Model 8000 Automated Sampler

Operations and Maintenance Manual

Version 3.02

January 17, 2019

ATEC Model 8000 Toxic Air Sampler

Limited Warranty

Atmospheric Technology (ATEC) warrants to the original purchaser of the Model 8000 Toxic Air Sampler that should it prove defective by reason of improper workmanship and/or material:

> Parts and Labor: For one year on all components from the date of original purchase, we will repair or replace, at our option, any defective part without charge for the part. Parts used for replacement are warranted for the remainder of the original warranty period.

To obtain warranty service, return the unit to ATEC. Shipping expenses are your responsibility. This WARRANTY DOES NOT COVER damage caused by: modification, alteration, repair or service of this unit by anyone other than ATEC; physical abuse to, or misuse of the unit; operation in a manner contrary to the instructions which accompany the unit; freight damage; or any damage caused by acts of God such as lightning or fluctuation in electrical power. This warranty also excludes all costs arising from installation, adjustment of user controls, initial technical adjustments (set-up) and user-required maintenance including filter changing.

Any express warranty not provided herein, and any remedy which, but for this provision, might arise by implication or operation of law, is hereby excluded and disclaimed. The implied warranties of fitness for any particular purpose are expressly limited to a term of one year.

Under no circumstances shall ATEC be liable to purchaser or any other person for any incidental, special, or consequential damages, whether arising out of breach of warranty, breach of contract, or otherwise.

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1. Introduction

This manual covers the installation, operation and routine maintenance of the ATEC Model 8000 Automated Sampler. This instrument is a microprocessor controlled sampler that can be programmed to draw ambient air through cartridges, filters, or sorbent tubes for specified time periods. The sampler can be configured with various options to provide up to three independent flow channels. Channel 1 is a multi-port channel containing 8 ports. Each port can be programmed to sample over a specific time period. The optional Channels 2 and 3 consist of single ports that can be activated concurrently or for different time periods than Channel 1. All channels use separate mass flow controllers (MFC) to regulate the flowrate. The number of ports on Channel 1 can be increased in multiples of 8 up to a total of 24 ports by adding the Model 80xx expansion modules.

The sampler has the following features:

- Channel 1 ports and Channels 2 and 3 can be programmed to sample on a specified date (e.g. 06/01/95) for a specified duration.
- All channels are automatically leak checked prior to sampling. If a leak is detected, a leak check error is recorded for that channel or port.
- Sampling date, start time, stop time, average flowrate, minimum flowrate, maximum flowrate, total volume sampled, sampling time duration, and error status are stored for all channels. These data can be displayed on the screen or transferred to a laptop or PC. Sampling data (i.e. time, flowrate, and volume) can be logged at a minimum of every 5 minutes. These items are included in the data transmitted to the PC or laptop.
- The mass flow controllers are auto zeroed prior to sampling.
- A leak check option is provided to manually leak check a port or channel.

2.

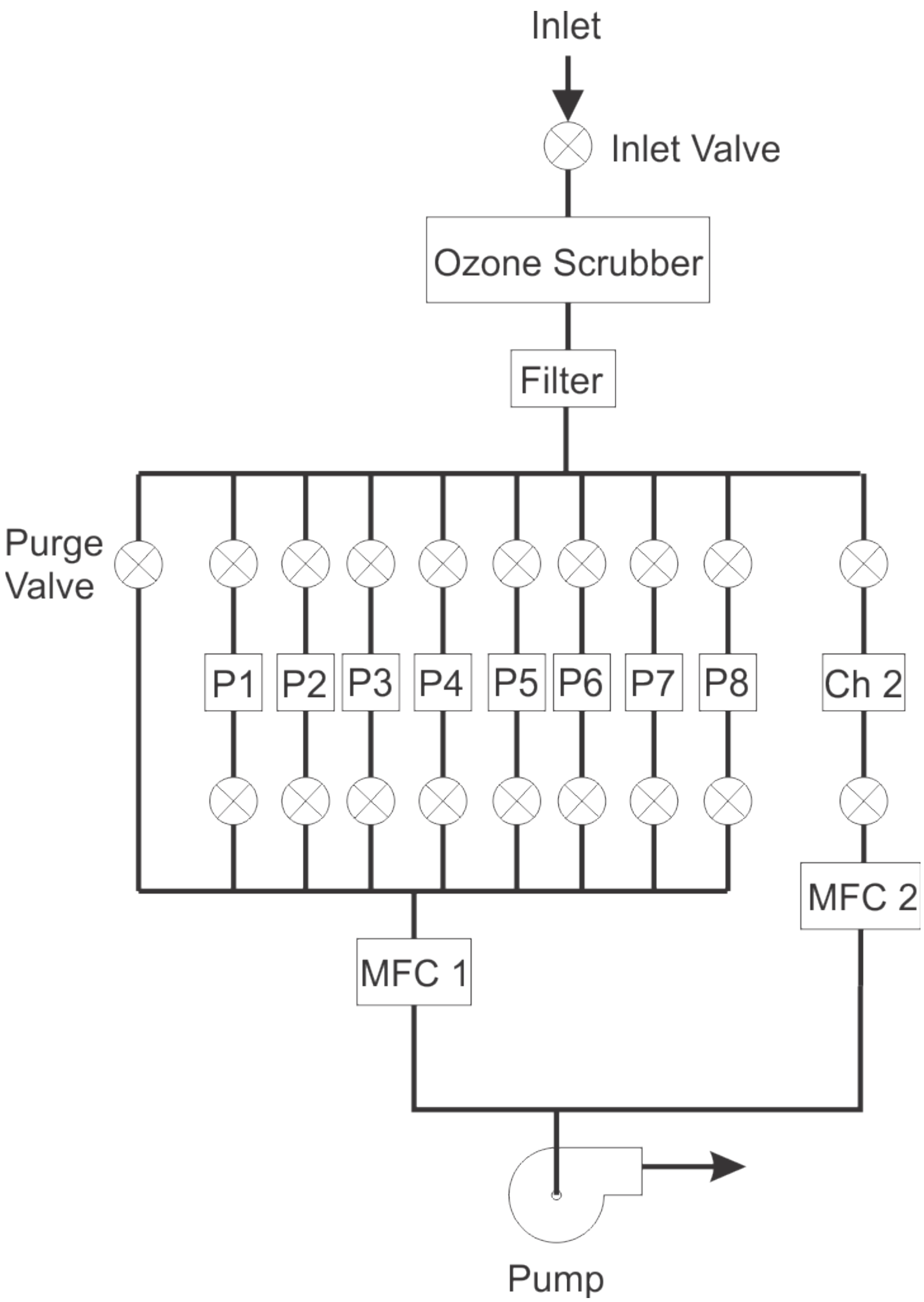
3. System Configuration

3.1 Hardware

3.1.1 System Specification

Flowrate:	Nominal 1.0 lpm with Sep-Pak cartridges. Adjustable between 0-2 lpm depending on cartridge restriction. Optional ranges available. Accuracy: ±1% FS
No. of Channels:	8 ports on Channel 1. Two other single port channels with independent operation are optional. One blank position. The number of channels can be increased up to 24 with the addition of the either the Model 8008 or Model 8016 expansion modules.
Size:	17” (width) x 19” (depth) x 7” (high)
Weight:	Approximately 50 pounds
Power:	115VAC, 7 amps maximum.
Inlet:	¼” tubing connector.
Cartridge Connections:	Polypropylene Luer fittings.
Construction Materials:	Teflon filter and PFA Teflon internal tubing, copper coated with KI ozone scrubber, stainless steel solenoid valves with viton seals.

3.1.2 Sampler Components



This section describes the general operation and major components of the ATEC Model 8000 Automated Sampler. Shown here is a schematic diagram of the sampler. Air enters the sampler to the inlet valve. The inlet valve is normally closed and allows leak checking of the entire flow system. Out of the inlet valve, the air passes through the ozone scrubber and filter, and then enters a solenoid manifold. When a selected port is activated, the air stream passes through the inlet solenoid, through the cartridge, and returns to the outlet solenoid valve. Two solenoids are used to isolate the cartridge when sampling is not occurring. The flow from the outlet solenoid valve passes through the outlet manifold to a mass flow controller (MFC) and is exhausted with a vacuum pump. Only one port for Channel 1, consisting of two solenoids and the cartridge, can be activated at a given time. However, two optional channels can be used to obtain concurrent or co-located samples. A microcomputer with a touchscreen display provides control for the automated sampling.

3.1.2.1 **Inlet Valve**

The first component after the sampler inlet fitting is the inlet valve. This valve isolates the system from the inlet air and allows the system to be fully leak checked. If the ozone scrubber or inlet filter is changed, the total sysem should be checked for leaks. This valve enables this to be done. If the SOP screen is used to setup sampling, a system leak check is performed after the ports are leak checked.

3.1.2.2 **Inlet Filter**

A Teflon PFA filter holder contains a 47mm Teflon filter to remove particulates from the air stream prior to entering the flow lines. The filter should be periodically changed; the frequency will depend on conditions at the sampling site.

3.1.2.3 **Temperature Controlled Ozone Scrubber**

A temperature controlled copper tube coated with KI is used to remove ozone during carbonyl sampling with DNPH cartridges. The microcomputer maintains a constant heater temperature inside the ozone scrubber enclosure. The heater temperature can be set using the Setup Option on the sampler display. The heater temperature in Celsius is shown on the display. The controller is factory set to 50°C. An alarm is displayed if the temperature exceeds +/- 5°C.

3.1.2.4 **Solenoid Valves**

Two 15VDC solenoid valves are used for each port. The normally closed valves are mounted upstream and downstream of the cartridge. During normal sampling, both solenoid valves are opened. A leak check is performed during the first 30 seconds of each sampling interval. During leak check, the upstream solenoid is closed and the entire sampling line, downstream solenoid valve, cartridge, and flow controller are evacuated by the vacuum pump. If a small leak exists, the flowmeter will detect the flow. During automatic operation, the microcomputer will set a flag if the flow exceeds 0.03 lpm (other values can be selected by the operator) at the end of the 30 second leak check.

3.1.2.5 **Cartridge Connections**

Inlet and outlet tubes are connected using male Luer fittings that have been swaged on the end of the PFA Teflon flow lines attached to the solenoid valves. Some types of cartridges have a male fitting on one end that requires a female connector to adapt the sample lines. Excess tubing has been provided to accommodate different length cartridges. Pushing or pulling the tubing at the point where it emerges from the front panel can change the tubing length extending from the front panel. Make sure that the tubing and not the Luer connection is pulled; excess force may separate the fitting from the PFA Teflon tubing.

3.1.2.6 **Mass Flow Controllers**

Mass flow controllers with a range of 0-2 liters/min (other ranges available) are used to control the sampling flowrate in each channel. Operation and maintenance instructions are provided in Appendix A. Using the Setup option on the display sets the flowrate.

3.1.2.7 **Vacuum Pump**

A diaphragm pump is used to draw air through the instrument. The pump is mounted inside the sampler. It is rated for continuous duty and can maintain a maximum vacuum level of 24 in Hg. using two MFCs flowing at 1 lpm.

3.1.2.8 **Optional 8-Port or 16-Port Expansion Module**

The Model 8000 can be expanded to a total of either 16 ports or 24 ports by the addition of an expansion module. The Model 8008 adds an additional 8-ports while the Model 8016 adds an additional 16-ports. The expansion module is electrically connected to the Model 8000 by a single ribbon cable attached to the “EXP 1” connector on the rear panel. Inlet and outlet pneumatic lines are connected by attaching the “Flow 1” and “Flow 2” lines form the Model 8000 to the “Flow 1” and “Flow 2” on the expansion module.

The Model 8000 looks for the expansion unit when power is turned on. If the expansion module is not connected or there is a communication problem, the software will not display the additional ports. If the connection between the expansion module and the Model 8000 is correctly made, the additional ports will display once the Model 8000 is turned off and then turned back on.

4. Running the System

4.1 Hardware Setup

Upon arrival, check all shipping containers for damage and notify the shipper if damage has occurred. Retain the shipping container because the sampler must be returned in the original packaging if warranty repairs are required. Plug the main power cord into a 115VAC outlet. Turn the main power on by using the power switch on the rear of the sampler. When power is applied, the display will illuminate in approximately 20 seconds.

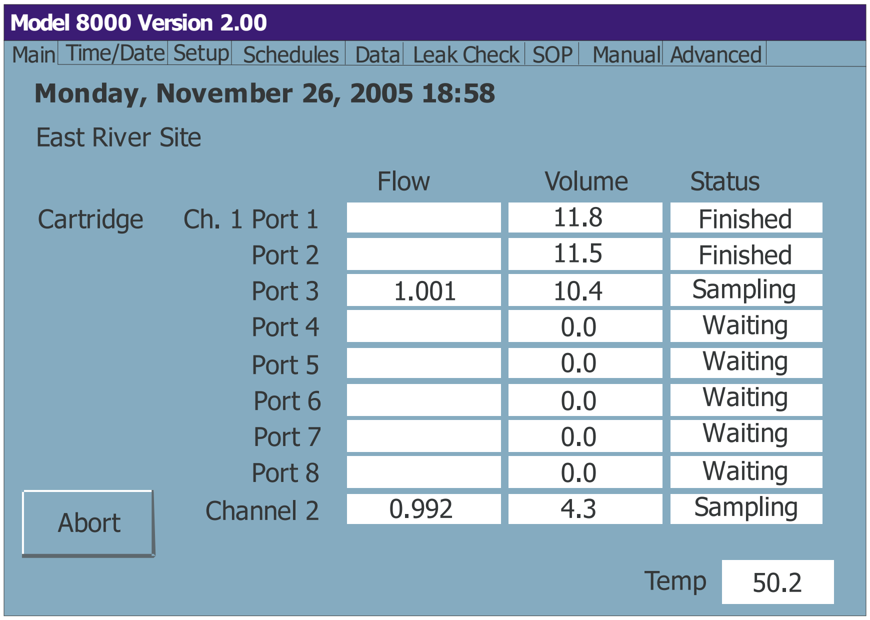
The Model 8000 uses an WVGA LCD color touch screen display to show current operating status and to enter information into the computer. The computer is accessed using the tabs which are displayed on the screen and can be activated by finger touch or stylus. A pencil eraser also works well. The touch level of the screen can be calibrated by using the ***TouchScreen*** button in the ***Setup*** function.

A USB connector is mounted below the touchscreen. This can be used to connect a mouse, keyboard, label printer, or jump drive for retrieving data and updating the sampler software.

All components, tubing, and fittings have been cleaned prior to assembly. The completed sampler has been purged with clean humidified air prior to shipment. After unpacking the instrument and verifying operation, the Model 8000 should be purged with humidified zero air for a minimum of 24 hours before sampling.

4.2 Display and Function Tabs

Normally the display will show the default main screen as illustrated here. This screen displays current sampling information and provides function tabs for the operator to enter operating parameters and retrieve data. The main screen displays the following:



4.3 Date and Time

The current date, time, and day of the week is displayed at the top of the screen

4.4 Site Identification

A site identification label can be displayed below the time and date to identify the sampler. For example “East River Site” could be shown to identify this sampler from others used in a sampling network.

4.5 Cartridge Sampling Information

The cartridge flow rate and total volume are displayed. These values are continuously updated every 10 seconds. One of the following status indicators will also be shown in each status box, depending upon the sampling conditions:

Sampling—Indicates a channel is sampling

Waiting—Indicates a channel has been programmed to sample

Purging—Indicates a channel is purging prior to sampling

Idle—Indicates a channel has not been programmed to sample

Aborted—Operator terminated sampling

Finished—A successful sample has been collected without errors

Leak Err—Cartridge failed spedified leak rate tolerance on start-up

Post Leak Err—Cartridge failed auto leak check at the end of sampling

Temp Tol—Ozone scrubber temperature exceeded ±5°C

Flow Tol—Specified cartridge flow rate tolerance exceeded

Zero Tol—Cartridge MFC required more than 1% zero compensation

Errors—Multiple errors, power outage, or sample aborted

4.6 Ozone Scrubber Temperature

The temperature of the ozone scrubber is displayed in the lower right hand corner of the screen.

4.7 Abort

The **Abort** button is used to terminate sampling after purging has started. Pressing the **Abort** button will require the operator to enter a new sampling sequence to resume sampling.

4.8 Function Tabs

Several function tabs are located along the top of the screen to enable the operator to interact with the sampler to set the date and time, enter operating parameters, input a sampling schedule, retrieve data, leak check cartridges, set-up the sampler using the SOP (Standard Operating Procedure) option, manually operate the hardware, and input advance system parameters. The operation of each tab is described in the Programming Section.

5. <u>Programming the Model 8000</u>

The Model 8000 uses eight function tabs to allow the operator to enter or retrieve information from the sampler**: Time/date, Set-up, Schedules, Data, Leak Check**, **SOP, Manual**, and **Advanced**. **Time/date** is used to enter the current time and date. **Set-up** is used to configure the sampler and store sampling parameters. Sampling schedules are entered through the **Schedules** tab. Data can be displayed or downloaded to a jump drive using the **Data** tab. Cartridges are manually leak checked with the **Leak Check** tab. The **SOP** tab uses a standard operating procedure to install and leak check the cartridges and program sampling schedules. In **Manual** mode, the hardware can be uniquely activated to allow checkout and troubleshooting. The system configuration and advance parameters are entered using the **Advanced** tab.

5.1 Time/Date

The time and date that is stored in the Model 8000 can be changed using the **Time/Date** tab. When this tab is touched, the operating system data and time selection screen will appear. Once the changes have been made, pressing the **OK** button in the upper right corner of this window will bring back the main screen that should show the correct day of the week, date, and time.

5.2 Setup

The **Setup** tab is used to input cartridge operating parameters, , enable software updates, and calibrate the touch screen. When the **Setup** tab is touched, a green screen appears which allows the operator to change the following parameters for cartridge sampling:

Setup Parameters

Ch.1 MFC Set Point

The sampling flow rate for the Channel 1 cartridge is specified in this box.

Ch.2 MFC Set Point

The sampling flow rate for the Channel 2 cartridge is specified in this box

Flow Leak Limit

The flow leak limit is the maximum flow rate that is allowed for a cartridge to pass either manual or automatic leak check. This value has the same units as the flow rate.

Flow Tolerance

The cartridge flow rate is continuously monitored during sampling. If the flow rate specified in Ch.1 MFC or Ch.2 MFC Set Point box is outside this tolerance, an error status for flow tolerance will be generated. This value has the same units as the flow rate.

Cycled Schedule

The Cycled Schedule value specifies the time interval in days between schedules. This allows the operator to schedule repeated samples at a set interval automatically (i.e. sampling repeated every 6 days if set to 6). The value must be greater than 1 to be applied.

Purge Time

Purge time specifies the purging time in minutes of the inlet line and inlet manifold before sampling the cartridges.

Data Write Interval

The Data Write Interval specifies the time interval for recording canister pressure and cartridge flow rate data. The minimum time interval is 5 minutes.

Site Label

Touching the site label box brings up an alphanumeric keypad that can be used to input a site specific label (e.g. East River Site No. 2) that appears on the main screen.

TouchScreen

Pressing the **TouchScreen** button brings up the touchscreen calibration routine. The screen is calibration by touching five crosses that appear at different places on the sceen. After all the crosses have been touched, touch the middle of the screed to teminate the routine and to save the new settings.

Set

Pressing the **Set** button saves the data that was entered in the Set-up screens and returns the program to the main screen.

Update

If the **Update** button is pressed, the sampler searches for the presence of a jump drive in the USB connector below the screen. If the jump drive is present and has the proper updating files, the sampler software will be updated. If the update is successful, a message will appear on the screen instructing that file transfer was successful and that the system will reboot. If the jump drive cannot be recognized or it does not have the proper update files, a message will be display warning of an incomplete update and no software changes will be made.

5.3 Schedule

The **Schedule** tab is used to enter sampling schedules for the cartridges. Ccartridge channels can run independently or together (co-located sampling). When the **Schedule** tab is pressed, a yellow screen appears which shows the start date, start time, and sample duration for Port 1. The values in each box can be changed by touching the text box and using the keypad to enter the appropriate values. All times are military times with midnight as 00:00. A 24-hour sample would be entered with a start time of 00:00 and a duration of 24:00 hours for the date entered in the "date" box. An identification label (e.g. Can 13420, Cart A6672) can also be entered for each cartridge. This label will appear with the data to identify each sample. If only one cartridge is to be sampled, the **Done** button is pressed and the sampler will return to the main screen.

If additional channels are to be sampled, The **Next** button must be pressed to display the schedule for the next port. For each subsequent port, the start date, start time, and duration can be entered. If the port sampling time is to follow immediately after the previous port and is of the same duration, the information can be entered automatically by check the box labeled “Follow the previous port”. After all the ports are displayed, the data for Channel 2 can be entered. The **Done** button can be used to return to the main screen at any time. The Prev button will show the previous screen.

5.4 Leak Check

The **Leak Check** tab is used to verify the cartridge connections prior to sampling. The first screen is identified as “Port 1 Leak Check” and is used to leak check the Port 1 cartridge. Cartridges are leak checked by turning on the vacuum pump and closing the upstream isolation solenoid valve. The downstream solenoid valve remains open to evacuate the cartridge, mass flow controller and tubing to the pump. If a leak is present, the flow controller will show a small flow. A leak is identified if the flow rate exceeds the flow leak limit set in the setup section.

The **Start** button is pressed to begin the leak check. The leak rate box will show “testing” during the measurement period. The cartridge leak check runs for 30 seconds. During this time, the vacuum pump is started and the flow rate is monitored. If the flow rate is above the leak limit at the end of the test, a “Failed” message is displayed and the leak flow rate is displayed in red. If a cartridge fails, the test should be repeated to verify the first test. After repeated failures, the fittings should be checked and the cartridge re-tested or replaced. If the test passes, the rate will appear in green. The test can be repeated by pressing the **Start** button, or the **Next** button can be used to advance to the next port, or Channel 2.

If the **Next** button is pressed after checking the last cartridge channel, a total system leak check can be performed. This checks the entire cartridge sampling path from the outlet of the inlet valve to the vacuum pump. This is especially important when maintenance is performed, and the Teflon filter or ozone scrubber has been replaced. The total system leak check if performed by closing the system valve and opening the inlet and outlet valves for Port 1. The pump is started, and the flow is monitored for 40 seconds. A leak is identified if the flow rate exceeds the flow leak limit set in the setup section.

5.5 Data

The **Data** tab is used to display or download data. After sampling has been completed, the **Data** tab is touched and the "Port 1 Data" screen is displayed. The stored data includes: start time; stop time; average, minimum, and maximum flow rate; collected volume; error status, and elapsed time.

NOTE: The start time is when the sampling cycle starts. This includes 20 seconds of leak check prior to allowing flow through the cartridge. The end time is when the sampling cycle is completed after a thirty second leak check. Therefore, the total time for flow through the cartridge is the end time minus the start time minus 50 seconds.

If the label printer option has been installed, a label can be printed for each port by pressing the **Label** button. On each label the following information will be printed: start date/time, end date/time, total sampled volume, average flow rate, and error flag. The error flag is the sum valve of all errors that occurred during the sample period. The error values are:

0	No Errors
2	Leak Check Flow Limit Exceeded
4	Temperature Tolerance Exceeded
16	Flow Rate Tolerance Exceeded
32	Flow Rate Zero Exceeded
64	Power Failure
128	Aborted

256 Post Run Leak Check Flow Limit Exceeded

The entire data set can be downloaded to a jump drive inserted into one of the USB connectors below the screen. The following jump drives are known to work with this sampler:

Lexar JumpDrive Sport 256MB

Lexar JumpDrive Sport 512MB

SanDisk Cruzer Micro 256MB

Other jump drives may work with the samplers, but only those shown above have been verified.

It takes approximately 20 seconds for the operating the system to recognize the jump drive. Pressing the ***Store*** button will cause all available data to be transferred. If data has already been transferred to the jump drive, it must be deleted from the jump drive before the drive can be used again to store data. Once all the files have been received, a message will appear confirming completion of the transfer. An example of transmitted data is shown below:

```
Southern County Site
Cartridge A312
Ch. 1 Cartridge Started at 11/25/01 8:15:06 PM
       Flow Rate Set Point 1.000 lpm
                Stopped at 11/26/01 8:15:36 PM
              Total Volume 1428.05 liters
         Total Sample Time 24.00 hours
         Average Flow Rate 0.996 l/min
         Minimum Flow Rate 0.984 l/min
         Maximum Flow Rate 1.017 l/min
       Pre Start Leak Rate 0.000 l/min
          Ending Leak Rate -0.003 l/min
                Error Code 4
              Error Status Temperature Tolerance Exceeded

     Time          Flow Rate          Volume        Temp

11/25/01 8:15:28 PM      1.902          0.35          48.8
11/25/01 8:20:36 PM      0.997          5.47          50.1
11/25/01 8:25:36 PM      0.996          10.45          49.7
      •                  •
      •                  •
      •                  •
11/26/01 7:50:35 PM      0.998          1403.48          49.8
11/26/01 7:55:45 PM      0.994          1408.62          49.8
```

11/26/01 8:00:45 PM	0.995	1413.60	50.0
11/26/01 8:05:55 PM	0.996	1418.75	49.9
11/26/01 8:11:05 PM	0.994	1423.90	50.1

The **Next** button on the 8000 Data screen will advance to the next data screen or **Exit** can be used to return to the main screen.

5.6 Power Failures

If a power failure occurs during sampling, the sampler will resume sampling based on the programmed sampling schedule. The sampling schedule and data will not be lost during a power failure. The actual sampling time will be shorter than programmed because of the power loss. Data will show a power loss error, and the volume/time data will show the missing sampling interval during the power outage.

5.7 SOP

The **SOP** tab provides a Standard Operating Procedure for installing, leak checking, and scheduling the Model 8000. The SOP software guides the user through the required procedures and enables inexperienced operators to successfully program the sampler.

Pressing the **SOP** tab initializes the program. The **Back**, **Next,** and **Exit** buttons are used to advance through the procedure or return to the main screen.

Initially, the program brings up a screen that requires the user to check the number of cartridges to be sampled. Several screens follow which lead the operator through an automated leak check procedure. Each cartridge must pass leak check or the program will not continue. After all of the cartridges have been installed and leak checked, and the total system leak check has been performed successfully, the SOP leads the user through a scheduling procedure to program the sampling times. When scheduling has been completed, the Next button returns the program to the main screen. After sampling has been finished, the operator uses the Data tab to retrieve the collected data.

5.8 Manual Mode

A **Manual** tab is provided to allow the operator to activate any solenoid valve or pump. This mode is useful in troubleshooting and testing individual components. In addition, the flow set point of each mass flow controller can be individually set. Upon leaving the manual mode screen, all settings revert to the values used in automatic mode**.**

NOTE*: All values displayed in Manual Mode are raw signal values and are NOT corrected by the calibration constants entered in the Set-Up screen.*

5.9 Advanced

Additional settings can be stored in the Advanced Setup section that is accessed through the **Advanced** tab. This portion of setup should only be used by individuals familiar with the operation and calibration of components used in the Model 8000. Changing the values in the Advanced Setup will alter the accuracy of the instrument. Several of the parameters are hardware dependent. These are set at the factory and require a password to be entered to be changed.

Mass Flow Controller Calibration

The calibration of the mass flow controllers can be changed by entering the appropriate slope and intercept for each mass flow controller. See Appendix A.

Mass Flow Meter Range (password controlled)

If the full scale range of a mass flow controller is changed, the corresponding full-scale range must be entered in the MFC Range box.

Heater Set Point

The set point of the ozone scrubber heater may be changed by replacing the value in the box marked Heater Set Point. The normal set point is 50 °C.

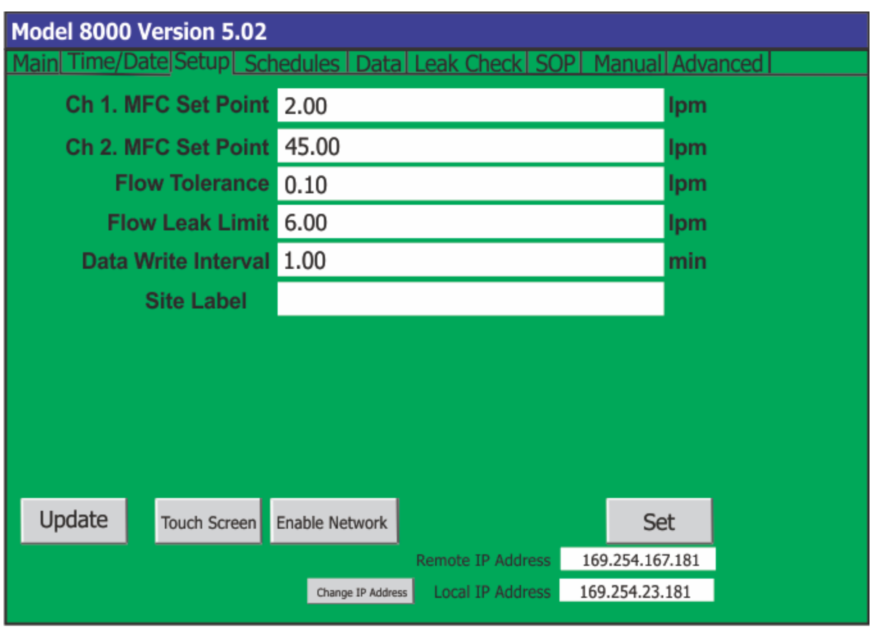
6. Local Area Network Connection

If the sampler is to be connected to a local area network (LAN), the following steps will need to be taken to enable communication between the sampler and a PC or tablet on the same LAN.

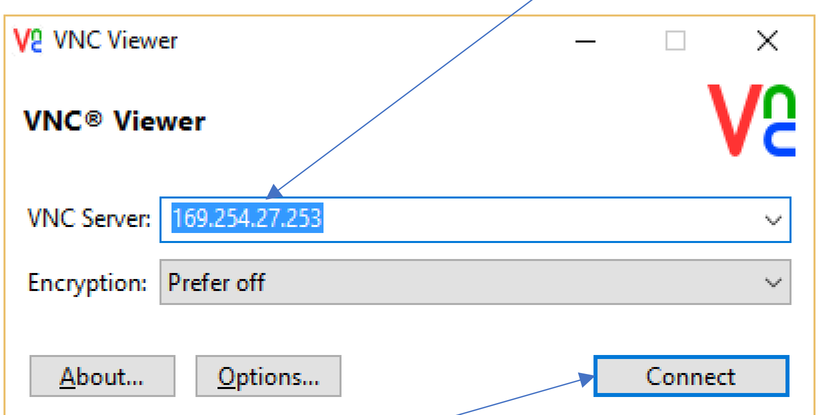
6.1 Initial Network Setup

Before communication is started, the IP addresses of the sampler and the remote PC/tablet must be determined. This will insure that only these devices can communicate and other devices will be locked out. The remote PC/tablet must also have a copy of "VNC Viewer" for communicating (enclosed on jump drive). This software is available on the internet. The following steps need to be done only once unless noted.

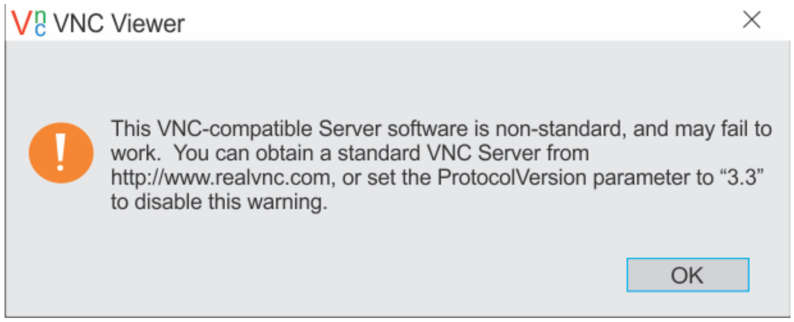
1. Connect the PC/tablet and the sampler to the LAN.
2. On the PC/tablet, bring up the "command prompt" window.
    - Type: ***ipconfig***
    - Record the IP Address that appears under the Ethernet Adapter setting: Autoconfiguration IPv4 Address. This is the "Remote IP Address".
3. On the Sampler, go to the **Setup** screen. The IP Address for the sampler will be in the text box with the label "Local IP Address".



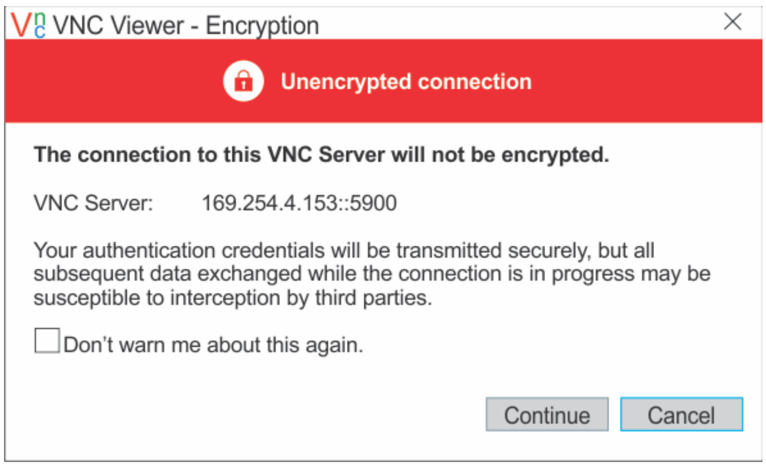
4. If the Local IP Address is invalid or needs to be changed, select the "Change IP Address" button and do the following (you will need a USB keyboard plugged into the USB port below the screen):
    a. Select the ENET1 icon.
    b. Select the "Specify an IP Address" button.
    c. Enter an IP Address, Subnet, and Default Gateway. For example, if the IP Address is 169.254.167.102, the subnet is 255.255.255.1, and the gateway is 169.254.1.1.
    d. Exit the screen by OK in the upper right corner of the small center screen.
    e. Exit the Network Connections screen by selecting the "X" in the upper right hand corner.
5. Select the "Remote IP Address" text box. A keypad will appear in the upper left corner. Enter the IP Address of the PC/Tablet that is to be connected to the sampler.
6. On the Sampler, press the **Enable Network** button to start communication.
7. On the PC/tablet, start VNC Viewer. Enter the "Local IP Address" in the box labeled "VNC Server:" and the encryption should be "Prefer Off".



8. On the PC/tablet, press the "Connect" button and the following screen may appear:



8. Press the “OK” button to proceed.
9. The following screen will appear:



10. Press the “Continue” button and connection will be made. The “Setup” screen of the sampler should now be appearing on the PC/Tablet.

These steps do not have to be done again. If a different PC/Tablet is to be used, the “Remote IP Address” will have to updated in the sampler. If communication is no longer needed, clicking the “Disable Network” button the Setup screen will terminate communication. It can be reactivated at any time by clicking on the “Enable Network” button. The values for the IP Addresses and the network status (enabled or disabled) are retained in memory and communication will automatically be restarted if a power failure or a reboot occurs on the sampler.

7. Maintenance

This section describes routine maintenance procedures for the Model 8000 Automated Sampler. All other repair work should be performed by trained personnel.

7.1 Vacuum Pump

To remove the vacuum pump from the sampler, remove the top and side covers. Remove the inlet tube and disconnect the electrical connector. Remove the four screws attaching the pump mounting bracket to the side of the sampler and remove the pump.

Inspect the pump but DO NOT at any time lubricate any of the parts with oil, grease, or petroleum products nor clean with acids, caustics or chlorinated solvents. Be very careful to keep the diaphragm from contacting any petroleum product or hydrocarbons. It can affect the service life of the pump.

WARNING: To prevent explosive hazard, do NOT pump combustible liquids or vapors with these units. Personal injury and or property damage would result.

To clean or replace the filters and/or rubber gasket, remove the five screws in the top of the unit. The filters and gasket are located beneath this top plate. Remove the filters and wash them in a solvent and/or blow off with air and replace. The gasket may be cleaned with water. Replace the filters in proper position and replace the gasket. Note that the gasket and top plate will fit in one position only.

To replace the diaphragm, remove the socket cap screws from the head of the pump. The diaphragm is held in place by two Phillips head screws. Remove screws, retainer plate, and the diaphragm. The diaphragm will fit in any position on the connecting rod. Replace the plate and the two Phillips head screws. Torque to 17- inch-pounds.

CAUTION: Do not raise any burrs or nicks on the heads of these screws. These burrs could cause damage to the inlet valve.

For replacing the inlet and outlet valve, remove the slotted machine screw that holds each valve in place. The stainless steel inlet and outlet valves are not interchangeable. Clean them with water. When replacing the outlet valve, place the new valve in location and note there is a retaining bar near the machine screw hole. This retaining bar holds the valve in position. When replacing the inlet valve, note that the valve holder is marked with an X in one corner. This X should be in the lower right hand corner toward the inlet of the air chamber. Replace the head and tighten the socket head screws. Torque to 30 inch-pounds.

WARNING: The motor may be thermally protected and can automatically restart when the overload resets. Always disconnect the power source before servicing. Personal Injury and/or property damage could result.

Do not attempt to replace the connecting rod or motor bearings. If after cleaning the unit and/or installing a new Service Kit, the unit still does not operate properly, contact your representative, the factory, or return the pump to an authorized Service Center.

7.2 Cartridge Filter

The operator should periodically replace the Teflon filter located in the cartridge sample path. The replacement frequency will depend on site conditions. The filters must be replaced when the flow rate through the cartridges cannot be maintained. However, it is recommended that the filter be replaced before this condition exists. The operator should periodically check the filter and determine when it needs to be replaced. To replace the filter, turn off the main power to the sampler, remove the four screws that fasten the top to the sampler, slide the top towards the rear of the instrument and remove. Loosen the tubing nuts on each end of the filter housing and remove the housing. Remove the filter by removing the retaining ring on the filter using the hand wrenches supplied with the sampler. Replace the filter with a 10 micron Teflon filter and replace the filter housing in the sampler. Perform the Sampler Leak Check described in Section 5.3.

7.3 Ozone Scrubber

The ozone scrubber should be replaced after approximately 100,000 ppb ozone hours of either sampling or purging at 1 lpm. This is generally every 6-12 months depending on the sampling frequency. The operating life in hours can be estimated by:

Life (hrs) = 100,000/Average Ozone concentration at site.

The ozone scrubber is replaced by removing the top cover on the sampler and removing the ¼" stainless steel sample line with fittings and the Teflon filter holder on each side of the scrubber. Remove the two retaining knobs on the heater cover and remove the cover, exposing the heater block and copper tube denuder. Remove the insulation surrounding the heater block and carefully remove the denuder. Install a new denuder and replace the insulation and heater cover. Replace the sample lines and Teflon filter.

Perform a Sampler Leak Check by disconnecting the sampling line at the rear of the instrument and capping the inlet. Use either the manual mode screen or schedule button to start sampling through one of the ports and additional channels.. During sampling, the cartridge flow in all channels should be very close to zero after several minutes of sampling. If a flow is indicated (usually 0.03 slp or larger), the interior lines should be checked for the presence of a leak.

7.4 Mass Flow Controller Calibration Procedure

Each mass flow controller should be calibrated on an annual schedule. The mass flow controllers can be calibrated either electronically or manually. Manual calibration consists of adjusting the zero (no flow) and span potentiometers on the side of the mass flow controller using a reference flow standard. The potentiometers can be accessed through holes in the flow controller housing. Electronic calibration can be performed by inserting the appropriate calibration constants into the advanced portion of the setup screen.

The calibration of the mass flow controllers can be changed by entering the appropriate slope and intercept for each mass flow controller.

The calibration of the flow controllers in ATEC samplers with software version 5.0 or higher requires a special calibration procedure because the analog-to-digital converters in the embedded computer do not read negative voltages. Therefore, to detect MFC negative zero drift, a zero bias needs to be applied to the MFC. Once the zero is established, the slope is applied to adjust the MFC span to agree with a certified flow standard referenced to EPA standard conditions of 25°C and 760mm Hg.

It is important to understand that the flow values shown on the Manual Screen can be referenced to two conditions, either the MFC manufacturer's reference condition of 0°C and 760 mmHg, or another referenced condition, usually 25°C and 760 mmHg. The latter is the condition used during sampling and also displayed in red on the Manual Screen when the "Calibrated Flow" box is checked.

When it becomes necessary to re-calibrate the MFCs, the flowing procedure should be followed:

1. Go to the Advanced screen and change the slope for the MFC to be calibrated to 1.00 and change the intercept value to the negative value of 1.5% of the full MFC range (the MFC range is displayed in the Advanced Screen). For example, if the MFC has a full range of 2.0 lpm, the intercept value should be set to -0.030.

2. Go to the Manual screen and check the box next to "Calibrated Values". With no flow, mechanically adjust the MFC zero potentiometer until the screen display for the flow rate is close to zero (refer to the MFC Operations Manual in the Appendix for adjustment procedures). There will be some small oscillations around zero when doing this but try to get it as close as possible.

3. Activate the necessary valve(s) and pump to establish flow rate through the MFC. Set the MFC flow set value to the nominal flow (the flow rate most commonly used in sampling). Double press the Set button to apply the new flow rate set value. If there is no Set button then pressing the Accept button will set the flow rate.

4. Attach a certified calibrator in series with the MFC to record the flow rate. For calibrating the Channel 1 MFC attach the calibrator to one of the port outlet tubes. For calibrating the Channel 2 MFC, attach the calibrator to the Channel 2 outlet tube.

   If the calibrator is a direct volume measuring device (e.g. soap bubble, BIOS, etc.) then you need to record the volumetric flow rate along with the temperature and pressure. If the calibrator is a thermal device (e.g. mass flow meter) then you need to record the reference temperature and pressure for the calibrator.

5. Use the following equation to calculate the slope from the recorded calibration data and desired sampler reference conditions, where:

   PC=calibrator pressure (mm Hg)
   TC=calibrator temperature (°K)
   T=Sampler MFC reference temperature (°K)—normally 298 °K
   PF=MFC factory reference pressure = 760 mm Hg
   TF=MFC factory reference temperature = 273 °K
   W=calibrator flow rate
   F=sampler flow rate set

   $$\text{Slope} = \frac{TF \times PC \times W \times T}{PF \times TC \times F \times TF}$$

   To simplify, this equation reduces to:

   $$\text{Slope} = \frac{0.392 \times PC \times W}{TC \times F}$$

   for a sampler MFC reference condition of 25 °C and 760 mm Hg

   For example, a volumetric calibrator is operated in series with the sampler to check the flow rate at 3.8 ccpm. The “Calibrated Values” box is checked and the sampler will be calibrated to display the flow rate at the normal EPA reference conditions of 25°C and 760 mm Hg. During the calibration procedure, the calibrator air flow is measured at 292°C and 740 mm Hg and 4.1 ccpm. The slope is calculated as:

$$\text{Slope} = \frac{0.392 \times 740 \text{ mmHg} \times 4.1 \text{ ccpm}}{292°\text{K} \times 3.8 \text{ ccpm}} = 1.072$$

6. Go to the Advanced screen and change the slope to the value calculated in Step 5. To verify the slope, return to the Manual screen and verify that the Calibrated Values box is checked when validation the slope. Calculate the resulting flow using:

$$\text{Flow} = \frac{0.392 \times \text{PC} \times \text{W}}{\text{TC}}$$

The value calculated here should be very close to that shown in the Flow Set box. It can be trimmed in by adjusting the slope using the following:

New Slope=Old Slope x (calculated flow/desired flow)

Final Note: The MFC zero will drift over time. To compensate for this, the sampler software auto zeros the MFC prior to sampling. However, a “zero tolerance” error flag will be displayed whenever the computer needs to zero compensate +/- 1% of the range of the MFC. At this point, ATEC recommends that the MFC be mechanically zeroed to eliminate excessive software compensation which may be a cause of a MFC malfunction.

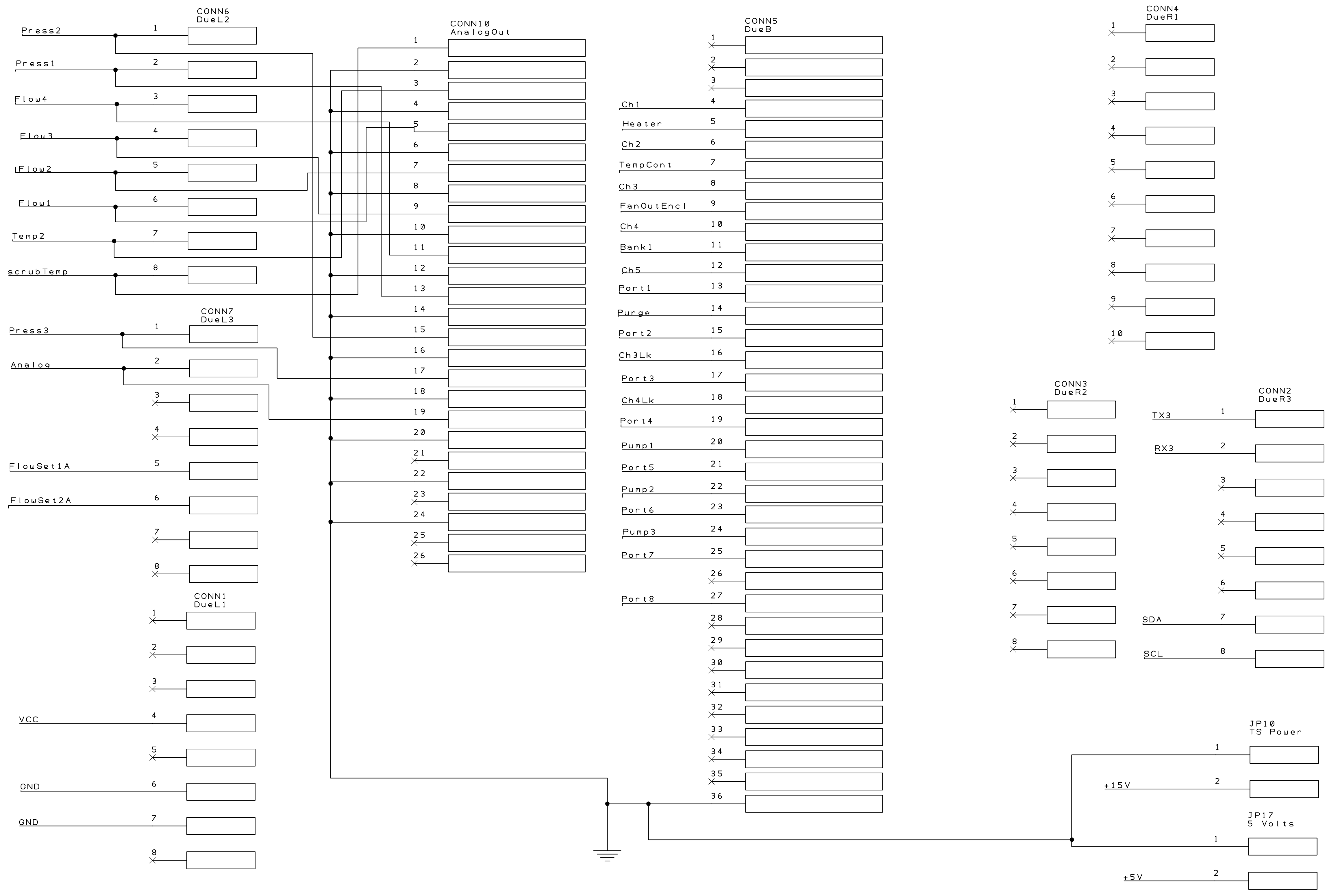
8. **Model 8000 Parts List**

Components of the Model 8000 are shown in the following Parts List. This list does not include common parts such as fuses, fittings, or fasteners.

Chassis	8000-100-1
Front Panel	8000-100-2
Rear Panel	8000-100-3
Mass Flow Controller (Specify Range)	8000-200-1
Cartridge Tubing Set	8000-200-4
Cartridge Filter Holder	8000-200-5
Cartridge Filter (47mm Teflon)	8000-200-6
Ozone Scrubber Heater (Complete)	8000-200-10
Ozone scrubber (KI copper coil)	8000-200-11
Heater Relay	8000-300-1
Vacuum Pump	8000-200-12
Vacuum Pump Relay	8000-300-2
2-Way Solenoid Valve	8000-200-13
Single Board Computer	8000-400-1
GPIO Board	8000-400-2
Interface Board	8000-400-3
Temperature Probe	8000-400-4
Power Supply	8000-300-3
Cooling Fan	8000-300-4
Power Switch	8000-300-5
Fuse Holder	8000-300-6
Pump Fan Guard	8000-500-1
Cooling Fan Guard	8000-500-2
Vacuum Line Tubing Set	8000-200-16
MFC Cartridge Ch.1 Cable	8000-700-3
MFC Cartridge Ch.2 Cable	8000-700-4

GPIO Cable Set	8000-700-5
Rear Panel Output Cable Set	8000-700-7
Interface Board Ribbon Cable Set	8000-700-8
Vacuum Pump Relay Cable	8000-700-10

Appendix A Schmatics



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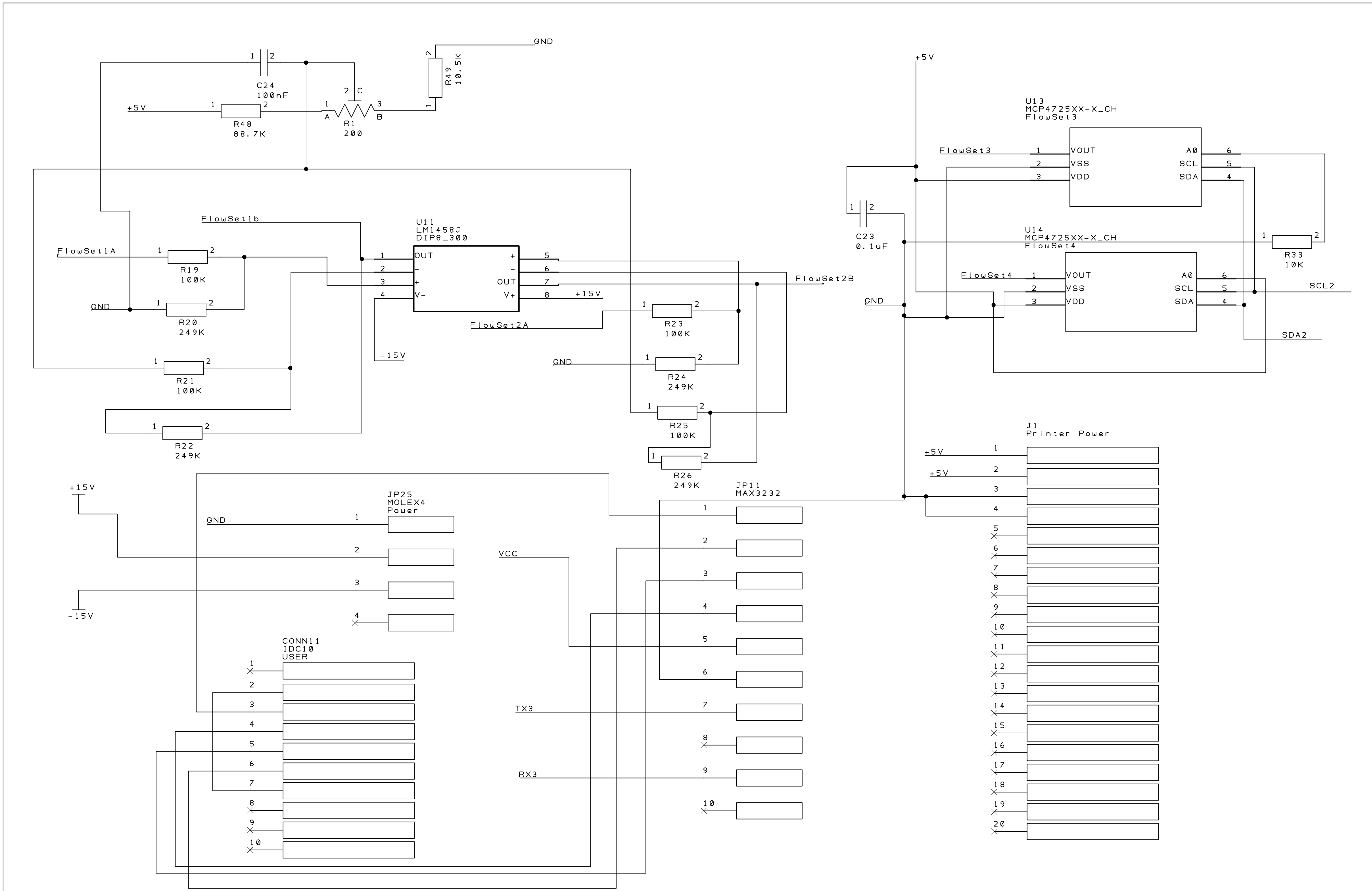

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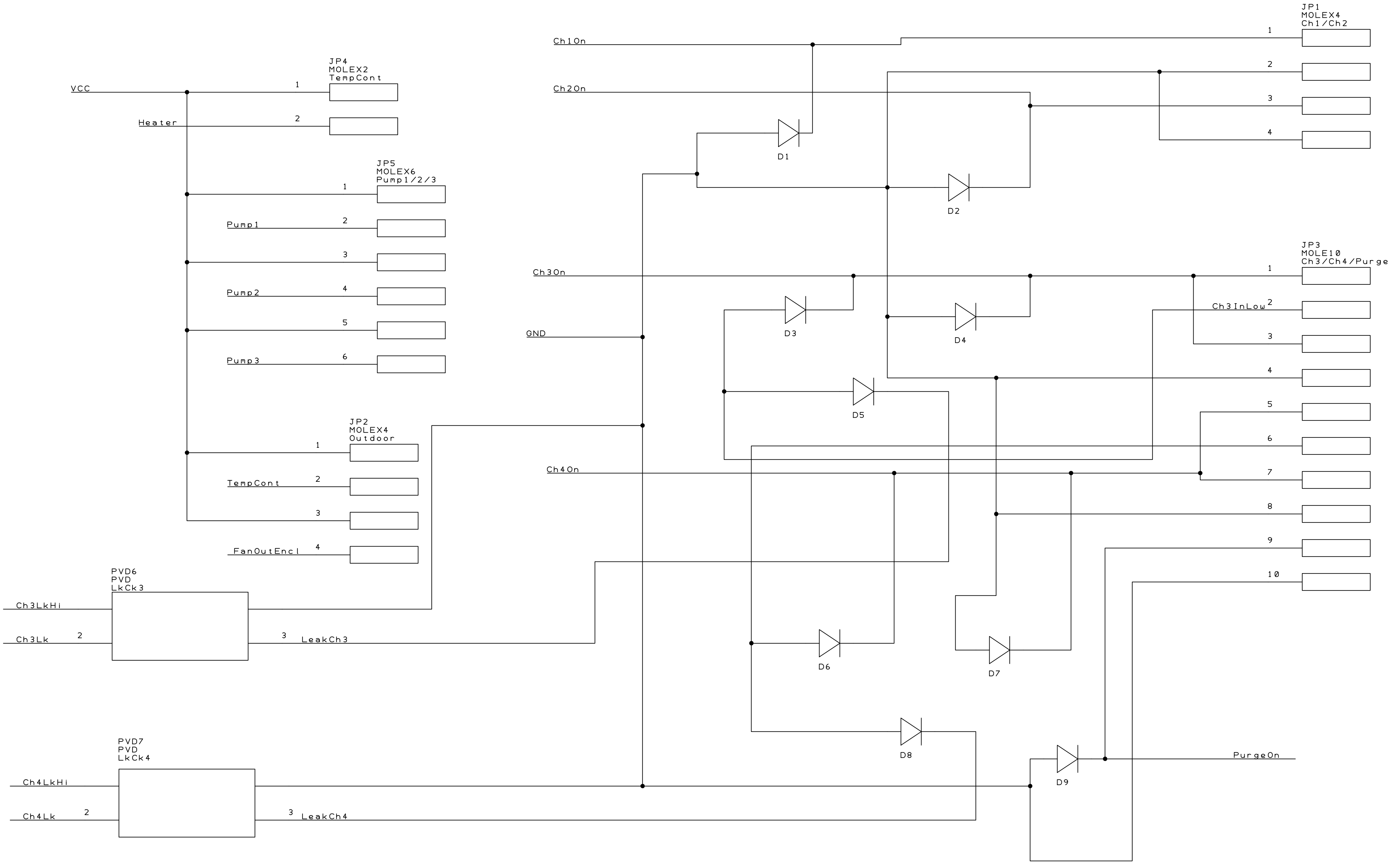

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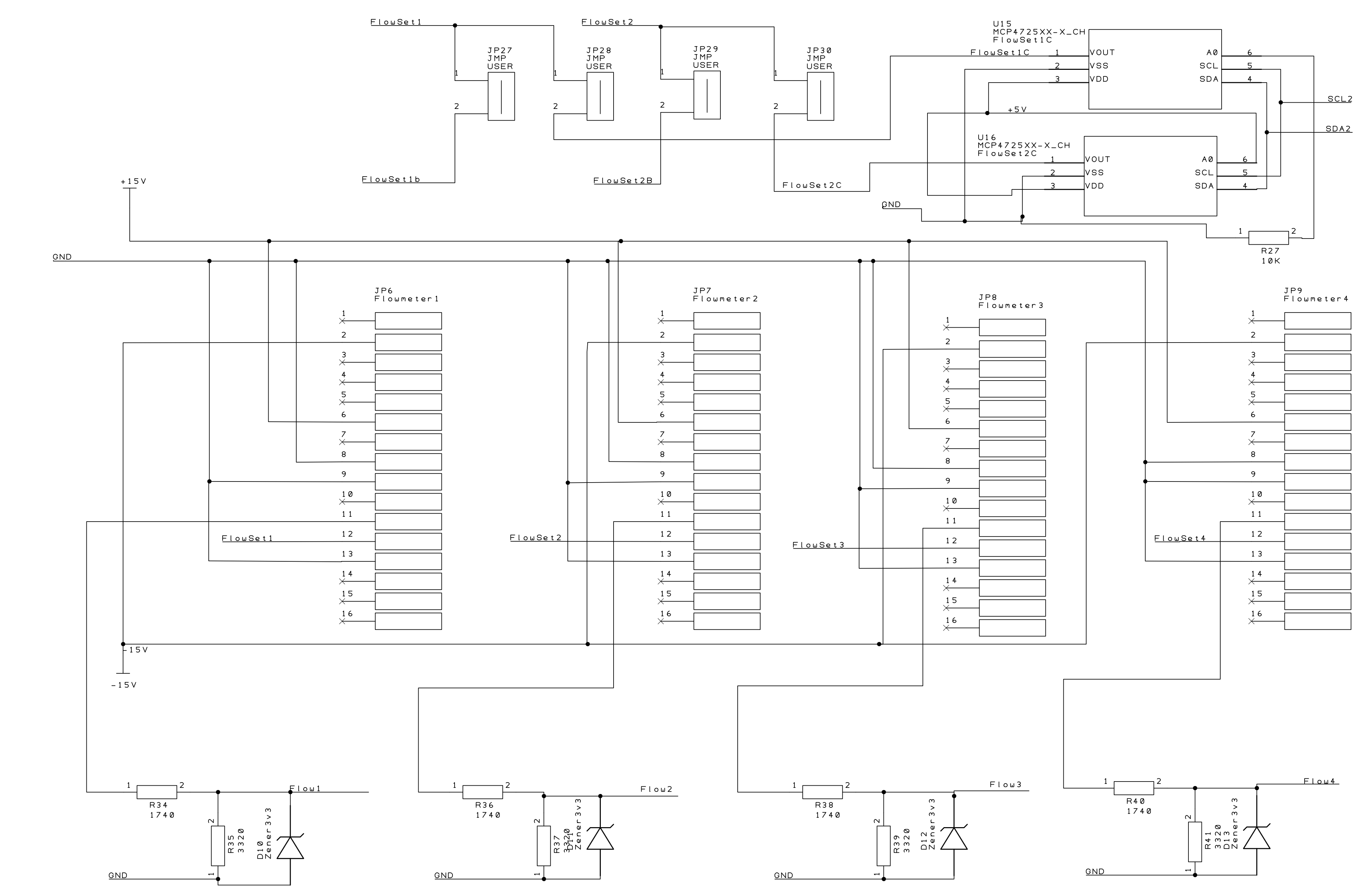
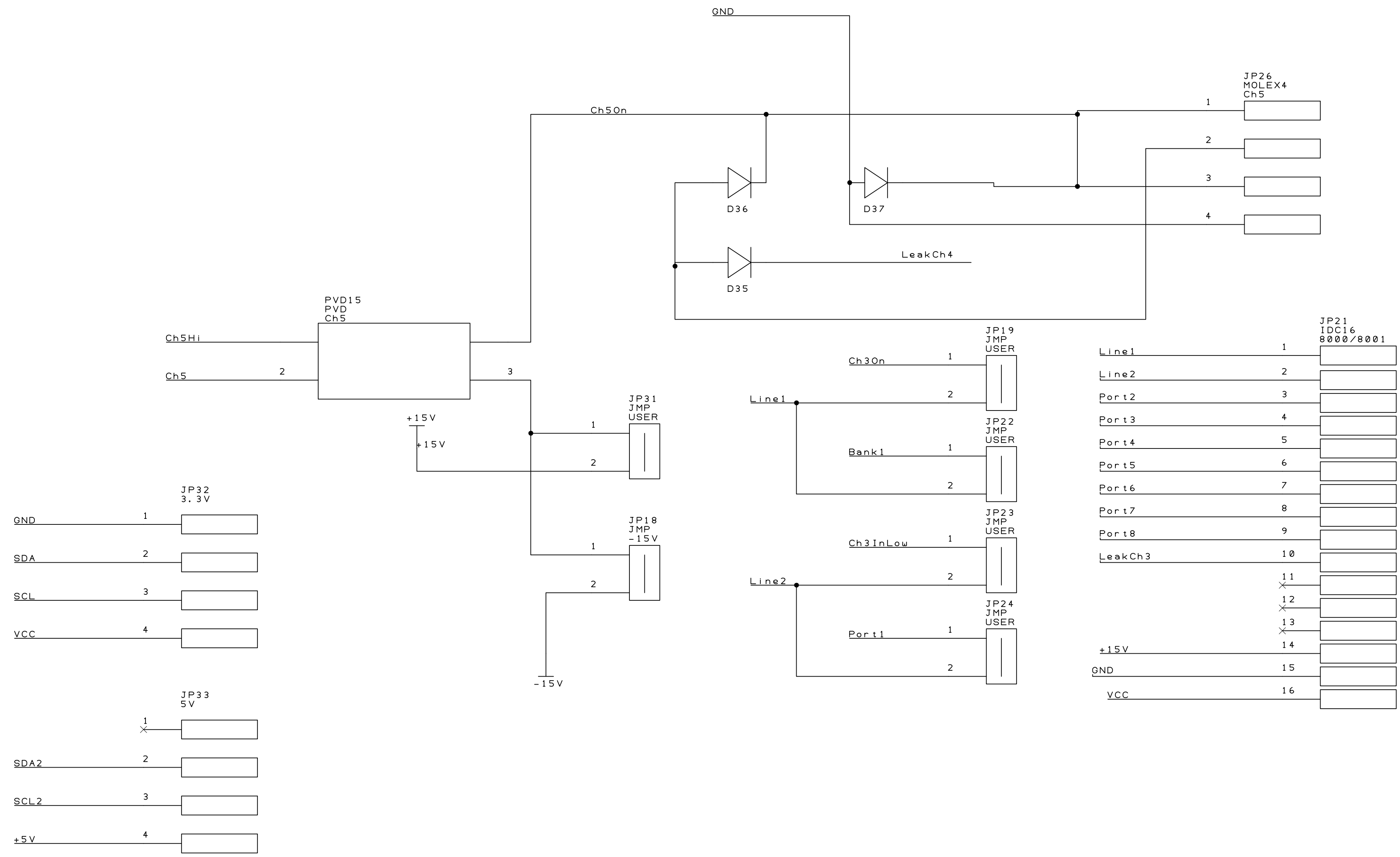


E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title **Model 2200V11 Interface Board**			Filename **Schmatic-4.sch**	Drawing No. / Sheet **4** of **7**



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
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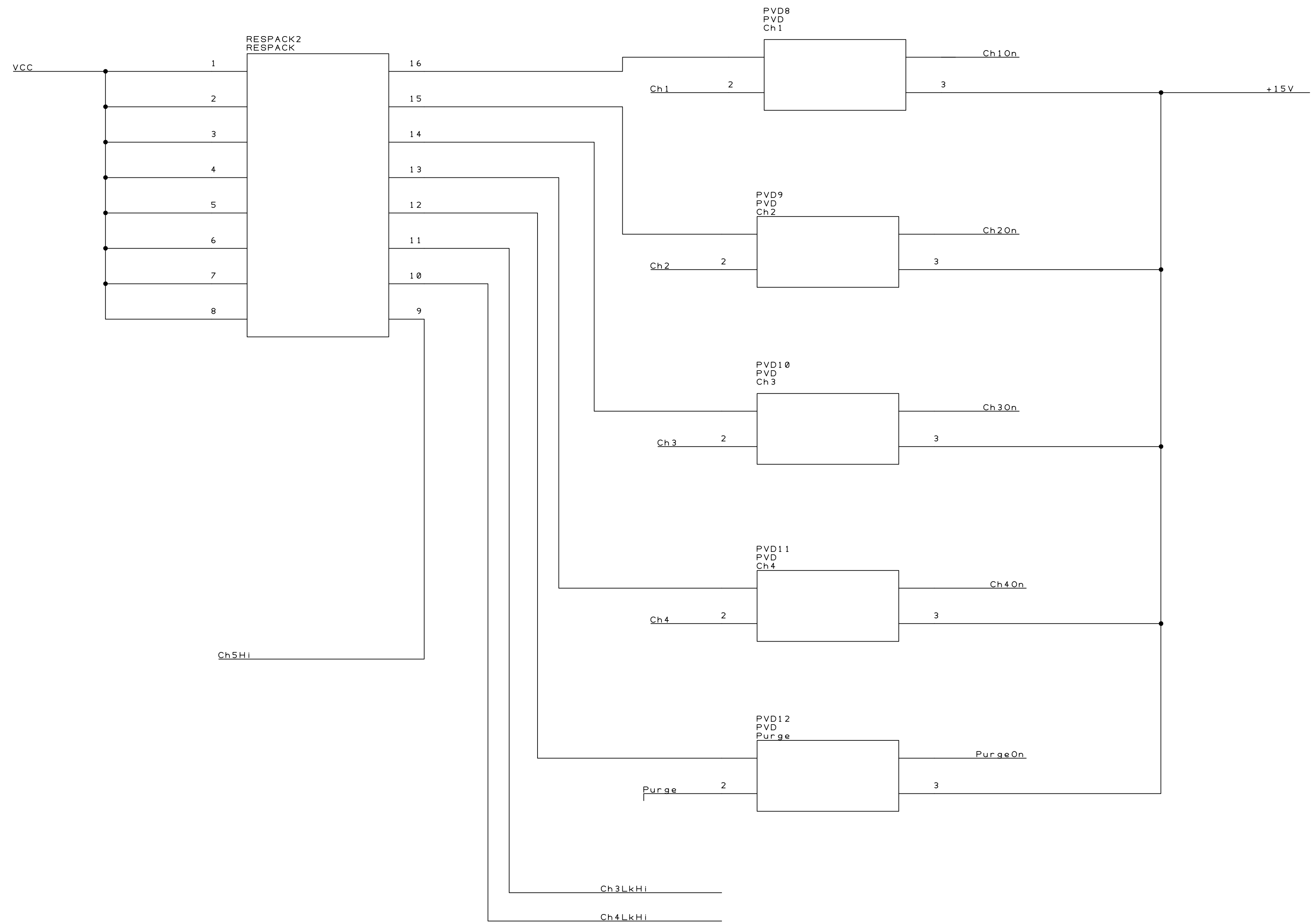

E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
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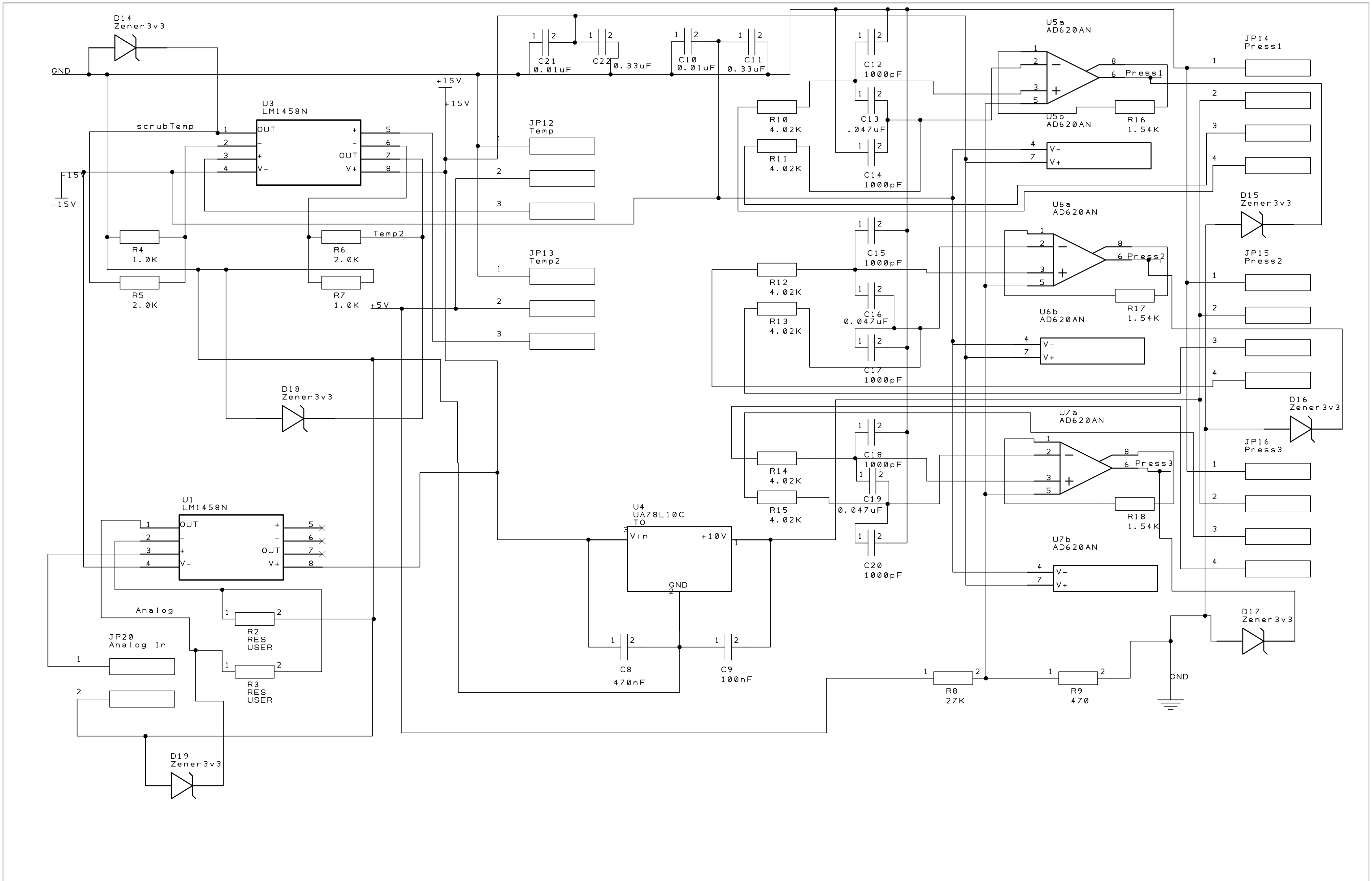

E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title **Model 2200V11 Interface Board**			Filename **Schematic-7.sch**	Drawing No.	Sheet **7** of **7**

Appendix B Manual for Mass Flow Controller

TELEDYNE
HASTINGS
INSTRUMENTS

INSTRUCTION MANUAL

200/202 SERIES
FLOWMETERS/CONTROLLERS

TELEDYNE
HASTINGS INSTRUMENTS
A Teledyne Technologies Company

ISO 9001
CERTIFIED

Manual Print History

The print history shown below lists the printing dates of all revisions and addenda created for this manual. The revision level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new revision is created, all addenda associated with the previous revision of the manual are incorporated into the new revision of the manual. Each new revision includes a revised copy of this print history page.

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Revision K (Document Number 140-102009A)	October 2009
Revision L (Document Number 140-082010)	August 2010
Revision M (Document Number 140-072011)	July 2011

Visit www.teledyne-hi.com for WEEE disposal guidance.

CAUTION: The instruments described in this manual are available with multiple pin-outs. Ensure that all electrical connections are correct.

CAUTION: The instruments described in this manual are designed for INDOOR use only.

CAUTION: The instruments described in this manual are designed for Class 2 installations in accordance with IPC standards

Hastings Instruments reserves the right to change or modify the design of its equipment without any obligation to provide notification of change or intent to change.

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The Hastings HFM-200 mass flow meter and HFC-202 flow controller are designed to accurately measure and control mass flow over the range of 10 sccm to 30 slm, without corrections or compensations for gas pressure and temperature with an accuracy of better than ±1% FS. Hastings mass flow instruments do not require any periodic maintenance under normal operating conditions with clean gases. No damage will occur from the use of moderate overpressures (~500 psi/3.45MPa) or overflows. Instruments are normally calibrated with the appropriate standard calibration gas (nitrogen) then a correction factor is used to adjust the output for the intended gas.

1.1. Features

- **LINEAR BY DESIGN**. The HFM-200/HFC-202 series is inherently linear (no linearization circuitry is employed). Should recalibration in the field be desired (a calibration standard is required), the customer needs to simply set the zero and span points. There will be no appreciable linearity change of the instrument when the flowing gas is changed.
- **MODULAR SENSOR**. The HFM-200/HFC-202 series incorporates a removable/replaceable sensor module. Field repairs to units can be achieved with a minimum of production line downtime.
- **METER SETTLING TIME**. Changes in flow rate for the HFM-200 are detected in less than 2 seconds when using the fast-response circuitry.
- **LOW TEMPERATURE DRIFT**. The temperature coefficient of span for the HFM-200/HFC-202 series is typically less than 0.05% of full scale/°C from 15-45°C. The temperature coefficient of zero is typically less than 0.1 % of reading/°C from 0-50°C.
- **CURRENT LOOP**. The 4-20 mA option gives the user the advantages of a current loop output to minimize environmental noise pickup.

1.2. Specifications HFM-200*

Accuracy[1] and Linearity	±1% F.S.
Repeatability	±0.05% F.S.
Standard Pressure Rating	500 psig
Pressure Coefficient	-0.0067%/psi (0 - 1000 psig N2) typical
High-Pressure Option	Proof tested to 1500 psig
Leak Integrity	< $1x10^{-9}$ sccs
Temperature Coefficient	Zero ±0.035% FS/°C (0 - 60°C)
	Span ±0.05% RDG/°C (0 - 60°C)
STP	0°C and 760 Torr
Power (±15 Volt flow meter)	±(14-16) VDC @ ±30 mA (< 1 Watt)
Power (24 Volt flow meter)	(14 - 32) VDC < 1.9 Watts
Flow Signal	(inherently linear) 0 - 5.00 VDC or 4 - 20 mA
Wetted Material[2]	316 SS, Viton®, 82/18 Au/Ni Braze,
	Trace Silver Solder
Connector	15-pin subminiature D / (9-pin for 24 Volt)
Fittings	¼ in. Swagelok®, others available
Weight (approx.)	1.8 lb (0.82 kg)

1.3. Specifications HFC-202*

Accuracy[1] and Linearity	±1% F.S.
Repeatability	±0.05% F.S.
Std. Pressure Rating	500 psig
High Pressure Option	Proof tested to 1500 psig
Pressure Coefficient	-0.0067%/psi (0 - 1000 psig N2) typical
Control Valve DP*	per customer order
Leak Integrity	< $1x10^{-9}$ sccs
Temperature Coefficient 3	Zero ±0.035% FS/°C (0 - 60°C)
	Span ±0.05% RDG/°C (0 - 60°C)
STP	0°C and 760 Torr
Power (±15 Volt controller)	±(14 - 16) VDC @ +60 mA/-185 mA (< 3 Watts)
Power (24 Volt controller)	(14 - 32) VDC < 4.2 Watts
Flow Signal	(inherently linear) 0 - 5.00 VDC or 4 - 20 mA
Command Signal	0 - 5.00 VDC or 4 - 20 mA
Wetted Material[2]	316 SS, 302 SS, Nickel, Viton,
	82/18 Au/Ni Braze, Trace Silver Solder, Kalrez®
Connector	15-pin subminiature D / (9-pin for 24 Volt)
Fittings	¼ in. Swagelok, others available
Weight (approx.)	1.8 lb (0.82 kg)

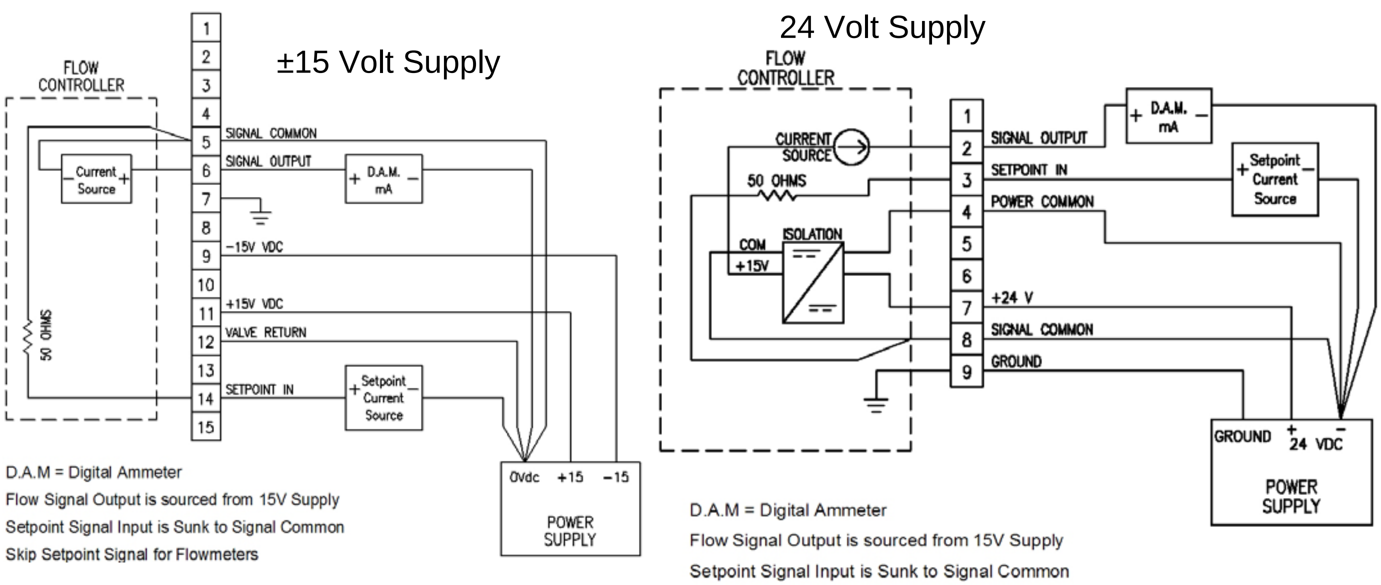
1 Stated accuracy is for nitrogen or other gas specific calibration and using this gas only.
2 Other materials are available. Viton is the standard O-ring option.
* Specifications may vary for instruments with ranges greater than 10 slpm.

1.4. Optional 4-20 mA Current Output

An option to the standard 0 - 5 VDC output is the 4 - 20 mA current output that is proportional to flow. The 4 - 20 mA signal is produced from the 0 - 5 VDC output of the flow meter. The current loop output is useful for remote applications where pickup noise could substantially affect the stability of the voltage output or long cable runs where cable resistance would cause a voltage signal to decay.

The current loop signal replaces the voltage output on pin 6 of the DA-15 connector (pin 2 of DE-9 24 Volt). The current loop is sourced internally from the +15 VDC supply and must be returned to the signal supply common after (pin 5 [±15 VDC] or pin 8 [24 VDC]) passing through the monitoring circuitry to complete the loop. The load must be between 0 and 600 Ohm.

The 4-20 mA I/O option can accept a current input for flow controllers. The 0-5 VDC command signal on pin 14 / (pin 3 for 24 Volts) can be replaced by a 4 - 20mA command signal. The loop presents an impedance of 50 Ohms and is returned to the signal common. On the 24 Volt units, the signal common will need to be tied to the power supply common external to the flow controller to complete the loop since the signal common is galvanically isolated internally from the supply common. This line must be current limited (< 50 mA) to prevent short circuit currents from damaging the receiving circuit in the flow controller.



1.5. Other Accessories

1.5.1. Hastings Power supplies

Hastings Power Pod power supply/display units are available in one and four channel versions. They convert 100, 115 or 230 VAC to the ±15 VDC required to operate the flow meter and provide a digital indication of the flow rate. Interface terminals for the retransmission of the flow meter analog output signal are located on the rear of the panel.

The Power Pod 100 and 400 models are built with controllers in mind but will work with meters as well. The Model 40 is for flow meters only. Throughout this manual, when reference is made to a power supply, it is assumed the customer is using a Hastings power supply. Hastings PowerPod-100 and PowerPod-400 power supplies are CE marked, but the Model 40 does not meet CE standards at this time. The Model 40 and PowerPod-100 are not compatible with 4 – 20 mA analog signals. With the PowerPod 400, individual channels' input signals, as well as their commands, become 4 – 20 mA compatible when selected. The PowerPod-400 also sports a Totalizer feature. More information about the Power Pods can be found on the Hastings web site. http://www.teledyne-hi.com/products/powerpod-series.htm

1.5.2. Interconnecting Cables

Cables are available from Hastings, in various lengths, to connect from the 15 pin "D" connector on the back of the Power Pod directly to any of the 200 series and 300 series flow instruments (including digital versions). More information about the available cables can be found in the Power Pod 400 bulletin on the Hastings web site. http://www.teledyne-hi.com/pdfs/bulletins.htm

2. Installation and Operation

This section contains the steps necessary to install a new flow meter/controller into operation as quickly and easily as possible. Please read the following thoroughly before attempting to install the instrument.

2.1. Receiving Inspection

Carefully unpack the Hastings HFM-200/HFC-202 series instrument and any accessories that have also been ordered. Inspect for any obvious signs of damage to the shipment. Immediately advise the carrier who delivered the shipment if any damage is suspected. Check each component shipped with the packing list. Insure that all parts are present (i.e., Flowmeter, power supply, cables, etc.). Optional equipment or accessories will be listed separately on the packing list. There may also be one or more OPT-options on the packing list. These normally refer to special ranges or special gas calibrations. They may also refer to special helium leak tests, or high pressure tests. In most cases, these are not separate parts, but special options or modifications built into the flow meter.

2.2. Power Requirements

The HFM-200/HFC-202 series (bipolar 15 Volt version) require ±15 VDC @ ±30 mA / 1 Watt (HFM-200) +60 mA, -185 mA / 3 Watts (HFC-202) for proper operation. The supply voltage should be sufficiently regulated to no more than 50 mV ripple. The supply voltage can vary from 14.0 to 16.0 VDC. Surge suppressors are recommended to prevent power spikes reaching the instrument. The Hastings power supplies described in Section 1.4.1 satisfy these power requirements.

The HFM-200/HFC-202 series (24 Volt version) require 14 - 32 VDC @ 1.9 Watts (HFM-200) and 4.2 Watts (HFC-202) for proper operation. The supply voltage should be reasonably regulated as power supply ripple may propagate to the output. The supply common is galvanically isolated from the signal common such that this instrument can be powered from a bipolar 15 Volt supply using only the positive and negative output terminal (30 Volts). Surge suppressors are recommended to prevent power spikes reaching the instrument.

Warning: Attempting to operate the 24 volt version for any significant length of time at a voltage less than the specified minimimum voltage will cause the internal DC-DC convertors to fail.

The HFM-200/HFC-202 series instruments have an integral 5 VDC reference source. This stable voltage is on pin 15 of the DA-15 connector (pin 1 of the DE-9 for 24 Volt) and may be used for the command voltage.

2.3. Output Signal

The standard output of the flow meter is a 0-5 VDC signal proportional to the flow rate. In the Hastings power supplies, the output is routed to the display and is also available at the terminals on the rear panel. If a Hastings supply is not used, the output is available on pin 6 of the DA-15 connector (pin 2 of the DE-9 for 24 Volt) and is referenced to pin 5 (pin 8 for 24 Volt). It is recommended that the load resistance be no less that 2kΩ. If the optional 4-20 mA output is used, the load impedance must be selected in accordance with Section 1.3.

2.4. Mechanical Connections

2.4.1. Standard Configuration

The flow meter may be mounted in any position as long as the direction of gas flow through the instrument follows the arrow marked on the bottom of the flow meter case label. The preferred orientation is with the inlet and outlet fittings in a horizontal plane (if operating with a dense gas or at high pressures the instrument must be installed horizontally). When mounted in a different orientation the instrument should be re-zeroed at zero flow with the system pressurized to the expected operating pressure.

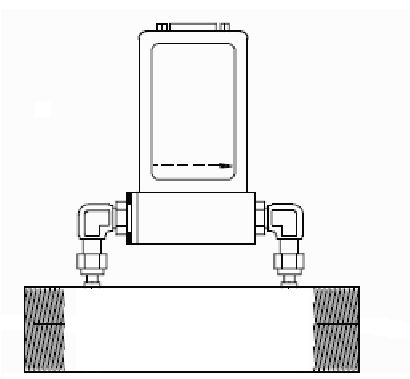
The smallest of the internal passageways in the HFM-200/HFC-202 series is the diameter of the sensor tube, which is 0.0125" (0.31 mm), so the instrument requires adequate filtering of the gas supply to prevent blockage or clogging of the tube.

The pressure regulator and the plumbing upstream must be of sufficient size to minimize changes in the upstream pressure. When switching from full flow to zero flow, the inlet pressure of the instrument should rise to no more that 30% above the inlet pressure at full flow. In general, high capacity regulators and large internal diameter plumbing help to make the system more stable. The pressure drop between the regulator and the instrument due to line resistance should be minimized. The differential pressure across a meter should be less than 6" of H_2O at maximum flow. Controllers may have much higher differential pressures depending upon the size of the installed orifice.

There are two 8-32 threaded holes, located on the bottom of the base that can be used to secure it to a mounting bracket, if desired (screws provided). Other holes for special mounting can be added to the end cap as desired.

The standard inlet and outlet fittings for the 200/202 are 0.25" and 0.125" Swagelok (optional VCR or VCO fittings). The O-rings for the end cap and the sensor are Viton (optional Kalrez or Neoprene). It is suggested that all connections be checked for leaks after installation. This can be done by pressurizing the instrument (do not exceed 500 psig unless the Flowmeter is specifically rated for higher pressures) and applying a diluted soap solution to the flow connections.

2.4.2. LFE Configuration

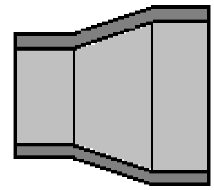


The installation of a Laminar Flow Element (LFE) in a flow circuit requires sufficient conductance before entering and after exiting the LFE sensor taps to allow the flow to fully develop with a minimum of turbulence. This provides the best conditions for accurate sampling of the flow by the sensor branch (See Theory of Operation). Please note that, for laminar flow elements whose diameter is less than 3", the inlet and outlet taps of the sensor circuit are 1.5" from the ends of an 8" LFE. Laminar flow elements whose diameter is 3" or greater, have inlets and outlets sensor taps 2.5" from the ends of a 10" LFE. These distances may be taken into account and treated as part of the following rule-of-thumb:

1) an upstream flow tube length of 5 times, or greater, the diameter of the selected LFE before the sensor inlet tap.
2) a downstream tube length of 1 time, or greater, the diameter of the selected LFE after the sensor inlet tap.

EXAMPLE:

Suppose a 4" LFE is selected. The length of 4" diameter tubing or pipe, upstream of the sensor inlet tap, will be a minimum of 20". The minimum length of 4" tubing or pipe downstream from the sensor outlet tap will be 4". The length of additional 4" inlet tubing required for the 4" LFE is 20" – 2.5" = 17.5". The additional length of 4" tubing required for the outlet side of the 4" LFE is 4" – 2.5" = 1.5". This brings the overall length of the assembly to 19".

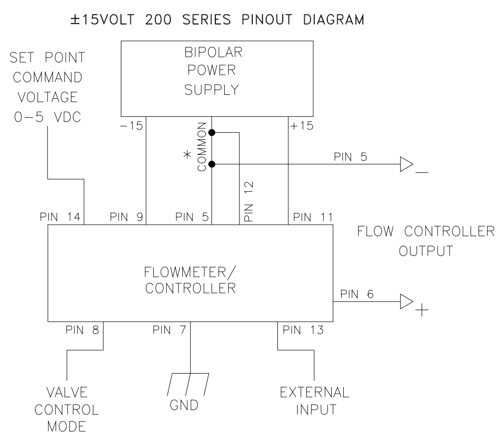


Tubular configurations upstream or downstream that involve conical shapes or optimized expansion nozzles will reduce the length of tubing required for flow straightening, but the actual length necessary will be a function of that geometrical shape. Testing of that configuration will be necessary for each application. The same is true for screen meshes or flow straighteners.

2.5. Electrical Connections

If a power supply from Hastings Instruments is used with a ±15 Volt version of the HFM-200/HFC-202, installation consists of connecting the HFM-200/HFC-202 series cable (#AF-8AM) from the "D" connector on the rear of the power supply to the "D" connector on the top of the flow meter. If a different power supply is used, follow the instructions below when connecting the flow meter.

Bipolar (±15 Volt) Power Supply to Bipolar Connections



*Need to be tied together at the Power Supply.

PINOUTS

PIN #	
1	Do Not Use
2	Do Not Use
3	Do Not Use
4	Do Not Use
5	Signal Common
6	Signal Output 0-5 VDC (4-20mA)
7	Case Ground
8	Control Valve Over-ride
9	-15 VDC
10	Do Not Use
11	+15 VDC
12	Valve Return
13	External Input
14	Set Point 0-5 VDC (4-20mA)
15	Do Not Use

Connecting the HFM-200/HFC-202 series flow meters with anything other the prescribed cables and power supplies discussed above, can severely damage the instrument and void the warranty. The figure to the left shows the schematic layout for connecting the instrument to an appropriate ±15 Volt power supply.

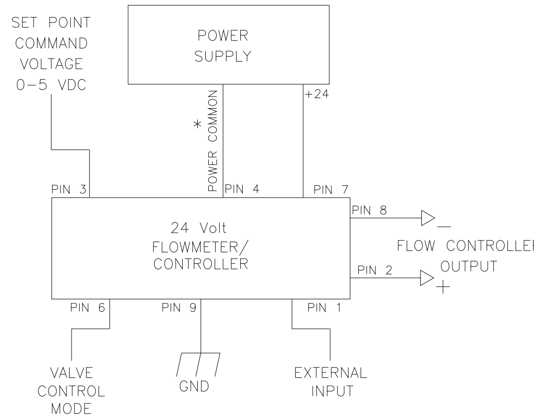
The power supply used must be meet the power requirements delineated in section 2.2 (Power Requirements) above. If a bipolar supply is required the voltages must be referenced to a common ground.

Connect -15 VDC to pin 9 of the DA-15 connector and +15 VDC to pin 11. Pins 5 and 12 are both commons and they must be connected together and to the ground connection at the power supply. Do not connect them together at the flow controller as the resulting crosstalk could result in flow instabilities.

24 Volt Connections

Refer to the diagram to the right when connecting 24 Volt units.

24 Volt 200 SERIES PINOUT DIAGRAM



*Power Common is isolated from the signal common

PINOUTS	
PIN #	
1	+5VDC Ref/Ext In
2	Signal Output (0–5V/4–20mA)
3	Set Point In (0–5V/4–20mA)
4	Power Common
5	Valve Voltage
6	Control Over–Ride
7	Power Input (15–30VDC)
8	Signal Common
9	Case Ground

Connect the positive lead of the power supply to pin 7 of the DE-9 connector and negative lead to pin 4. The supply input is diode protected such that reversing the input polarity will not damage the instrument. The power supply is galvanically isolated from all other pins.

General Connection Notes

Pin 7 of the DA-15 (15 Volt), Pin 9 of the DE-9 (24 Volt) is the case ground. It should be connected to the cable shield if available and to the AC ground to the power supply.

Pin 6 of the DA-15 (15 Volt), Pin 2 of the DE-9 (24 Volt) is the output signal from the flow controller. This output will be 0 – 5 VDC/(4 - 20 mA), 5 VDC/20 mA being 100% of rated or full flow. Pin 14 of the DA-15 (15 Volt), Pin 3 of the DE-9 (24 Volt) is the command input. This should be a 0 – 5 VDC or (4 - 20 mA) signal and must be free of spikes or other electrical noise, as these will generate false flow commands that the controller would attempt to adjust flow. Pin 15 of the DA-15 (15 Volt), Pin 1 of the DE-9 (24 Volt) is a regulated +5.00VDC output reference that is normally adjusted to 5.01VDC so that the user can achieve full scale command set point. The reference is designed to provide the command signal for pin 14 by connecting one end of a potentiometer to the voltage reference and the other end to ground. The center lead would then be connected to setpoint input.

If a valve override switch is not desired, the unit is ready for use at this time. If the override switch is desired, connect the center pin of a single pole, three-position switch with the center off position to pin 8 of the DA-15 (15 Volt), Pin 6 of the DE-9 (24 Volt). Connect a voltage source >10 VDC to one end of the switch, and negative voltage to the other end. This will result in the valve being full open when the positive is supplied to the override pin, off when the negative voltage is supplied and auto-control when there is no connection to the valve override pin (OPEN-AUTO-CLOSE). This setup will be adequate for most purposes, but there will be a small delay for capacitors to charge between switch operation and control override.

2.6. Operation

The standard instrument output is a 0 - 5 VDC out and the signal is proportional to the flow i.e., 0 Volts = zero flow and 5 Volts = 100% of rated flow. The 4 - 20 mA option is also proportional to flow, 4 mA = zero flow and 20 mA = 100% of rated flow. It is suggested that all connections be checked for leaks after installation. This can be done by pressurizing the instrument (do not exceed 500 psig unless the instrument is specifically rated for higher pressures) and applying a diluted soap solution to the connections.

2.6.1. Operating Conditions

For proper operation, the combination of ambient temperature and gas temperature must be such that the flow meter temperature remains between 0 and 60°C. The most accurate measurement of flow will be obtained if the flow meter is zeroed at operating temperature as temperature shifts result in some zero offset. The HFM-201/HFC-203 series is intended for use in non-condensing environments only. Condensate or any other liquids which enter the flow meter may destroy its electronic components.

2.6.2. Zero Check

Turn the power supply on if not already energized. Allow for a 1 hour warm-up. Stop all flow through the instrument and wait 2 minutes. Caution: Do not assume that all metering valves completely shut off the flow. Even a slight leakage will cause an indication on the meter and an apparent zero shift. For the standard 0 - 5 VDC output, adjust the zero potentiometer located on the lower outlet side of the flow meter until the meter indicates zero. For the optional 4 - 20 mA output, adjust the zero potentiometer so that the meter indicates slightly more than 4 mA, i.e. 4.03 to 4.05 mA. This slight positive adjustment ensures that the 4-20 mA current loop transmitter is not in the cut-off region. The error induced by this adjustment is approximately 0.3% of full scale. This zero should be checked periodically during normal operation. Zero adjustment is required if there is a change in ambient temperature, or vertical orientation of the flow meter/controller.

2.6.3. High Pressure Operation

When operating at high pressure, the increased density of gas will cause natural convection to flow through the sensor tube if the instrument is not mounted in a level position. This natural convection flow will be proportional to the system pressure. This will be seen as a shift in the zero flow output that is directly proportional to the system pressure.

2.6.4. Blending of Gases

In the blending of two gases, it is possible to maintain a fixed ratio of one gas to another. In this case, the output of one flow controller is used as the reference voltage for the set point potentiometer of a second flow controller. The set point potentiometer then provides a control signal that is proportional to the output signal of the first flow controller, and hence, controls the flow rate of the second gas as a percentage of the flow rate of the first gas.

EXAMPLE: Flow controller A has 0 - 100 slpm range with a 5.00 Volt output at full scale. Flow controller B has 0 - 10 slpm range with a 5.00 Volt output at full scale. If flow controller A is set at 80 slpm, its output voltage would be 4.00 Volts (80 slpm/100 slpm x 5.00 Volts = 4.00 Volts). If the output signal from flow controller A is connected to the command potentiometer of flow controller B, it then becomes a variable reference voltage for flow controller B proportional to the flow rate of flow controller A.

If the set point potentiometer of flow controller B is set at 50% of full scale, and the reference voltage from flow controller A is 4.00, then the command signal going to flow controller B would be 2.00 Volts (4.00 Volts x 50.0% = 2.00 Volts). The flow of gas through flow controller B is then controlled at 4 slpm (2.00 Volts/5.00 Volts x 10 slpm = 4 slpm).

The ratio of the two gases is 20:1 (80 slpm/4 slpm). The % mixture of gas A is 95.2 (80 slpm/84 slpm and the % mixture of gas B is 4.8% (4 slpm/84 slpm).

Should the flow of flow controller A drop to 78 slpm, flow controller B would drop to 3.9 slpm, hence maintaining the same ratio of the mixture. (78 slpm/100 slpm x 5 Volts = 3.90 Volts x 50% = 1.95 Volts; 1.95 Volts /5.00 v x 10 slpm = 3.9 slpm; 78 slpm: 3.9 slpm = 20:1)

2.7. Operation with External Devices

2.7.1. Operation with a Hastings power supply.

There are two controls for each flow controller connected to a Hastings power supply. A switch labeled "OPEN; AUTO; CLOSED" (valve override THPS 400 only) and a potentiometer labeled "COMMAND". For normal operation, the valve override switch will be in the "AUTO" position. The "CLOSE" position removes all power from the valve, shutting off flow regardless of the command pot setting. The "OPEN" position applies full available valve voltage to the valve, causing it to open, regardless of the command pot setting. The "OPEN" position is useful for purging systems. It is recommended that the valve override switch not be left in this position for extended periods of time, with no flow through the controller, as a small positive zero shift may be observed.

The "COMMAND" pot adjusts the Analog command signal sent to the flow controller. The setting for each controller connected to the power supply can be observed. (Depending on how the power supply was set up, the display could indicate in flow units or percent of full scale).

Hastings Power Supply Feature Guide			
Feature	Model 40	Power Pod 100	Power Pod 400
Digital Readout	✓	✓	✓
± 15 Volts	✓	✓	✓
Analog Outputs	✓	✓	✓
Controller		✓	✓
Analog Control	✓		
Front Panel Override	✓		✓
Totalizer			✓
4 -20 mA	✓		✓
Ratio Control			✓
Alarms	✓	✓	✓
Multi-Channel Display			✓
Conversion Factors	✓	✓	✓
Communications		RS232	RS232/RS485

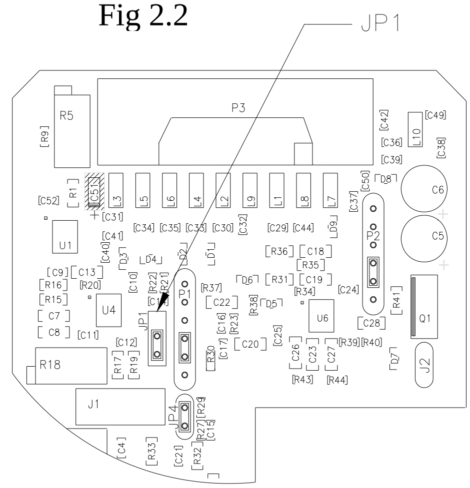
2.7.2. Operation with a Power Supply other than a Hastings

The flow controller must be connected to the power source as specified in section 2.6. In general, a 0 - 5 VDC command signal proportional to the intended flow (0 Volts = zero flow; 5 Volts = 100% of rated flow) must be applied to pin 14 of the DA-15 (15 Volt), Pin 3 of the DE-9 (24 Volt) connector. A 0 - 5 VDC signal proportional to the flow rate through the instrument will be present on pin 6 of the DA-15 (15 Volt), Pin 2 of the DE-9 (24 Volt) connector. The control mode is selected via pin 8 of the DA-15 (15 Volt), Pin 6 of the DE-9 (24 Volt) connector. Apply > 10 Volts for full open, < 0 Volts for closed and allow the override to float for flow proportional to the command voltage. Refer to your power supply manual for the specifics of implementing these parameters.

2.7.3. Operation with an external sensor (Fig. 2.2)

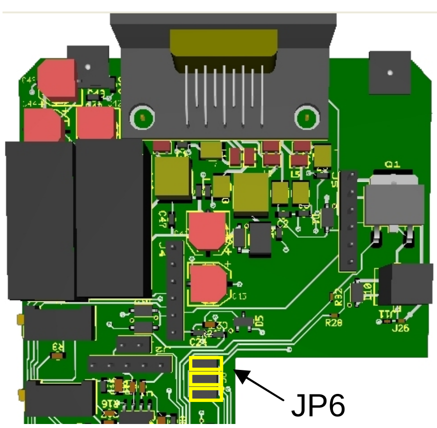
In some instances, it might be desirable to use an external sensor to provide process information to the control circuitry in the flow controller. For example, you might want to control the pressure in a vacuum system by adjusting the rate at which the system is backfilled with a gas. The new, enhanced HFC series of flow controllers have provision for accepting a 0 – 5 VDC (or 0 - 10 VDC) output from an external sensor at pin 13 of the DA-15 (15 Volt), Pin 1 of the DE-9 (24 Volt) connector. To activate this feature, the cover of the HFC must be removed to gain access to the electronics card and move a jumper.

Fig 2.2

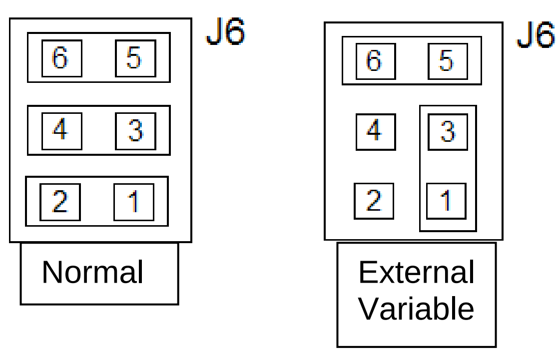


For the 15 Volt units, JP1 is a three pin jumper block located just below the "D" connector. In the normal operating mode, the jumper covers the bottom two pins. To select "External Sensor", move the jumper to the upper two pins. This swaps the flow input to the controller circuit from the flow meter output to pin 13 of the "DA-15" connector.

Fig 2.3



For the 24 Volt units JP6 is a six pin jumper block located just to the right of the sensor connector. Pin 1 is in the lower right corner. There are three jumpers installed horizontally. The bottom jumper ties the flow output to the valve control circuit and the middle jumper ties Pin 1 of the DE-9 connector to reference voltage circuit. Remove both of the lower two jumpers and reinstall one jumper vertically between the outside two pins (pins 1 & 3). This will tie Pin 1 of the DE-9 connector to the valve control circuit and allow the controller to maintain the external process variable equal to the desired setpoint. The 5 Volt reference is not available in this configuration.



2.7.4. Response to Command Changes

The response of the control circuit to changes to the command signal is set at the factory for fast, stable response. If excessive overshoot is present, the response can be slowed removing the jumper labeled "JP4," located in the center of PC-828 for the 15 Volt units or by removing the top jumper of JP6 for the 24 Volt boards (located to the right of the sensor connector.

The fastest response to command changes is obtained when JP4/(JP6) is covered by the jumper. This setup allows large overshoot and undershoot in the actual flow rate while the control circuit is establishing control at the new command point. A slower response to command changes is obtained when JP4/JP6 is not covered by a jumper. This setup results in no overshoot or undershoot in the actual flow rate as the controller circuit establishes control at the new command point. This jumper does not affect the system gain and will not dampen out oscillations.

To adjust the response, you need a means of producing a step change in the command voltage from 10% of full scale to 100% of full scale. Follow the steps outlined below:

1) Cover the pins of JP4/JP6 with a jumper. (see fig. 2.2 & fig 2.3)

2) Set the command voltage to 10% of full scale. Allow the flow to stabilize.

3) Step change the command voltage to 100%, and observe the flow through the controller. If the overshoot is too large, remove the jumper. Reset the command voltage to 10%, and allow the controller to stabilize.

4) To prevent loss of the unused jumper, place it over one pin only on JP4/JP6.

2.8. Range Changing

The range of the flow controller can be changed in the field if recalibration facilities are available. The flow controller may require a different orifice, which can be purchased separately from the factory. A listing of the orifices available and their flow rates can be found in Section 5.0. The instructions to change the flow range can be found in Section 4.6.

2.9. Valve-Override Control

The valve override control line provides a method to override the loop controller and open or close the valve regardless of the flow or command signals. During normal operation this line must be allowed to float freely. This will allow the loop control to open and close the valve as it requires. If the valve override line is forced high (> +10 Volts) the valve will be forced full open. If the valve-override line is forced negative (< 0 Volts) the valve will be forced closed.

3. Theory of Operation

This section contains a functional description of Hastings flow controllers. Detailed schematics and parts lists can be obtained by contacting Hastings using the contact information found at the end of this document. In this section and other sections throughout this manual, when a power supply is mentioned, it is assumed that the customer has a Hastings Power Supply. These sections are not applicable if another type of power supply is used.

3.1. Overall Functional Description

The Hastings flow controller consists of a sensor, electronic circuitry, a shunt and a valve. The sensor measures the flow rate from 0 to 10 sccm of the gas to be metered. The shunt divides the flow such that the flow through the sensor is a precise percentage of the flow through the shunt. The flow through the sensor and the shunt is always laminar. The circuit board amplifies the sensor output and uses this output to control the valve position. The valve is an automatic metering solenoid type; its height off the seat is controlled by the voltage in its coil. All of these components working together result in a fast, stable flow controller.

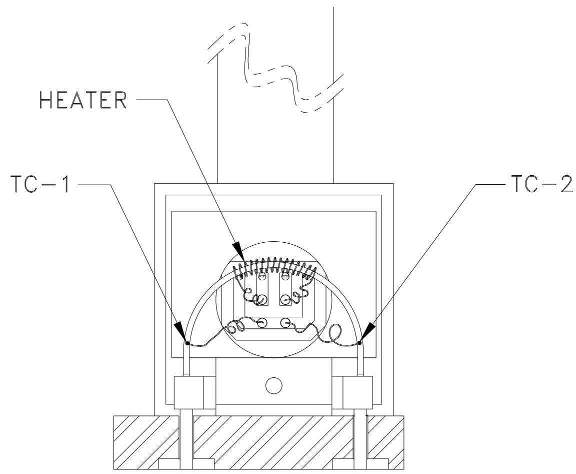


Figure 3.1

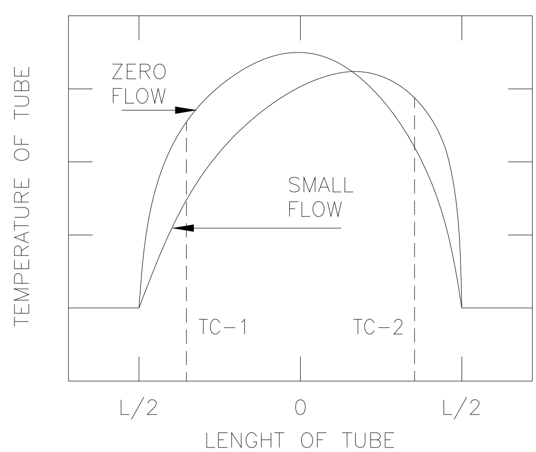
3.2. Sensor

The Hastings HFM-200/HFC-202 series operates on a unique thermal electric principle whereby a metallic capillary tube is heated uniformly by a resistance winding attached to the midpoint of the capillary (see Figure 3.1). Thermocouples TC-1 and TC-2 are welded at equal distances from the midpoint and develop equal outputs at zero flow.

When flow occurs through the tubing, heat is transferred from the tube to the gas on the inlet side, and from the gas back to the tube on the outlet side creating an asymmetrical temperature distribution (see Figure 3.2). The thermocouples sense this decrease and increase in the capillary tube temperature and produce a millivolt output signal proportional to that change.

For a constant power input, the differential thermocouple output is a function of the mass flow rate and the heat capacity of the gas. Since the heat capacity of many gases is

Figure 3.2



relatively constant over wide ranges of temperature and pressure, the flow meter may be calibrated directly in mass units for those gases. Changes in gas composition usually only require application of a simple multiplier to the air calibration to account for the difference in heat capacity and thus the flow meter is capable of measuring a wide variety of gases. The HFM sensor measures approximately 10 sccm, full scale flow.

3.3. Electronics

The Hastings HFM-200/HFC-202 series uses a thermal flow sensor to measure through a capillary tube, which is a fixed percentage of the total flow through the instrument. This sensor develops an output signal proportional to flow which is approximately 1 mV full scale magnitude. This signal is amplified by the meter circuitry until it is 0-5.00 VDC. This 5 Volt output is sent back to the power supply and to the flow meter circuitry, if applicable. At the power supply the 5 Volt output is sent to the terminals on the back and to the decoding circuitry in the display which converts it to a 3-digit output.

The controller circuitry utilizes the command and the flow voltages as input signals. The 0-5VDC command signal is subtracted from the 0-5VDC flow signal creating an error signal. This signal is amplified and causes the solenoid valve to move. The amount and direction of the movement is dependent upon the value and the sign of the error signal, and tends to minimize the error signal.

3.4. Shunt

Measurement of flow rates higher than the 10 sccm full scale is achieved by dividing the flow with a fixed ratio shunting arrangement, as is illustrated in Figure 3.3. This is accomplished by placing the measuring capillary tube parallel with one or more dimensionally similar channels, called a laminar flow element (LFE). Therefore, the sensor only needs to heat the gas passing through the capillary tube resulting in low power requirements, while retaining all the mass measuring characteristics.

The HFM-200/HFC-202 series has two possible shunts. The low range shunt consists of tubes inserted into a cylindrical base. This shunt is adjustable for ranges from 0-10 sccm to 0-250 sccm (see Figure 3.4). The medium range shunt consists of a corrugated stainless steel ribbon wound into a coil and fused. It is adjustable from 0-0.25 slm to 0-25 slm ranges.

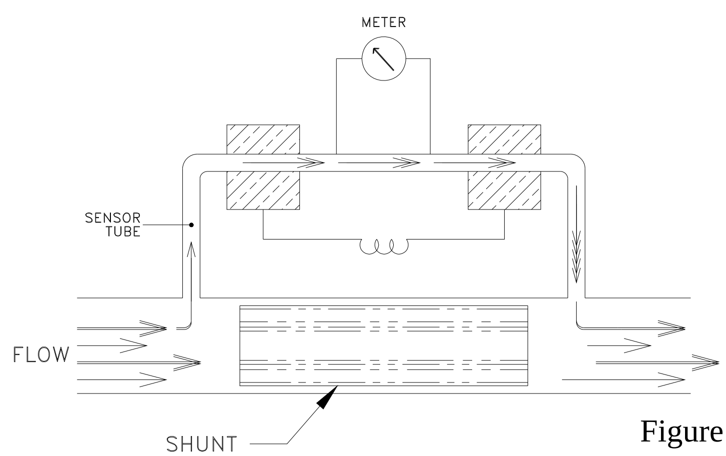
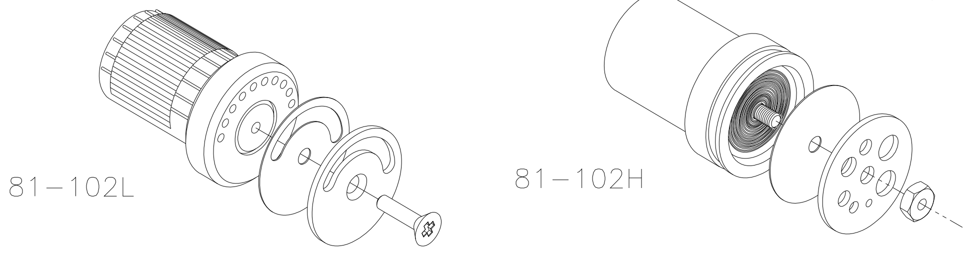


Figure 3.3

Figure 3.4



3.5. Valve

The control valve is an "automatic metering solenoid" valve. While most solenoids operate in either the fully open or fully closed state, the automatic metering solenoid valve is designed to control flow (see Figure 3.5). A spring, connected to the plunger assembly, holds a magnetic plunger tightly against an orifice to shut off flow. The magnetic plunger is surrounded by an electrical coil which, when energized with electrical current, lifts the plunger off the orifice and allows flow to pass between the orifice and the plunger seat. Controlling the current through the coil controls the distance between the orifice and the plunger seat, effectively controlling the flow through the valve. This current is controlled by a feedback loop that matches the transducer output with the command voltage.

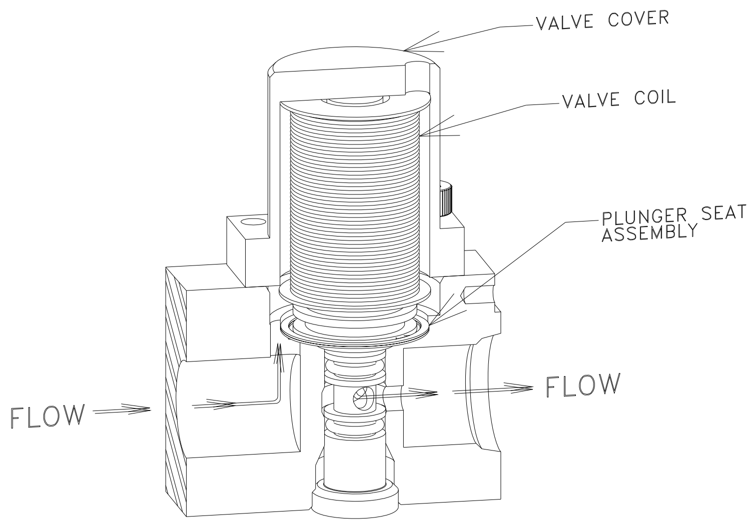


Figure 3.5

4. Maintenance

This section contains service and calibration information. Some portions of the instrument are delicate. Use extreme care when servicing the flow controller.

4.1. Authorized Maintenance

With proper care in installation and use, the flow controller will require little or no maintenance. If maintenance does become necessary, most of the instrument can be cleaned or repaired in the field. Some procedures may require recalibration. Do not attempt these procedures unless facilities are available. Entry into the sensor or tampering with the printed circuit board will void the warranty. Do not perform repairs on these assemblies while unit is still under warranty.

4.2. Troubleshooting

SYMPTOM: Override CLOSE function is enabled but flow remains or 0.00 VDC is commanded and flow remains.

CAUSE: Orifice out of adjustment or faulty op-amp

ACTION: Check the valve voltage between pins 2 & 12 on the 15-pin D-connector for 15 Volt units and Pins 5 & 8 on the DE-9 connector for 24 Volts. If the voltage is less than 3.00 VDC, then turn the orifice clockwise until flow stops.

SYMPTOM: Output of unit is proportional to flow but extremely small and not correctable by span pot.

CAUSE: Sensor is not being heated.

ACTION: Unplug connector J1. Check the following resistance: The resistance between pins 2 & 3 of the sensor should be approximately 2500 Ohms (see Figure 3.1 on page 8). The resistance between pins 1 & 4 should be approximately 2.3 Ohms. The resistance between pins 2 & 3 and the base of the sensor should be essentially infinite. If not, replace the sensor unit. If sensor reads O.K., check the voltage output on pins 2 & 3 of the jack in the board. If it does not read approximately 22 VDC then replace regulator U2 (U3 on 24 Volt board).

SYMPTOM: Sensor has proper resistance readings, but little or no output with flow.

CAUSE: Plugged sensor.

ACTION: Shut off gas supply and power supply. Remove cover and PC board from unit. Remove sensor assembly and examine. If sensor has evidence of plugging, clean or replace as applicable

SYMPTOM: Flow controller oscillates.

CAUSE: Flow controller not adjusted for the dynamics of the flow system.

ACTION: Check upstream and downstream pressures. The gas supply regulator should not have excessive lockup when flow shuts off. Also ensure that there is not a large drop in pressure between the regulator and the instrument due to line resistance. Oscillations can also be caused if a large flow restriction is pneumatically close to the downstream end of the flow controller. The differential pressure across the unit must be between 10-50 psig.

SYMPTOM: Little or no flow, even with Valve Override OPEN enabled.

CAUSE: Plugged orifice.

ACTION: Verify the presence of a 10-50 psig pressure across the instrument. If present, shut off gas supply and power supply. Remove orifice per Section 4.9. Examine orifice. If plugged, clean or replace as applicable. Reassemble valve.

SYMPTOM: Flow meter reads other than 0.00 VDC with no flow, or there is a small flow when flow meter reads 0.00 VDC.

CAUSE: ZERO potentiometer is out of adjustment.

ACTION: Shut off all flow. Adjust ZERO potentiometer until output reads 0.00 VDC.

SYMPTOM: Flow meter out of calibration and nonlinear.

CAUSE: Leaks in gas inlet or outlet fittings.

ACTION: Check all fittings for leaks by placing soap solution on all fittings between gas supply and final destination of gas. Check flow meter for leaks. Replace "O" rings if required or recalibrate as necessary.

4.3. ADJUSTMENTS

4.3.1. Calibration Procedure: (Figure 4.1)

5) NOTE: Steps 5 and 6, adjusting the SPAN pot and performing a calibration run, will require the use of a calibration reference.

1) Connect power cable to D connector as specified in Section 2.7. Allow instrument to warm up for 30 minutes with 10% flow and instrument in AUTO position.

2) After the warm up period, set the flow to zero and insure that, indeed, there is zero flow. Wait for 2 minutes.

3) Set ZERO (R13 on 15 Volt / R20 for 24 Volt) potentiometer for 0.000 VDC output.

4) Turn on gas supply to inlet of instrument. Use the Valve Override CLOSE feature or, if Valve Override is unavailable, give the controller a command of zero. Adjust the orifice underneath the controller to obtain zero flow. If the Valve Override feature was used to close the valve, set it to AUTO. Ensure that full range flow can still be obtained at minimum inlet pressure.

5) NOTE: Perform this step only if a calibrated flow reference is available. Set command to 100%. Adjust SPAN (R18 on 15 Volt / R2 for 24 Volt) pot until the flow reference reads full scale flow (5.000 VDC).

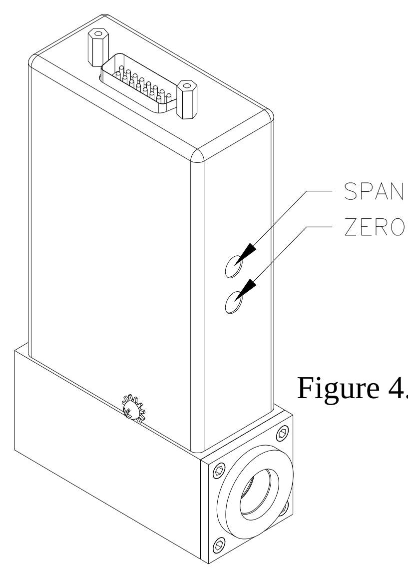


Figure 4.1

6) Record flow meter and flow reference outputs for flow rates of 20%, 40%, 60%, 80% and 100%.

4.3.2. Miscellaneous adjustments

Periodically, during normal operation, the ZERO should be checked and adjusted when required. If the instrument is not shutting completely off when the Valve Override CLOSE function is active, or a command of zero flow has been given, then the orifice may require approximately 1/8 turn clockwise.

4.4. End Cap Removal

The end cap on the inlet side must be removed to gain access to the filter or shunt assembly. First shut off the supply of gas to the instrument. Disconnect the Swagelok fitting on the inlet and outlet sides of the transducer, and remove it from the system plumbing. Remove the four hex bolts holding the end cap to the instrument (see Figure 4.1). Carefully remove the end cap, filter, wave spring (if present) and shunt, noting their order and proper orientation. The shunt can be severely damaged if dropped. Examine the filter and shunt. If either is dirty or blocked, clean or replace as applicable. Reassembly is the reverse of the removal procedure. Recalibration of the HFC is necessary.

4.5. Printed Circuit Board Replacement

In the unlikely event that the PC board fails, it is easily removed from the instrument and replaced with a spare to minimize instrument downtime. Replacement of the PC board will require the instrument to be recalibrated per Section 4.3.1.

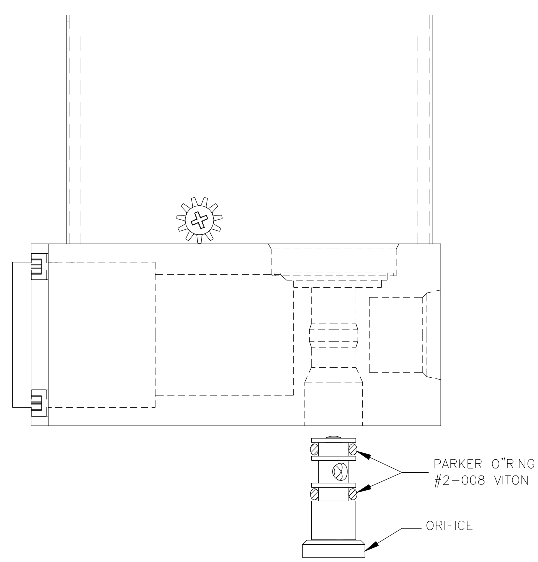
Unplug the power cable from the top of the transducer. Remove the two jackscrews next to the "D" connector and the two screws on the sides of the cover. Lift off the cover and unplug the four-wire sensor plug and the two wire valve plug, noting their orientation prior to removal.

Remove the screw that holds the PC board to the sensor. Troubleshoot or replace as applicable. Installation is the reverse of the above procedure. Recalibrate if any components were changed or if any potentiometers were adjusted.

4.6. Sensor Replacement

If the sensor fails or becomes plugged it can be removed. Remove the cover and the PC board per Section 4.5 above. Remove the three bolts holding the sensor to the instrument base. Remove the sensor from the base noting the two O-rings (Parker 2-005, V884-75) between the sensor and the base. If the sensor is plugged it can be cleaned by running a fine wire (approximately 0.008" diameter) through the tube. If sensor needs replacement, obtain another from the factory and install it. Ensure that O-rings are clean and intact. Install O-rings on seating surface, then carefully place sensor over O-rings and tighten down the three screws evenly. Replacement of sensor will require recalibration per Section 4.3.1.

4.7. Orifice Changes



The orifice may require replacement if a large flow range change is desired, if changing to a gas that has a specific gravity significantly different than the original gas, if a large change in the differential pressures across the valve is desired or in the event that a small orifice becomes plugged. Replacement orifices can be acquired from the factory. The diameter of the orifice can be calculated using the following procedure:

Orifice Changes:

A) Determine the minimum expected upstream pressure (P_u) in absolute pressure units (add atmospheric pressure – 14.7 psia) and the maximum expected downstream pressure (Pd) in absolute pressure units for full flow conditions.

B) If $P_u > 2P_d$, use formula 1; otherwise use formula 2.

C) Use a consistent set of units for pressure, flow, and density (i.e all lengths, masses, times in the same units, cm, ft, kg, sec etc.) 1 liter/minute = 1.667 x 10^{-5} m^3/sec, 1 gm/liter = 1 kg/m^3, 1 psia = 6895 kg/m★sec^2, 1 Pa = 1 kg/m★sec^2,

D) This formula provides approximate results that tend to be undersized because it neglects pressure drops internal to the flow controller, compressible gas effects and temperature effects. Multiply the result by ≈1.5 to get the expected minimum orifice size that can reliably pass the desired flows at the expected pressures.

Where:

Formula 1:

$$D = \sqrt[4]{\frac{Q^2}{P_u^{\ 2}} \frac{\sigma}{\gamma} \frac{16\rho_0 P_0}{\pi^2}}$$

Formula 2:

$$D = \sqrt[4]{\frac{\sigma Q^2}{P_d\left(P_u - P_d\right)} \frac{8\rho_0 P_0}{\pi^2}}$$

D = Orifice Diameter

Q = Flow rate in standard volumetric unit (slm, sccm, scfh)

P_0 = Standard Pressure (760 Torr, 101.325 kpa)

P_u = Upstream pressure in absolute units (use minimum expected value)

P_d = Downstream pressure in absolute units (use maximum expected value)

γ = Ratio of specific heats, ≈ 1.2 for monatomic gases, 1.4 otherwise

ρ_0 = Density of gas @ standard pressure and temperature of flow unit

π = Pi (3.1415…)

σ = Specific gravity of gas (ratio of gas density to density of air)

Choose the available orifice with the closest diameter that is larger than the calculated diameter. Orifice diameters (inches) available are 0.001, 0.002, 0.003, 0.007, 0.014, 0.032, 0.042, 0.052, 0.070. Contact factory to order new orifice.

As an example, if the maximum controlled flow will be 10 slm of air with an upstream pressure of 50 psig and exhausting to atmospheric pressure the minimum orifice diameter calculated from the previous equation would be 0.0225 inches. The next larger orifice that has a diameter of 0.032 inches should be installed.

4.7.1. HFC-202 Orifice

To change the orifice in the HFC-202 series, turn the instrument upside-down and turn the orifice counterclockwise with a 9/64" Allen wrench until it stops coming out. Then grasp the exposed orifice end and pull it straight out. See Figure 4.2.

Prior to reinstallation of the orifice, inspect the two O-rings mounted on it for damage. Replace if cut or gouged.

Lubricate the O-rings slightly with a silicone based grease, and the threads with anti-galling compound. Push the orifice into its hole and screw it in until it is flush with the instrument base. Apply pressure to the inlet side of the instrument.

Enable the Valve Override CLOSE function or unplug the instrument. Screw the orifice in a few more turns until the flow through the instrument stops, then turn it an additional 1/4 turn clockwise.

5. Warranty and Repair

5.1. Warranty Repair Policy

Hastings Instruments warrants this product for a period of one year from the date of shipment to be free from defects in material and workmanship. This warranty does not apply to defects or failures resulting from unauthorized modification, misuse or mishandling of the product. This warranty does not apply to batteries or other expendable parts, or to damage caused by leaking batteries or any similar occurrence. This warranty does not apply to any instrument which has had a tamper seal removed or broken.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty as to fitness for a particular use. Hastings Instruments shall not be liable for any indirect or consequential damages.

Hastings Instruments, will, at its option, repair, replace or refund the selling price of the product if Hastings Instruments determines, in good faith, that it is defective in materials or workmanship during the warranty period. Defective instruments should be returned to Hastings Instruments, **shipment prepaid,** together with a written statement of the problem and a Return Material Authorization (RMA) number.

Please consult the factory for your RMA number before returning any product for repair. Collect freight will not be accepted.

5.2. Non-Warranty Repair Policy

Any product returned for a non-warranty repair must be accompanied by a purchase order, RMA form and a written description of the problem with the instrument. If the repair cost is higher, you will be contacted for authorization before we proceed with any repairs. If you then choose not to have the product repaired, a minimum will be charged to cover the processing and inspection. Please consult the factory for your RMA number before returning any product repair.

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INTERNET ADDRESS	http://www.teledyne-hi.com

Repair Forms may be obtained from the “Information Request” section of the Hastings Instruments web site.