respect to nitrogen=0.72, set switches 2, 3 and 5 to the open (off) position. CF=0.72=0.50+0.02+0.04+0.16. Switches 1, 4, 6 and 7 should remain in the closed (on) position.



INSTALLATION DIMENSIONS				
CODE	FITTING & SIZE	'A' DIMENSION	'B' DIM BASE + BODY LGTH	'C' DIM INSIDE FTG
2S	1/8 SWAGELOK	4.84 122.93 MM	4.32 109.72 MM	3.84 97.53 MM
4S	1/4 SWAGELOK	5.03 127.81 MM	4.44 112.77 MM	3.83 20.82 MM
4O	1/4 VCO	—	4.54 115.31 MM	—
4V	1/4 VCR	—	4.88 123.95 MM	—
6S	3/8 SWAGELOK	5.15 130.96 MM	4.56 115.82 MM	3.83 97.43 MM
6O	3/8 VCO	—	4.80 121.92 MM	—
6V	3/8 VCR	—	5.18 131.57 MM	—

Figure 16
FC-280A/FC-280SA/FM-380A
Mass Flow Controller/Flowmeter Outline



FITTING & SIZE	"A" DIM.	"B" DIM.	"C" DIM.
3/8" SWAGELOK	7.695 195.4mm	6.995 177.6mm	6.249 158.7mm
3/8" VCR	—	7.575 192.4mm	—

Figure 16A
FC-282S Mass Flow Controller Outline

Figure 17 - FC-280A/FC-280SA/FM-380A Flow Controller/Flowmeter Parts List

DESCRIPTION	Part Number
Cover	903063-001
Assembly, Circuit Board (FC-280A/FM-380A)	907214-001
Assembly, Circuit Board (FC-280SA)	908210-001
Restrictor Assembly	906026-XXX
Fittings, Outlet	
1/8-inch Swagelok (316 ss)	903452-001
1/4-inch Swagelok (316 ss)	903452-002
1/4-inch VCO (316 ss)	903452-004
1/4-inch VCR (316 ss)	903452-006
3/8-inch Swagelok (316 ss)	903452-003
3/8-inch VCR (316 ss)	903452-007
Fittings, Inlet	
1/8-inch Swagelok (316 ss)	903453-001
1/4-inch Swagelok (316 ss)	903453-002
1/4-inch VCO (316 ss)	903453-004
1/4-inch VCR (316 ss)	903453-006
3/8-inch Swagelok (316 ss)	903453-003
3/8-inch VCR (316 ss)	903453-007
O-rings, Fittings	
Inlet/outlet (Viton)	200472-004
Inlet/outlet (Neoprene)	200475-004
Inlet/outlet (Kalrez)	200471-004
Assembly, Sensor with Seals	
Viton (small bore)	902343-008
Neoprene (small bore)	902343-010
Kalrez (small bore)	908543-001
Kalrez (large bore)	908543-002
Seals only (2 required):	
Viton	908030-001
Kalrez	200471-005
Neoprene	908030-002
Assembly, Valve with Seals	Mass Flow Controller Only
Viton	904149-001
Kalrez	904149-003
Neoprene	904149-005
Seals only (1 required):	
Viton	200472-003
Kalrez	200471-003
Neoprene	200475-003
Valve Orifice Kit (contains all 5)	905491-001
10 sccm - 99 sccm	904006-006
100 sccm - 499 sccm	904006-001
0.5 slm - 2.9 slm	904006-002
3 slm - 10 slm	904006-005
10.1 slm - 30 slm	904006-003

Figure 17A - FC-282S Flow Controller

DESCRIPTION	Part Number
Cover	3523-103-3
Assembly, Circuit Board (FC-282S)	908210-001
Bypass Assembly with seal	908191-XXX
Seal only (Viton)	200472-006
Seal only (Kalrez)	200471-006
Seal only (Neoprene)	200475-006
Fittings, Outlet	
3/8-inch Swagelok (316 ss)	SS-600-1-0138
3/8-inch VCR (316 ss)	SS-8-VCR-1-01238
Fittings, Inlet	
3/8-inch Swagelok (316 ss)	3013-113-01
3/8-inch VCR (316 ss)	6007-008
O-rings, Fittings	
Inlet/outlet (Viton)	200472-004
Inlet/outlet (Kalrez)	200471-004
Inlet/outlet (Neoprene)	200475-004
Assembly, Sensor with Seals	
Viton (small bore)	902343-008
Neoprene (small bore)	902343-010
Kalrez (small bore)	908543-001
Kalrez (large bore)	908543-002
Seals only (2 required):	
Viton	908030-001
Kalrez	200471-005
Neoprene	908030-002
Assembly, Valve with Seals	
Viton	
25-150 slm	908796-001
151-200 slm	908796-002
Kalrez	
25-150 slm	908796-003
151-200 slm	908796-004
Neoprene	
25-150 slm	908796-005
151-200 slm	908796-006
Seals only:	
Viton	
Fixed pole (2 per assy)	200472-018
Orifice plate	200472-030
Base, Valve Upstream	200472-020
Base, Valve Downstream	200472-009
Kalrez	
Fixed pole (2 per assy)	200471-018
Orifice plate	200471-030
Base, Valve Upstream	200471-020
Base, Valve Downstream	200471-009
Neoprene	
Fixed pole (2 per assy)	200475-018
Orifice plate	200475-030
Base, Valve Upstream	200475-020
Base, Valve Downstream	200475-009

APPENDIX A

MASS FLOW CONVERSION FACTORS

1.0 Use of Gas Conversion Factors

The gas conversion factor is a dimensionless ratio describing the sensitivity of a mass flow controller to two different gases. Although this ratio is usually reported as a dimensionless number, the calculations can be followed much more easily if dimensions are added. The gas conversion factor for nitrogen is usually set to one, and then all other gases are referenced back to nitrogen. To determine the gas conversion factor referenced to a gas other than nitrogen, simply ratio the gas conversion factors of both gases referenced to nitrogen. The magnitude of the conversion factor is a function of the heat capacity, density, and molecular structure. A detailed description of how the gas conversion factors are derived is provided in section 3.0. Under normal conditions, it is not necessary for the customer to calculate a gas conversion factor from the heat capacity and gas density data.

This section contains a few examples to help understand how the conversion factors are applied. The conversion factors are primarily used when recalibrating a flow controller or flowing a gas other that the gas for which the controller was calibrated. The first example shows how to calibrate a mass flow controller with the test gas provided in the manual. In order to minimize the errors created in using conversion factors, the test gas is chosen so that the gas conversion factor is as close to one as possible. If the only gas available for calibration was something other than the test gas or nitrogen, then the gas conversion factor must be calculated. This process is shown in example 2. If you are using a mass flow controller for a gas other than the one for which it was calibrated, but you didn't want to recalibrate the MFC, then example 3 demonstrates how to determine the actual flow rate of the gas through the MFC.

<u>*Example 1:*</u> Calibrate a 500 sccm Ammonia (NH_3) flow controller with Nitrous Oxide.

Conversion Factor (NH_3 to N_2O) = 1.03

Calculate the flow rate of Nitrous Oxide which equals 500 sccm and 250 sccm of Ammonia.

$$\frac{500 \text{ sccm } NH_3}{1.03 \; NH_3/N_2O} = 485 \text{ sccm } N_2$$

$$\frac{250 \text{ sccm } NH_3}{1.03 \; NH_3/N_2O} = 243 \text{ sccm } N_2$$

Example 2: Calibrate the same 500 sccm Ammonia flow controller with Argon.

Conversion factor (NH_3 to N_2) = 0.74
Conversion factor (Ar to N_2) = 1.42

$$\text{Conversion factor } (NH_3 \text{ to } Ar) = \frac{0.74\ NH_3/N_2}{1.42\ Ar/N_2}$$

$$= 0.52\ NH_3/Ar$$

Calculate the flow rate of Argon which equals 500 sccm and 250 sccm of Ammonia.

$$\frac{500 \text{ sccm } NH_3}{0.52\ NH_3/Ar} = 962 \text{ sccm Ar}$$

$$\frac{250 \text{ sccm } NH_3}{0.52\ NH_3/Ar} = 481 \text{ sccm Ar}$$

Example 3: A 200 sccm Carbon Monoxide (CO) flow controller is to be temporarily used in a Carbon Dioxide (CO_2) application. How many sccm of CO_2 are flowing when the reading is 73%?

Conversion factor (CO to N_2) = 1.00
Conversion factor (CO_2 to N_2) = 0.74

$$\text{Conversion Factor } (CO_2 \text{ to } CO) = \frac{0.74\ CO_2/N_2}{1.00\ CO/N_2}$$

$$= 0.74\ CO_2/CO$$

$$(73\%) \times (200 \text{ sccm CO}) \times (0.74\ CO_2/CO) = 108 \text{ sccm } CO_2$$

2.0 CONVERSION FACTOR TABLE relative to nitrogen N_2, and test gas

GAS	SYMBOL	TEST GAS	CONVERSION FACTOR REL. TO TEST GAS	CONVERSION FACTOR REL. TO N_2	SPECIFIC HEAT, Cp cal/g C	DENSITY g/l @ 0°C
Acetylene	C_2H_2	C_2H_4	0.97	0.58	0.4036	1.162
Air	-	N_2	1.00	1.00	0.2400	1.293
Allene (Propadiene)	C_3H_4	$CHClF_2$	0.95	0.43	0.3520	1.787
Ammonia	NH_3	N_2O	1.03	0.74	0.4920	0.760
Argon	Ar	Ar	1.00	1.42	0.1244	1.782
Arsine	AsH_3	N_2O	0.95	0.67	0.1167	3.478
Boron Trichloride	BCl_3	$CHClF_2$	0.89	0.41	0.1279	5.227
Boron Trifluoride	BF_3	$CHClF_2$	1.11	0.51	0.1778	3.025
Bromine	Br_2	N_2O	1.14	0.81	0.0539	7.130
Boron Tribromide	BBr_3	CCl_2F_2	1.07	0.38	0.0674	11.180
Bromine Pentafluoride	BrF_5	CCl_2F_2	0.72	0.26	0.1369	7.803
Bromine Trifluoride	BrF_3	CCl_2F_2	1.09	0.39	0.1161	6.108
Bromotrifluoromethane (Freon-13 B1)	$CBrF_3$	CCl_2F_2	1.04	0.37	0.1113	6.644
1,3-Butene	C_4H_6	CCl_2F_2	0.91	0.32	0.3514	2.413
Butane	C_4H_{10}	CCl_2F_2	0.74	0.26	0.4007	2.593
1-Butene	C_4H_8	CCl_2F_2	0.85	0.30	0.3648	2.503
2-Butene CIS/TRANS	C_4H_8	CCl_2F_2	.92/.82	.33/.29	.336/.374	2.503
Carbon Dioxide	CO_2	N_2O	1.04	0.74	0.2016	1.964
Carbon Disulfide	CS_2	C_2H_4	1.00	0.60	0.1428	3.397
Carbon Monoxide	CO	N_2	1.00	1.00	0.2488	1.250
Carbon Tetrachloride	CCl_4	CCl_2F_2	0.88	0.31	0.1280	6.860
Carbon Tetrafluoride (Freon-14)	CF_4	$CHClF_2$	0.92	0.42	0.1654	3.926
Carbonyl Fluoride	COF_2	C_2H_4	0.91	0.55	0.1710	2.945
Carbonyl Sulfide	COS	N_2O	0.93	0.66	0.1651	2.680
Chlorine	Cl_2	N_2O	1.21	0.86	0.1144	3.163
Chlorine Trifluoride	ClF_3	$CHClF_2$	0.87	0.40	0.1650	4.125
Chlorodifluoroethane (Freon-22)	$CHClF_2$	$CHClF_2$	1.00	0.46	0.1544	3.858
Chloroform	$CHCl_3$	CCl_2F_2	1.11	0.39	0.1309	5.326
Chloropentafluoroethane (Freon-115)	C_2ClF_5	CCl_2F_2	0.68	0.24	0.1640	6.892
Chlorotrifluoromethane (Freon-13)	$CClF_3$	CCl_2F_2	1.08	0.38	0.1530	4.660
Cyanogen	C_2N_2	C_2H_4	0.98	0.45	0.2613	2.322
Cyanogen Chloride	ClCN	C_2H_4	1.02	0.61	0.1739	2.742
Cyclopropane	C_3H_5	$CHClF_2$	1.00	0.46	0.3177	1.877
Deuterium	D_2	N_2	1.00	1.00	1.7220	0.180
Diborane	B_2H_6	$CHClF_2$	0.95	0.44	0.5080	1.235
Dibromodiflouromethane	CBr_2F_2	CCl_2F_2	0.55	0.19	0.1500	9.362
Dibromethane	CH_2Br_2	$CHClF_2$	1.02	0.47	0.0750	7.760
Dichlorodifluoromethane (Freon-12)	CCl_2F_2	CCl_2F_2	1.00	0.35	0.1432	5.395
Dichlorofluoromethane (Freon-21)	$CHCl_2F$	$CHClF_2$	0.93	0.42	0.1400	4.592
Dichlorodimethylsilane	$(CH_3)_2SiCl_2$	CCl_2F_2	0.71	0.25	0.1882	5.758
Dichlorosilane	SiH_2Cl_2	$CHClF_2$	0.88	0.40	0.1500	4.506
1,2-Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$	CCl_2F_2	0.63	0.22	0.1600	7.626

GAS	SYMBOL	TEST GAS	CONVERSION FACTOR REL. TO TEST GAS	CONVERSION FACTOR REL. TO N_2	SPECIFIC HEAT, Cp cal/g C	DENSITY g/l @ 0°C
1,1-Difluoroethylene	$C_2H_2F_2$	$CHClF_2$	0.93	0.43	0.2240	2.857
Dimethylamine	$(CH_3)_2NH$	CCl_2F_2	1.05	0.37	0.3660	2.011
Dimethyl Ether	$(CH_3)_2O$	CCl_2F_2	1.10	0.39	0.3414	2.055
2,2-Dimethylpropane	C_3H_{12}	CCl_2F_2	0.61	0.22	0.3914	3.219
Disilane	Si_2H_6	CCl_2F_2	0.89	0.32	0.3100	2.776
Ethane	C_2H_6	$CHClF_2$	1.08	0.50	0.4097	1.342
Ethanol	C_2H_6O	CCl_2F_2	1.11	0.39	0.3395	2.055
Ethyl Acetylene	C_4H_6	CCl_2F_2	0.91	0.32	0.3513	2.413
Ethyl Chloride	C_2H_5Cl	CCl_2F_2	1.11	0.39	0.2440	2.879
Ethylene	C_2H_4	C_2H_4	1.00	0.60	0.3650	1.251
Ethylene Oxide	C_2H_4O	$CHClF_2$	1.13	0.52	0.2680	1.965
Fluorine	F_2	N_2	0.98	0.98	0.1873	1.695
Fluoroform (Freon-23)	CHF_3	$CHClF_2$	1.08	0.50	0.1760	3.127
Freon-11	CCl_3F	CCl_2F_2	0.93	0.33	0.1357	6.129
Freon-12	CCl_2F_2	CCl_2F_2	1.00	0.35	0.1432	5.395
Freon-13	$CClF_3$	CCl_2F_2	1.08	0.38	0.1530	4.660
Freon-13 B1	$CBrF_3$	CCl_2F_2	1.04	0.37	0.1113	6.644
Freon-14	CF_4	$CHClF_2$	0.92	0.42	0.1654	3.926
Freon-21	$CHCl_2F$	$CHClF_2$	0.93	0.42	0.1400	4.592
Freon-22	$CHClF_2$	$CHClF_2$	1.00	0.46	0.1544	3.858
Freon-113	CCl_2FCClF_2	CCl_2F_2	0.57	0.20	0.1610	8.360
Freon-114	$C_2Cl_2F_4$	CCl_2F_2	0.63	0.22	0.1600	7.626
Freon-115	C_2ClF_5	CCl_2F_2	0.68	0.24	0.1640	6.892
Freon-C318	C_4F_8	CCl_2F_2	0.47	0.17	0.1850	8.930
Germane	GeH_4	C_2H_4	0.95	0.57	0.1404	3.418
Germanium Tetrachloride	$GeCl_4$	CCl_2F_2	0.75	0.27	0.1071	9.565
Helium*	He	He	1.00	1.42	1.2410	0.179
Hexafluoroethane (Freon-116)	C_2F_6	CCl_2F_2	0.68	0.24	0.1843	6.157
Hexane	C_6H_{14}	$CHClF_2$	0.51	0.18	0.3968	3.845
Hydrogen	H_2	H_2	1.00	1.01	3.4190	0.090
Hydrogen Bromide	HBr	N_2	1.00	1.00	0.0861	3.610
Hydrogen Chloride	HCl	N_2	1.00	1.00	0.1912	1.627
Hydrogen Cyanide	HCN	N_2O	1.07	0.76	0.3171	1.206
Hydrogen Fluoride	HF	N_2	1.00	1.00	0.3479	0.893
Hydrogen Iodide	HI	N_2	1.00	1.00	0.0545	5.707
Hydrogen Selenide	H_2Se	N_2O	1.11	0.79	0.1025	3.613
Hydrogen Sulfide	H_2S	N_2O	1.13	0.80	0.2397	1.520
Iodine Pentafluoride	IF_5	CCl_2F_2	0.70	0.25	0.1108	9.900
Isobutane	$CH(CH_3)_3$	CCl_2F_2	0.56	0.20	0.3872	3.593
Isobutylene	C_4H_6	CCl_2F_2	0.83	0.30	0.3701	2.503
Krypton	Kr	Ar	1.00	1.41	0.0593	3.739
Methane	CH_4	N_2O	1.01	0.72	0.5328	0.715
Methanol	CH_3OH	C_2H_4	0.98	0.58	0.3274	1.429
Methyl Acetylene	C_3H_4	$CHClF_2$	0.94	0.43	0.3547	1.787
Methyl Bromide	CH_2Br	C_2H_4	0.97	0.58	0.1106	4.236
Methyl Chloride	CH_3Cl	C_2H_4	1.05	0.63	0.1926	2.253
Methyl Fluoride	CH_3F	C_2H_4	0.93	0.56	0.3221	1.518
Methyl Mercaptan	CH_3SH	$CHClF_2$	1.13	0.52	0.2459	2.146
Methyl Trichlorosilane	$(CH_3)SiCl_3$	CCl_2F_2	0.71	0.25	0.1640	6.669

Tylan General

GAS	SYMBOL	TEST GAS	CONVERSION FACTOR REL. TO TEST GAS	CONVERSION FACTOR REL. TO N_2	SPECIFIC HEAT, Cp cal/g C	DENSITY g/l @ 0°C
Molybdenum Hexafluoride	MoF_6	CCl_2F_2	0.60	0.21	0.1373	9.366
Monoethylamine	$C_2H_5NH_2$	CCl_2F_2	0.99	0.35	0.3870	2.011
Monomethylamine	CH_3NH_2	$CHClF_2$	0.99	0.45	0.4343	1.386
Neon	Ne	Ar	1.00	1.42	0.2460	0.900
Nitric Oxide	NO	N_2	1.00	1.00	0.2328	1.339
Nitrogen	N_2	N_2	1.00	1.00	0.2485	1.250
Nitrogen Dioxide	NO_2	N_2O	1.03	0.74	0.1933	2.052
Nitrogen Trifluoride	NF_3	$CHClF_2$	1.05	0.48	0.1797	3.168
Nitrogen Trioxide	N_2O_3	CCl_2F_2	1.11	0.39	0.2063	3.393
Nitrosyl Chloride	NOCl	C_2H_4	1.02	0.61	0.1632	2.920
Nitrous Oxide	N_2O	N_2O	1.00	0.71	0.2088	1.964
Octafluorocyclobutane (Freon-C318)	C_4F_6	CCl_2F_2	0.50	0.18	0.1850	8.930
Oxygen	O_2	N_2	0.99	0.99	0.2193	1.427
Oxygen Difluoride	OF_2	C_2H_4	1.06	0.63	0.1917	2.409
Pentaborane	B_5H_9	CCl_2F_2	0.72	0.26	0.3800	2.816
Pentane	C_5H_{12}	CCl_2F_2	0.60	0.21	0.3980	3.219
Perchloryl Fluoride	ClO_3F	CCl_2F_2	1.12	0.39	0.1514	4.571
Perfluoropropane	C_3F_8	CCl_2F_2	0.47	0.17	0.1940	8.388
Phosgene	$COCl_2$	$CHClF_2$	0.97	0.44	0.1394	4.418
Phosphine	PH_3	N_2O	1.07	0.76	0.2374	1.517
Phosphorous Oxychloride	$POCl_3$	CCl_2F_2	0.85	0.30	0.1324	0.684
Phosphorous Pentafluoride	PH_5	CCl_2F_2	0.85	0.30	0.1610	5.620
Phosphorous Trichloride	PCl_3	CCl_2F_2	1.01	0.36	0.1250	6.127
Propane	C_3H_8	CCl_2F_2	1.01	0.36	0.3885	1.967
Propylene	C_3H_6	$CHClF_2$	0.90	0.41	0.3541	1.877
Silane	SiH_4	C_2H_4	1.00	0.60	0.3189	1.433
Silicon Tetrachloride	$SiCl_4$	CCl_2F_2	0.80	0.28	0.1270	7.580
Silicon Tetrafluoride	SiF_4	CCl_2F_2	0.98	0.35	0.1691	4.643
Sulfur Dioxide	SO_2	N_2O	0.96	0.69	0.1488	2.858
Sulfur Tetrafluoride	SF_4	CCl_2F_2	1.00	0.36	0.1593	4.821
Sulfur Hexafluoride	SF_6	CCl_2F_2	0.74	0.26	0.1592	6.516
Sulfuryl Fluoride	SO_2F_2	CCl_2F_2	1.10	0.39	0.1543	4.562
Tetrafluorahydrazine	N_2F_4	CCl_2F_2	0.91	0.32	0.1820	4.640
Trichlorofluoromethane	CCl_3F	CCl_2F_2	0.93	0.33	0.1357	6.129
Trichlorosilane	$SiHCl_3$	CCl_2F_2	0.93	0.33	0.1380	6.043
Trichloro-Trifluoroethane (Freon-113)	CCl_2FCClF_2	CCl_2F_2	0.57	0.20	0.1610	8.360
Triisobutyl Aluminum	$(C_4H_9)_3Al$	CCl_2F_2	0.17	0.06	0.5080	8.848
Titanium Tetrachloride	$TiCl_4$	CCl_2F_2	0.76	0.27	0.1200	8.465
Trichloro Ethylene	C_2HCl_3	CCl_2F_2	0.91	0.32	0.1459	5.862
Trichlorethane (TCA)	$C_2H_3Cl_3$	CCl_2F_2	0.78	0.28	0.1654	5.950
Trimethylamine	$(CH_3)_3N$	CCl_2F_2	0.79	0.28	0.3710	2.639
Tungsten Hexafluoride	WF_6	CCl_2F_2	0.54	0.19	0.1079	13.290
Uranium Hexafluoride	UF_6	CCl_2F_2	0.55	0.20	0.0888	15.700
Water Vapor	H_2O	N_2	0.82	0.82	0.4450	0.804
Vinyl Bromide	CH_2CHBr	$CHClF_2$	1.01	0.46	0.1241	4.772
Vinyl Chloride	CH_2CHCl	$CHClF_2$	1.04	0.48	0.2054	2.788
Xenon	Xe	Ar	1.00	1.42	0.0378	5.858

NOTE: Conversion of controller to or from hydrogen or helium may alter dynamic response, stability, and leak through rate. In accordance with SEMI Standard E12-86, Standard Pressure is defined as 760 mm Hg (14.7 psia). Standard Temperature is defined as 0°C.

3.0 DETERMINING MASS FLOW CONVERSION FACTORS

The ratio of a flow rate ω_1 for a particular gas, to the flow rate of ω_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.

Equation 1:

$$\frac{C_1}{C^2} = \frac{\omega_1}{\omega_2}$$

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.

Equation 2:

$$\omega = \frac{KN}{\rho C_p}$$

Cp is the specific heat in cal/g-°C, ρ is the density of the gas at 0°C in g/liter, and 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 or controller, K is a constant.

Substituting Equation 2 into Equation 1 yields the following relationship:

Equation 3:

$$\frac{C_1}{C^2} = \frac{KN_1}{\rho_1 C_{p_1}} \times \frac{\rho_2 C_{p_2}}{KN_2}$$

If we define both the conversion factor and the correction factor N, for the gas nitrogen to be 1.00, Equation 3 can be reduced to the following:

Equation 4:

$$C = \frac{\rho N_2 C_p N_2}{\rho_1 C_{p_1}} N_1$$

By dropping the Subscript 2 and replacing ρN_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:

Equation 5:

$$C = \frac{0.3106}{\rho C_p} N$$

Section 2.0 lists the conversion factors for commonly used gases as derived from equation 5.

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 flow meter 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:

$$\frac{1.01}{.71} = \frac{5000}{\omega}$$

$$\omega = \frac{.71 \times 5000}{1.01} = 3514 \ sccm$$

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:

Equation 6:

$$\rho = \frac{\omega_1}{\omega_T}\rho_1 + \frac{\omega_2}{\omega_T}\rho_2 + \ldots + \frac{\omega_n}{\omega_T}\rho_n$$

Where:

- ω_1 is the flow of gas #1
- ω_2 is the flow of gas #2
- ω_n is the flow of gas #n
- ω_T is the total flow.
- ρ_1 is the density of gas #1
- ρ_2 is the density of gas #2
- ρ_n is the density of gas #n.

The equivalent specific heat is given by the equation:

Equation 7:

$$C_p = F_1 C_{p_1} + F_2 C_{p_2} + \ldots + F_n C_{p_n}$$

Where:

Equation 8:

$$F_1 = \frac{\omega_1 \rho_1}{\omega_T \rho}, F_2 = \frac{\omega_2 \rho_2}{\omega_T \rho}, \ldots F_N = \frac{\omega_n \rho_n}{\omega_T \rho}$$

The equivalent value of N is:

Equation 9:

$$N = \frac{\omega_1}{\omega_T} N_1 + \frac{\omega_2}{\omega_T} N_2 + \ldots \frac{\omega_n}{\omega_T} N_n$$

For gas mixtures, the values ρ, Cp and N from Equations 6, 7, and 9 are used in Equation 5.

Combining Numbers 5 through 8 results in the following equation:

Equation 10:

$$C = \frac{.3106\left(\frac{\omega_1}{\omega_T}N_1 + \frac{\omega_2}{\omega_T}N_2 + \ldots + \frac{\omega_n}{\omega_T}N_n\right)}{\frac{\omega_1}{\omega_T}\rho_1 C_{p_1} + \frac{\omega_2}{\omega_T}\rho_2 C_{p_2} + \ldots + \frac{\omega_n}{\omega_T}\rho_n C_{p_n}}$$

3.1 VALUES FOR THE MOLECULAR CORRECTION FACTOR

TABLE 1

GAS	N
Monatomic gases (e.g. argon, helium, xenon)	1.01
Diatomic gases (e.g. carbon monoxide, nitrogen, oxygen, nitric oxide)	1.00
Triatomic gases (e.g. carbon dioxide, nitrous oxide, sulfur dioxide)	.94
Polyatomic gases (e.g. ammonia, arsine, diborane, ethane, methane, phosphine)	.88

Note: Standard pressure is defined as 760 mm Hg (14.7 psia)
Standard temperature is defined as 0°C.

APPENDIX B

RECOMMENDED PROCEDURES TO AVOID CONTAMINATION OF HIGHLY REACTIVE GAS SYSTEMS

(Technical Bulletin 8901)

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 $1x10^{-8}$ 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, i.e. N_2 or Ar with less than 10 ppm O_2 and water vapor.

PURGING IS NOT NECESSARY, NOR IS IT RECOMMENDED, AT ANY OTHER TIME

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 microcavities 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

Figure 1 is a picture of a typical reactive gas flow controller installation. To initiate purge procedure, close Valves 2 and 3, and open Valve 1. Evacuate the line to base pressure. Close Valve 1 and open Valve 3 for one or two minutes to pressurize the controller with purge gas. Close Valve 3 and open Valve 1 to evacuate the controller back down to base pressure. Repeat the alternating application of evacuation and pressurization at least 20 times. 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 unreacted process gas.
> CONSULT YOUR PLANT SAFETY ENGINEER.

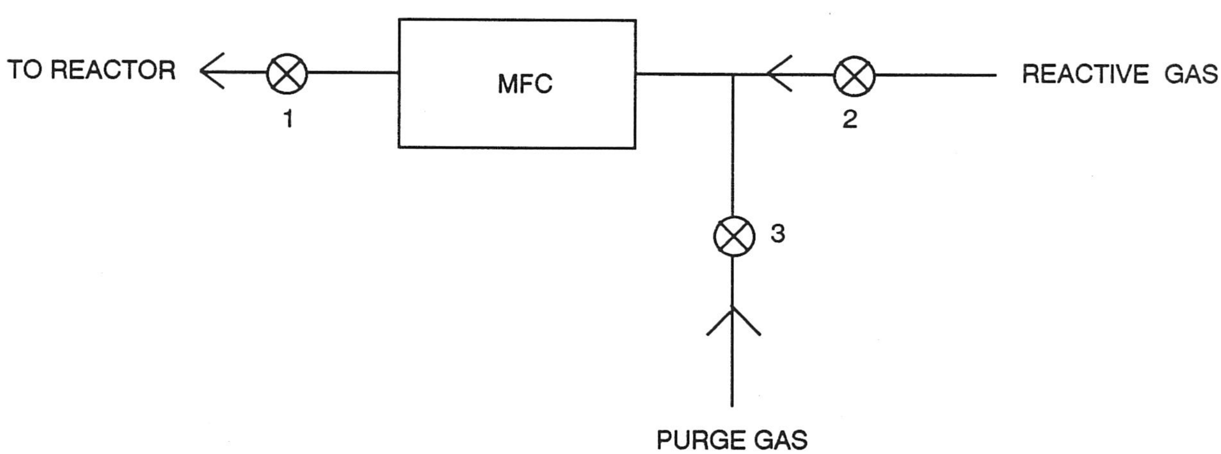


Figure 1

Highly Reactive Gas System

890818ra

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FLOW PRODUCTS

MASS FLOW CONTROLLERS/FLOWMETERS

FC-260 Series	Normally-open, thermal valve, up to 200 slm
FC-280A Series	Fast responding, normally-closed solenoid valve, up to 30 slm
FC-280SA	Ultra-fast response of 0.5 seconds, normally-closed solenoid valve up to 200 slm
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FC-2900 Series	Ultra-fast response, normally-closed solenoid valve with auto-zero up to 1000 slm
FC-760/780/1000 Series	Metal sealed for ultra-high leak integrity from 1 sccm full-scale, up to 50 slm
Source Series	Vaporized liquid mass flow controllers

FLOW CONTROL AND CALIBRATION SYSTEMS

Readout/Control Boxes	Monitor and control of mass flow products
Calibrators	Portable secondary standard calibration system
MFS-460 Series	Computer controlled gas blending and dilution systems
Tymgard	Microprocessor based process controller

OPTIONS

Mass Flow Instrument Maintenance Kits
Gasket kits used to seal and protect the mass flow device from harsh environmental conditions
Internal or external 4-20 mA DC control and output converter
+24 VDC series solenoid shut-off valves
FC-2900B Battery option enables field operation from a ±12 VDC battery source
RS-232C interface option on readout/control systems

VACUUM PRODUCTS

DIAFLEX PRESSURE SENSORS

CMH	1 to 100 Torr, temperature controlled up to 32°C, accurate to within 0.12% of reading
CMHT	1 to 10 Torr, temperature controlled up to 70°C, accurate to within 0.8% of reading
CMT	1 Torr, temperature compensated, accurate to within 0.15% of reading
CMO Series	1 and 2 Torr, accurate to within 0.25% of reading
CML Series	10 to 1,000 Torr, accurate to within 0.50% of reading
CMS	2 to 1,000 Torr, with 2 adjustable setpoints, accuracy to within 0.50% of setpoint
80-6B	Power supply and display module for DiaFlex pressure sensors

MOTORIZED THROTTLE VALVES

MDV Series	Accurate control of chamber pressure, 1 x 10^{-6} to 1,000 Torr range; heated version also available with temperature controlled to 70°C.
MCV Series	Chevron type; also available in cryo-cooled version

PRESSURE CONTROL SYSTEMS

AC-2	Adaptive throttle valve controller, microprocessor based, downstream pressure control for use with MDV and MCV series
ACR-26	Adaptive controller display module provides both command and readout functions for MDV and MCV series. Used with the AC-2, provides complete, automatic adaptive control in downstream pressure control applications.
80-2	Automatic throttle valve control module, downstream pressure control with manual gain and phase adjustment
80-1	Upstream pressure control module for use with CV series solenoid control valve

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NOTES: