Model 2200 Toxic Air Sampler

Operations and Maintenance Manual

Version 3.04

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ATEC Model 2200 Toxic Air Sampler
Limited Warranty

Atmospheric Technology (ATEC) warrants to the original purchaser of the Model 2200 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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Introduction

This manual covers the installation, operation and routine maintenance of the ATEC Model 2200 Toxic Air Sampler. This instrument is a microcomputer-controlled sampler that can be programmed to draw ambient air into cartridges and canisters for subsequent analysis of Volatile Organic Compounds (VOC's) and Carbonyl compounds according to the methods outlined in EPA Methods TO-14A and TO-15. The Model 2200 has been specifically designed to simultaneously collect both canister and cartridge samples using one easy-to-use instrument. The sampler can be configured with several options to provide co-located sampling of canisters and cartridges, pressurized canister sampling, and expanded canister and cartridge sampling with up to 16 additional ports. The Model 2200 uses independent mass flow controllers in each channel to accurately monitor and control the flow rate to the canisters and cartridges.

NOTE: The Model 2200 can be optionally configured with cartridge channels only. For this configuration, the information in this manual pertaining to canister sampling does not apply. Likewise, the Model 2200 can be configured with canisters only and in this case, the information in this manual pertaining to the cartridge sampling does not apply.

The Model 2200 has the following features:

- Manual leak check procedure during setup
- Automatic leak checks prior to the start of sampling
- Cartridge flow rate and volume, and canister flow rate and pressure logged during sampling
- Canister pressure and flow, and cartridge flow rate monitored for out of tolerance conditions
- Auto zero of mass flow controllers

- Software calibration of mass flow controllers and pressure transducers
- On screen Standard Operating Procedures provide step-by-step guidance for operators during instrument setup and post sample data retrieval
- Expansion capability of up to 16 cartridges or canisters
- Duplicate sampling with independent mass flow controllers (maximum of four independent channels)
- Auto sense feature only uses canisters that have not been sampled
- Sub-ambient or pressurized canister sampling
- User selectable final canister pressure
- 7” WVGA color touch-screen with TS4900 microprocessor
- Day interval for cycled schedule
- Optional label printer to provide QA labels for cartridges and canisters
- Data download to jump drive
- Ethernet connection to LAN for remote access
- Idle channels can be programmed while sampling
- Programmable purge for main units and expansion units- flushes entire sample path prior to sampling.
- Temperature controlled ozone scrubber for carbonyl sampling
- Specially designed inlet to minimize condensation in sampling lines
- Manual mode operation to activate all components
- Total system leak check of the entire carbonyl sampling path

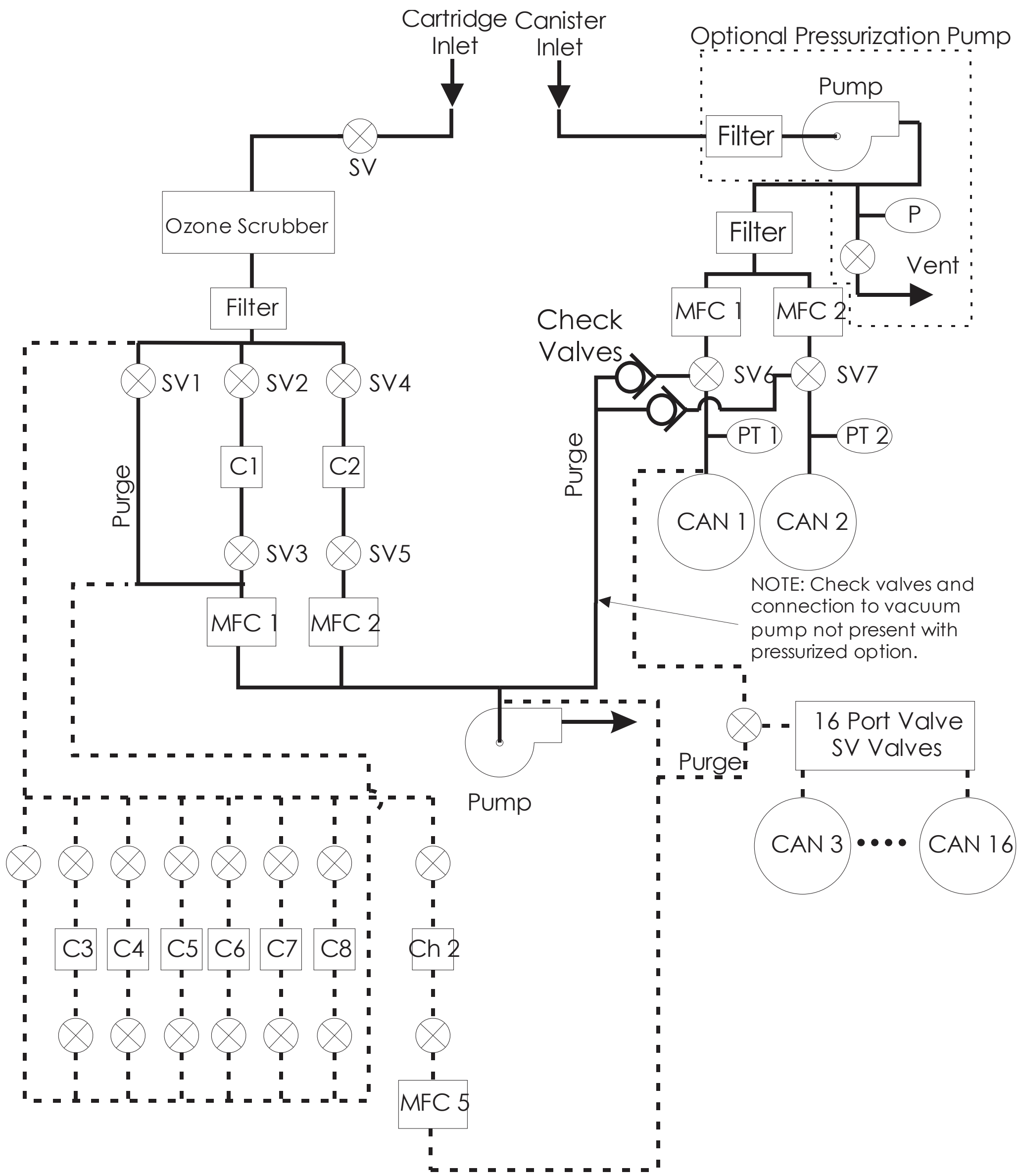
Operating Specifications

Canister Flow Rate:	Nominal 20 cc/min (Optional ranges available). Accuracy ±2%FS
Cartridge Flow Rate:	Nominal 2 liters/min (Optional ranges available). Accuracy ±2% FS
Canister Pressure Measurement Range:	0-50 PSIA. Accuracy ±0.25% FS
Maximum Canister Filling Pressure:	2 psi below ambient; 30 psia (pressurized option)
Canister Channels:	Maximum 2 independent channels. One channel is expandable with optional 8 or 16 port Expansion Module.
Cartridge Channels:	Maximum 2 independent channels. One channel is expandable with optional 8 or 16 port Expansion Module. One blank position.
Power: 115VAC.	Maximum 5 Amp
Inlet:	¼" OD tubing connector
Cartridge Connections:	Polypropylene Luer fittings
Canister connections:	1/8" OD tubing connector

Construction Materials:	Sample air exposed to stainless steel and Viton in canister section; and stainless steel, Viton, KI coated copper, PFA Teflon, TFE Teflon, and polypropylene in cartridge section.

Sampler Components

This section describes the general operation and major components of the ATEC Model 2200. Figure 1 is a schematic diagram of the sampler with co-located sampling option (two sub-ambient canister channels and two cartridge channels) and optional multi-port expansion units for canister and cartridge sampling. The Model 2200 is essentially an instrument that contains a separate dual channel (when configured for co-located sampling) canister and dual channel cartridge sampler which can be programmed using a common internal computer. This configuration requires less space and allows faster, easier and more accurate programming of sampling schedules and facilitates data retrieval.



Model 2200 Flow Schematic with Canister and Cartridge Expansions

Figure 1.

There are separate ambient air inlets to provide flow to the canister and cartridge sections. An internal vacuum pump is used to draw air into the inlets and through the cartridges during sampling. This vacuum pump also draws air through both the canister and cartridge flow paths using a by-pass solenoid valve (SV1) that is opened prior to sampling to purge the sampling lines. During sampling, the vacuum in the canisters provides the differential pressure for air to flow through the canister section (sub-ambient sampling). For pressurized canister sampling, an internal stainless-steel pump with a Viton diaphragm is mounted in the inlet to provide the differential pressure to fill the canisters above ambient pressure. A separate internal filter is mounted in the canister and cartridge sample paths to remove ambient particulates. The cartridge flow path also contains a system valve (SV) to allow leak checking of the total cartridge system and a heated KI coated copper tube denuder to remove ozone. The flow rate to each canister and cartridge is measured and controlled with a separate mass flow controller (MFC1 through MFC4).

Stainless steel solenoid valves with Viton seals (SV1 through SV7) are used to isolate the canisters and cartridges from the flow path and open only during the scheduled sampling period. The solenoid valves are special low wattage valves that operate at much lower temperatures than standard valves, thereby minimizing out-gassing of volatile organic compounds from Viton surfaces. Three-way solenoid valves (SV6 and SV7) are used with the canisters so that the mass flow controllers and inlet sampling lines can be conditioned with ambient air prior to sampling. Each canister line contains an accurate pressure transducer (PT1 and PT2) to measure the pressure within the canister. The pressure is periodically recorded during sampling to document the filling rate of each canister.

An internal microcomputer provides control for the automated sampling. A touch screen display allows operator input and shows sampling schedules and data.

Figure 2 is a picture of the interior of the Model 2200-2 showing the sampler components which consists of the following:

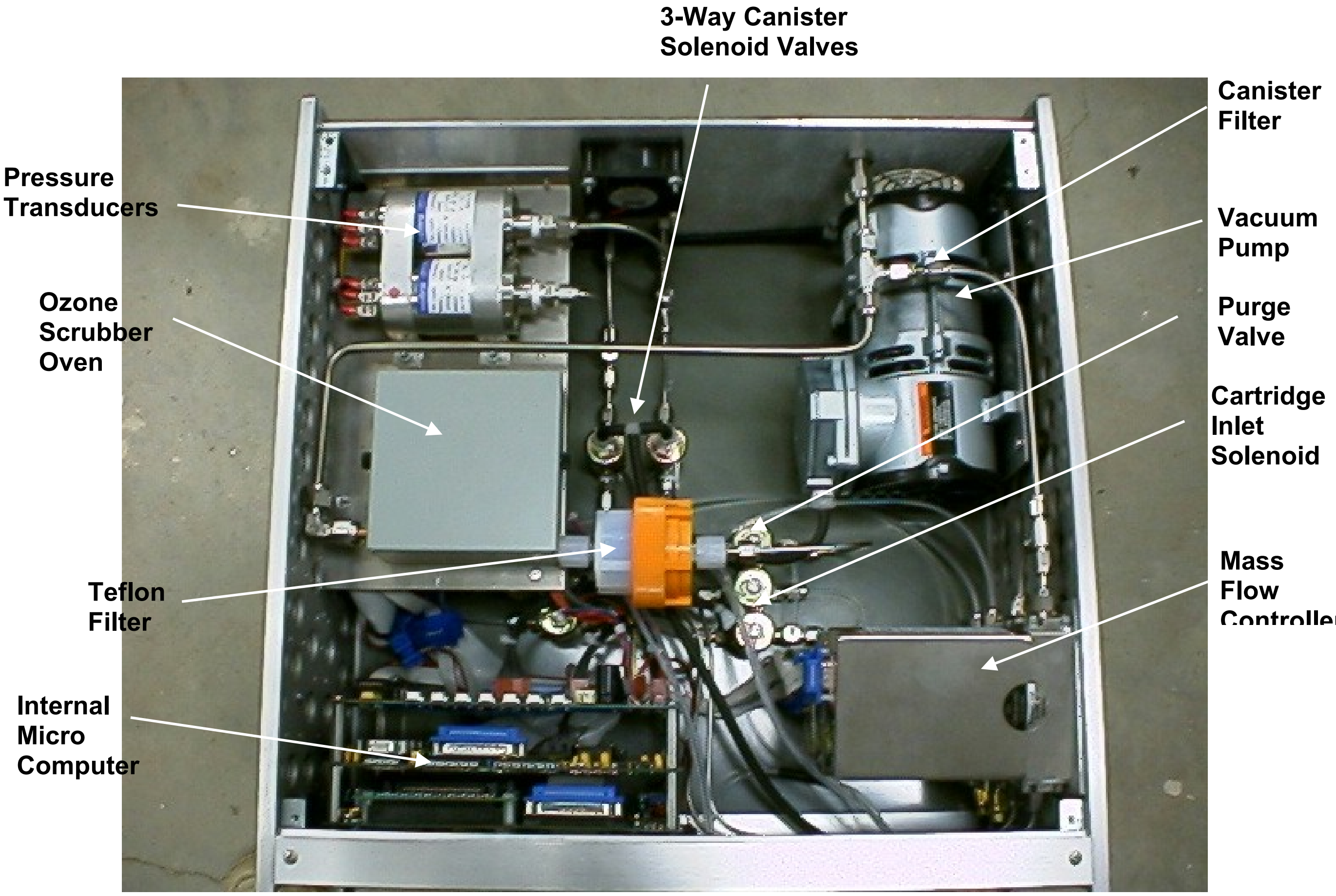


Figure 2. Model 2200 Internal Components

Inlets

External sampling lines (one for canister sampling, one for cartridge sampling) attach to the rear of the sampler using the ¼" Swagelok bulkhead fittings.

Canister connections

Canisters are connected to the sampler using the 1/8" Swagelok fittings mounted on the rear panel. For a duplicate canister sample, attach a Swagelok tee fitting to the Canister 1 connection and attach separate lines from the tee to each canister.

Cartridge Connections

Cartridges are mounted using the Luer-lok fittings on the front panel

Canister filter

A 2-micron sintered stainless steel filter is located between the inlet and canister mass flow controllers to remove particulates from the air stream

Cartridge filter

A medium porosity (5-10 micron) 47mm diameter Teflon filter is mounted in a Teflon PFA filter holder located downstream of the ozone denuder to remove particles from the sample path.

Ozone scrubber

An ozone scrubber consisting of a ¼” OD copper tube, 36” long, which has been internally coated with potassium iodide (KI), is located downstream of the sampling inlet. The scrubber is mounted in an insulated heater, which is maintained at a temperature of 50±0.5°C. The temperature is controlled and monitored by the internal computer.

Solenoid valves

Normally closed 2-way solenoid valves are used for each cartridge channel and the cartridge flow path. Valves are located upstream and downstream of each cartridge and on the cartridge inlet line. During normal sampling, the inlet valve and both solenoid valves are opened. A leak check is performed during the first 20 seconds of each sampling interval. During leak check, the upstream solenoid valve is closed and the sampling lines from the upstream solenoid valve, downstream solenoid valve, cartridge, and flow controller are evacuated by the vacuum pump. If a small leak exists, the flow meter will detect the flow. During automatic operation, the microcomputer will set an error status if the flow exceeds a preset tolerance. A by-pass solenoid valve is located parallel with the sampling valves to provide a purge flow to condition the sample lines prior to sampling. The purge flow is controlled using the cartridge Channel 1 mass flow controller.

A three-way solenoid valve is used to isolate each canister and corresponding pressure transducer from the flow path. When the valve is not activated, the sample path is connected to the vacuum pump, which pulls air through the inlet, filter, mass flow controllers and three-way solenoid valves to purge the entire sample path. When the solenoid valve is activated, the sample path is connected directly to the canister.

Mass flow controllers

A separate mass flow controller is used to measure and control the flow rate to each canister and cartridge. Various ranges of flow controllers can be installed depending on the required sampling flow rate. The control set point and output are interfaced to the internal computer. The mass flow controllers are zeroed prior to sampling to increase measurement accuracy.

Pressure Transducers

A precision pressure transducer is used to monitor the absolute pressure in each canister. The pressure transducers have a full-scale range of 0-30 psia. The output of each pressure transducer is interfaced to the internal computer.

Vacuum Pump

An internal diaphragm vacuum pump is used to draw air through the Model 2200 for purging and sampling. The pump is rated for continuous duty and can maintain a maximum vacuum level of 24 in Hg. The pump provides sufficient vacuum to simultaneously sample two DNPH cartridges at a flow rate of 1 lpm. Maximum flow rate depends on the flow resistance of the cartridges.

An optional stainless-steel pressure pump with a Viton diaphragm is mounted in the canister flow path downstream of the inlet for pressurized canister sampling. The pressure, which is adjusted with a needle valve and pressure gauge on the front panel, is set to 5 psi above the final canister pressure.

Power supply

The Model 2200 is powered by 115VAC and activated with the on/off switch located on the rear panel. The 115VAC power is used to run the vacuum pump, canister pressure pump, ozone scrubber heater, and electronics power supply. The internal electronic components are powered using a ±15 VDC power supply. This supply provides DC power for the mass flow controllers, interface electronics, pressure transducers, internal single board computer power supply, and cooling fan. A separate +12VDC power supply provides power to the sensor microprocessor.

Sampler Setup

Upon arrival, check all shipping containers for damage and notify the shipper if damage has occurred. Carefully unpack the instrument and either bench mount or rack mount using the optional rack mount kit. Verify that the power switch on the rear panel is in the "off" position. Plug the main power cord into an 115VAC outlet. Move the power switch to the "on" position and verify that the front display becomes illuminated after approximately the first 30 seconds of operation.

The Model 2200 uses a ¼ VGA LCD color touch screen display to show current operating status and to enter information into the computer. The computer is accessed using tabs and buttons 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 selecting the Touchscreen button under the **Setup** tab. Follow the directions on the screen to set the touch sensitivity. Once this is set, the buttons can be pressed using a finger or stylus.

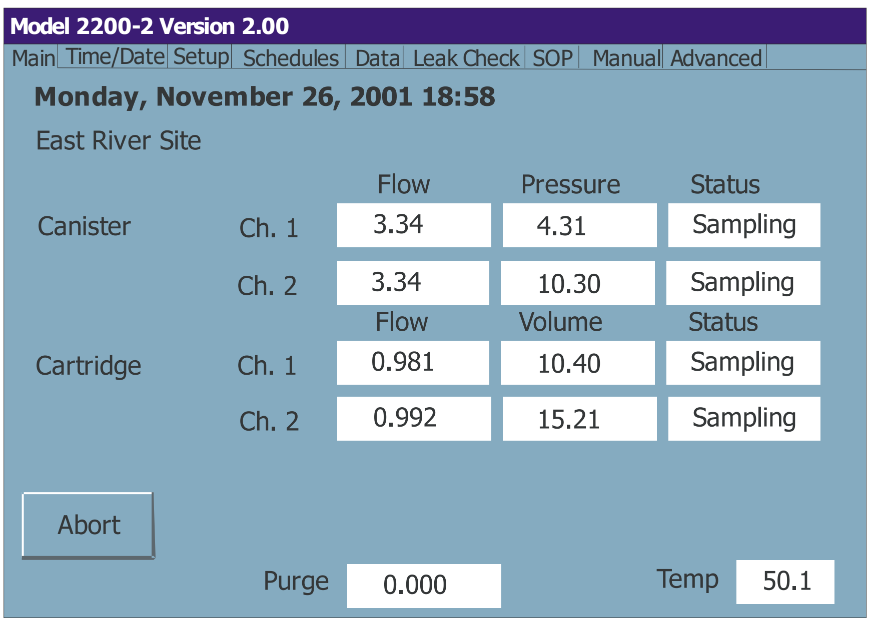
Quarter-inch sample lines are connected to the fittings labeled "Canister Inlet" and/or "Cartridge Inlet" on the rear of the sampler. Canister connections are made to the 1/8" fittings labeled "Canister Ch.1" and "Canister Ch.2" on the rear panel. Cartridges are installed in positions labeled "Channel 1" and Channel 2" on the front of the Model 2200 using the Luer fittings. The tubing length can be adjusted for various cartridge sizes by pushing the Teflon tubing through the hole in the panel.   A "Blank" location is provided to mount a field blank.

Below the touchscreen on the front panel is a USB connector for retrieving data using a jump drive, updating the system software, or attaching a USB keyboard, mouse or an optional label printer.

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 after verifying operation, the Model 2200 should be purged with humidified zero air for a minimum of 24 hours before sampling.

Display and Function Tabs

Normally the display will show the default main screen as illustrated here for a dual channel canister and dual channel cartridge configuration. 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:



Date and Time

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

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. This label is also displayed in the data that can be downloaded to a PC or laptop.

Canister and Cartridge Sampling Information

The canister flow rate (cc/min) and pressure (psia) along with the cartridge flow rate (liters/min) and total volume (liters) 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—The channel is sampling
Waiting—The channel has been programmed to sample
Purging—The channel is purging prior to sampling
Idle—The channel has not been programmed to sample
Aborted—Operator terminated sampling
Finished—A successful sample has been collected without errors
Used Can—Canister starting pressure exceeded used can limit—no sampling occurred
Leak Err—Cartridge failed the leak check on start-up
Post Leak Err—Cartridge failed auto leak check at the end of sampling
Temp Tol—Ozone scrubber temperature exceeded ±5°C
Press Tol—Canister pressure tolerance exceeded
Flow Tol—Cartridge flow rate tolerance exceeded
Zero Tol—Cartridge MFC required excess zero compensation
Errors---Multiple errors, power outage, or sample aborted

Ozone Scrubber Temperature

The temperature of the ozone scrubber is displayed in the lower right-hand corner of the screen. A red dot will appear next to the temperature when the heater is on.

Purge Flow Rate

When the sampler is purging prior to sampling, the purge flow rate will appear in the lower left-hand side of the main screen. Normal purge flow rate is 1.0 lpm.

Abort

The **Abort** button is used to terminate sampling after purging has started. Once the **Abort** button is pressed, the channels that are sampling will be put through shut down which may take a minute or two. Also, pressing the **Abort** button will require the operator to enter a new sampling sequence to resume sampling.

Function Tabs

Several function buttons are located along the tap 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 canisters and cartridges, or set-up the sampler using the Standard Operating Procedure (SOP) option. The operation of each tab is described in the programming section.

Programming the Model 2200

The Model 2200 uses nine tab functions to allow the operator to enter or retrieve information from the sampler**: Main, Time/date, Setup, Schedules, Data, Leak Check**, **SOP, Manual,** and **Advanced**. **Time/date** is used to enter the current time and date. **Setup** is used to configure the sampler and store sampling parameters. Sampling schedules are entered through the **Schedules** tab. Data can be displayed, sent to an optional label printer or downloaded to a jump drive using the **Data** tab. Canisters and cartridges are manually leak checked with the **Leak Check** option. The **SOP** tab uses a standard operating procedure to install and leak check canisters and cartridges and program sampling schedules. The **Manual** tab allows operational check out of the sampler hardware and the **Advanced** tab allows configuration of critical hardware parameters.

<u>Time/Date</u>

The time and date that is stored in the Model 2200 can be changed using the **Time/Date** tab. When this tab is selected, a operating system screen will appear which will allow the user to change time, date, time zone, etc. Once this window is closed, the main screen should show the changed day of the week, date, and time.

<u>Setup</u>

The **Setup** tab is used to input canister and cartridge operating parameters. This section is designed to allow field operators to change common operating parameters. When the **Setup** tab is selected, a screen appears which shows the following canister and/or cartridge operating parameters depending on the sampler configuration. This screen also enables recalibration of the touchscreen and the installation of software updates.

Canister Parameters

Pressure Tolerance

The Model 2200 continuously monitors the canister pressure during sampling and will produce an error flag if the pressure falls outside the pressure tolerance limit specified here. This tolerance is the difference between the expected pressure and the actual canister pressure. The sampler calculates the expected pressure based on the starting pressure, end pressure, and sampling duration.

End Pressure

The final end pressure is the desired canister pressure at the end of sampling. This value is an absolute pressure that should be determined from the atmospheric pressure at the sampling site or a value that is 5 psi below the pump pressure for the pressurized canister option. The end pressure must be at least 2 psia below this value to insure proper operation of the mass flow controllers (sub-ambient canister sampling only). The Model 2200 can be used to measure the site pressure by monitoring the canister pressure on the main screen without a canister attached.

The sampler uses the specified end pressure to calculate the necessary flow rate to fill the canister to this pressure. It must be noted that the mass flow controllers are factory calibrated to a volumetric flow rate at 760 mm Hg at 0°C (273°K). If the canister is sampled at a different temperature other than 0°C, the canister mass flow controller calibration slope must be adjusted. The filling rate and the resulting end pressure must be corrected using the ratio of sampling temperature to canister mass flow controller calibration temperature. For example, if the canister is filled at 273°K (0°C), the standard mass flow controller calibration (slope = 1.0) will provide the correct end pressure. However, if the canister is normally filled at 298°K (25°C), the canister mass flow controller calibration slope specified in Setup should be changed to 1.09 (298°K/273°K) to fill the canister to the specified pressure. As an alternative to changing the canister mass flow controller calibration slope, the end pressure can be specified at a lower value to compensate for temperature. In the above example, the end pressure should be entered at 0.92 (273°K/298°K) times the desired end pressure.

Leak Rate Limit

The leak rate limit is the increase in pressure that is allowed to pass a canister during the manual leak check. This value is normally set to 0.1 psia/min.

Used Can Limit

The Model 2200 checks the pressure of each canister prior to sampling. The pressure specified in the used can limit is used to determine if a used or leaking canister has been installed. If the starting pressure is above this value, a used can error status code will be set and sampling will be stopped.

Canister and Cartridge Parameter

Purge Time

Purge time specifies the purging time before sampling either canisters or cartridges.

Cartridge 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.

Flow Tolerance

The cartridge flow rate is continuously monitored during sampling. If the measured flow rate deviates from the flow rate specified in Ch.1 MFC or Ch.2 MFC Set Point by this amount or more, an error status for flow tolerance will be generated.

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.

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. This label will also appear in the data downloaded to a PC or laptop.

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** 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 stating that the update was successful and that the system will reboot in 15 seconds. 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 not software changes will be made.

Schedules

The **Schedules** tab is used to enter sampling schedules for the canisters or cartridges. Canister or cartridge channels can run independently or together (co-located sampling or duplicate sampling). When the **Schedules** tab is pressed, a screen appears which shows the start date, start time, and sample duration for Canister Ch.1. The values in each box can be changed by touching the text box and using the keypad or calendar to enter the appropriate values. All times are in military time format with midnight being 00:00. A 24-hour sample starting at midnight 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 canister and cartridge. This label will appear with the data to identify each sample. If a duplicate canister sample is to be taken (i.e. the Canister 1 connection on the rear of the sampler is connected to two canisters), the "with Duplicate Can" box should be checked. If only Canister Ch. 1 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 Canister Ch. 2. The start date, start time, and duration can be entered for Canister Ch. 2. However, if Canister Ch. 2 is to run as a co-located sample (i.e. same sampling time as Canister Ch. 1), the box marked "Sample with Ch. 1" should be checked and the same schedule for canister Ch. 1 will be entered for Canister Ch. 2. A label for Canister Ch. 2 can also be entered in the "Run Label" box. If no cartridges are to be sampled, the **Done** button can be used to return to the main screen. If a change must be made to the Canister Ch. 1 schedule, the **Prev** button will show the previous screen.

Pressing the **Next** button will show the schedule screen for Cartridge Ch. 1. The start date, start time, duration and label must be entered for this channel. However, if Cartridge Ch. 1 is to run at the same time as canister Ch. 1, the box labeled "Sample with Can" should be checked and the sampling schedule for Canister Ch. 1 will be automatically entered for cartridge Ch. 1. If desired, an identification label for this cartridge can be entered in the "Run Label" Box.

If a second cartridge is to be sampled, pressing the **Next** button will show the schedule for Cartridge Ch. 2. The schedule information can be entered or the "Collocated Cartridge" box could be pressed to enter the same schedule as Cartridge Ch. 1. The **Prev, Next** and **Done** buttons can be used to return to the previous screen, scroll around to the first screen, or move to the main screen.

<u>Data</u>

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

If the label printer option has been installed, a label can be printed for each channel by pressing the **Label** button. On each label the following information will be printed: start date/time, end date/time, start and end pressure or 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
1	Used Can Pressure Limit Exceeded
2	Leak Check Flow Limit Exceeded
4	Temperature Tolerance Exceeded
8	Pressure 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
512	Inlet Purge Line Flow Limit

The entire data set can be downloaded to a jump drive inserted into one of the USB connectors below the screen. 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. The data file name has the format: [*SiteLabel_*]*Can1Data_DateofTransfer.txt.* This name is unique so that existing data on the jump drive will not be overwritten. Using the site label in the file name allows data from different sampler to be stored on the same jump drive. Once all the files have been received, a message will appear confirming completion of the transfer.

An example of transferred canister data file is shown here.

```
East River Site
Canister 13249
Ch. 1 Canister Started at 11/20/00 9:00:06 PM
        Starting Pressure 0.11 psia
      Flow Rate Set Point 3.29 cc/min
               Stopped at 11/21/00 9:00:05 PM
             End Pressure 11.68 psia
        Average Flow Rate 3.29 cc/min
        Minimum Flow Rate 0.94 cc/min
        Maximum Flow Rate 3.47 cc/min
     Flow Controller Zero 0.03 cc/min
             Error Status Pressure Tolerance Exceeded

     Time           Can Pressure

11/20/00 9:00:17 PM      0.26
11/20/00 9:05:26 PM      0.16
11/20/00 9:10:36 PM      0.24
      •            •
      •            •
      •            •
11/21/00 8:45:25 PM      11.61
11/21/00 8:50:25 PM      11.63
11/21/00 9:00:05 PM      11.68
```

The **Next** button on the 2200 Data screen will advance to the next canister or cartridge data or **Exit** can be used to return to the main screen.

The cartridge data screens follow the canister data screens. The stored cartridge data includes: start time; stop time; average, minimum, and maximum flow rate; error status; total volume sampled, and elapsed time.

An example of a cartridge data file 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
         Average Flow Rate 0.996 lpm
         Minimum Flow Rate 0.984 lpm
         Maximum Flow Rate 1.017 lpm
       Pre Start Leak Rate 0.012 lpm
          Ending Leak Rate 0.022 lpm
      Flow Controller Zero -0.003 lpm
              Error Status Temperature Tolerance Exceeded

     Time          Flow Rate          Volume

11/25/01 8:15:28 PM      1.902               0.35
11/25/01 8:20:36 PM      0.997               5.47
11/25/01 8:25:36 PM      0.996               10.45
11/25/01 8:30:46 PM      0.995               15.59
11/25/01 8:35:46 PM      0.995               20.57
11/25/01 8:40:56 PM      0.996               25.72
11/25/01 8:45:56 PM      0.996               30.70
11/25/01 8:51:06 PM      0.995               35.84
      •                 •
      •                 •
      •                 •
11/26/01 7:35:15 PM      0.997               1388.21
11/26/01 7:40:25 PM      0.996               1393.35
11/26/01 7:45:35 PM      0.995               1398.50
11/26/01 7:50:35 PM      0.998               1403.48
11/26/01 7:55:45 PM      0.994               1408.62
11/26/01 8:00:45 PM      0.995               1413.60
11/26/01 8:05:55 PM      0.996               1418.75
11/26/01 8:11:05 PM      0.994               1423.90
```

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. Both canister and cartridge data will show a power loss error, and the pressure/time and volume/time data will show the missing sampling interval during the power outage.

NOTE: The power failure error will also be reported if the system goes through a reboot during sampling. A hardware timer is monitoring system activity and if there is no activity for 30 seconds, the system will automatically reboot. The software sees this as a power outage and will record the power failure error. Sampling will resume with a minor loss of sampling data.

Leak Check

The **Leak Check** button is used to verify the canister and cartridge connections prior to sampling. The first screen is identified as “Can Ch. 1 Leak Check” and is used to leak check the Ch. 1 canister. Before starting the check, the operator must install an evacuated can on the Canister Ch. 1 port on the rear of the sampler. After the connections have been tightened, the canister valve is opened and then closed to evacuate the connecting line, internal sample tubing, and pressure transducer up to the isolation solenoid valve. Since the tubing has a small volume, small leaks will cause a rise in the measured pressure. The automated leak check routine will sample the pressure and determine if a leak is present. Even though pressure measurements fluctuate, the program will uses a least square data analysis routine to determine an accurate leak rate.

The **Start** button is pressed to begin the leak check. The leak rate box will show “testing” during the measurement period. The canister pressure measurement is shown in the lower right-hand side of the screen along with the elapsed time. Testing can be stopped at any time by pressing the **Stop** button. After sampling for one minute, the calculated leak rate is shown in the leak rate box. If the test passed, the value is shown and "Passed" is displayed below the leak rate box. If the test failed, the value is shown and "Failed" is displayed below the box. When a canister fails, the test should be repeated to verify the first test. After repeated failures, the connections should be tightened again or replaced and the leak check repeated. The **Next** button is used to advance to Canister Ch. 2. if a collocated can is to be tested.

A similar procedure is used to leak check the cartridges. After the Ch. 2 canister is tested, the **Next** button will display the cartridge "Ch. 1 Leak Check" screen. 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 cartridge leak check procedure is similar to the one used for canisters. After a cartridge has been installed, the operator must press the **Start** button to begin the test. The cartridge leak check runs for 20 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. 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. The test can be repeated by pressing the **Start** button, or the next button can be used to advance to Ch. 2 cartridge testing.

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 Canister Ch. 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.

SOP

The **SOP** tab provides a Standard Operating Procedure for installing, leak checking, and scheduling the Model 2200. 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 cans or cartridges to be sampled. Several screens follow which lead the operator through an automated leak check procedure. Each canister, cartridge, and cartridge system must pass leak check, or the program will not continue. After all cartridges and canisters have been installed and leak checked, and the canister system flow path has been leak checked, 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.

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. The flow rate and pressure values shown in this mode are ***not adjusted*** by the calibration constants (slope and intercept) entered in Setup.

Advanced

Additional settings can be modified in the Advanced tab section that is accessed through the **Advanced** tab. Portions of this screen can only be accessed with a password and should only be used by individuals familiar with the operation and calibration of components used in the Model 2200. Changing the values in the Advanced Setup will alter the accuracy of the instrument.

Mass Flow Meter Range

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. This item is hardware dependent and is password controlled.

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. This item is hardware dependent and is password controlled.

Purge Flow Rate

The purge flow rate can be changed by selecting a new value in the Purge Flow Rate box. The purge flow is regulated by MFC 3 and cannot be greater than the full-scale range of this mass flow controller.

Pressure Transducer Range

The range of each pressure transducer must be entered in the Press 1 and Press 2 Cal boxes. This item is hardware dependent and is password controlled.

Pressure Transducer Offset

Some pressure transducers have a zero offset. The value for the offset must be entered in the Press 1 and Press 2 Off boxes. This item is hardware dependent and is password controlled.

Temp High Limit

If the sampler is in an outdoor enclosure, the cooling fan will be turned on when the enclosure temperature exceeds this limit. The fan is also activated any time the pump is on. This item is hardware dependent and is password controlled.

Temp Low Limit

If the sampler is in an outdoor enclosure, a heater will be activated if the enclosure temperature should fall below this value. This item is hardware dependent and is password controlled.

Inlet Purge Flow Limit

If the sampler has an optional inlet purge mass flow meter, an error flag will be set if the inlet purge flow rate falls below this setting. This item is hardware dependent and is password controlled.

Language

If the sampler has been configured for multi-language capability, a dropdown box will be on the screen with the selection of available languages. To change to another language, select the language in the dropdown box and then press the ***Exit*** button. When returning to English from another language, the system will automatically reboot.

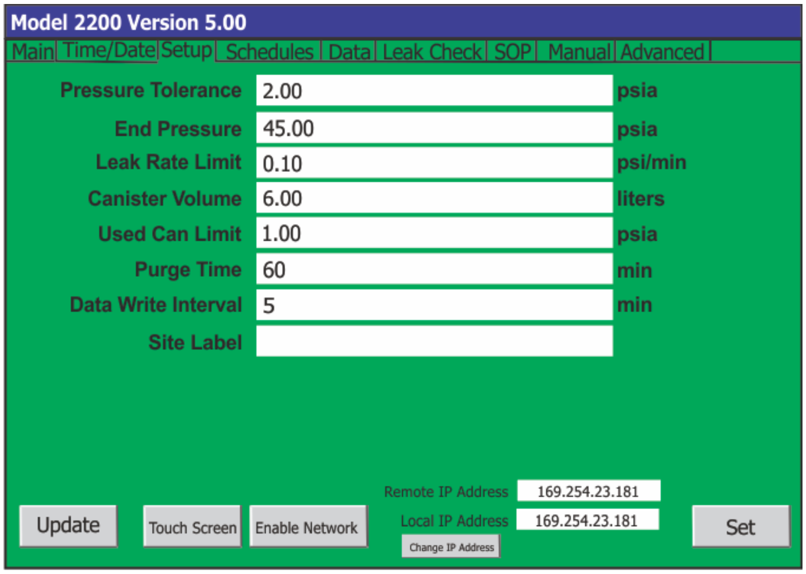
Local Area Network Connection

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. "VNC Viewer" or "UltraVNC Viewer" must be installed on the PC/tablet that is to communicate with the sampler. "VNC Viewer" is available for download from realvnc.com. To enable transfer of data files from the sample to a remote PC/tablet, "UltraVNC Viewer" **Version 1.2.0.3** must be used for communication. This software is available for downloading from "ultravnc.en.uptodown.com/windows/versions".

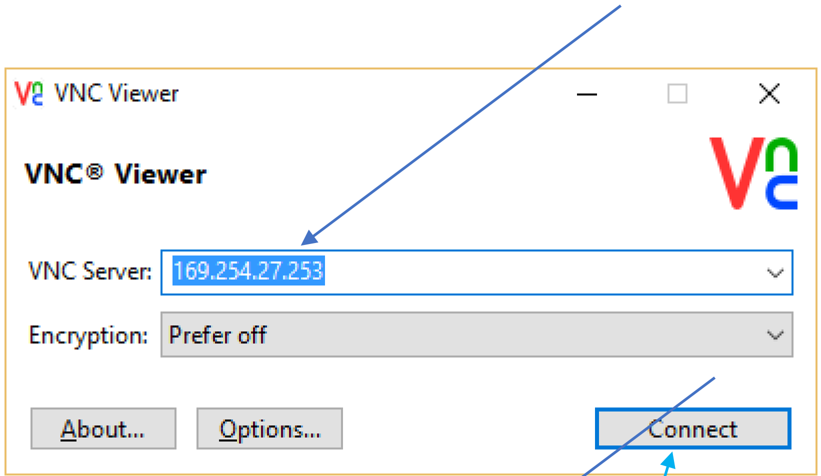
Initial Network Setup

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. This software is available on the internet. The following steps need to be done only once unless noted.

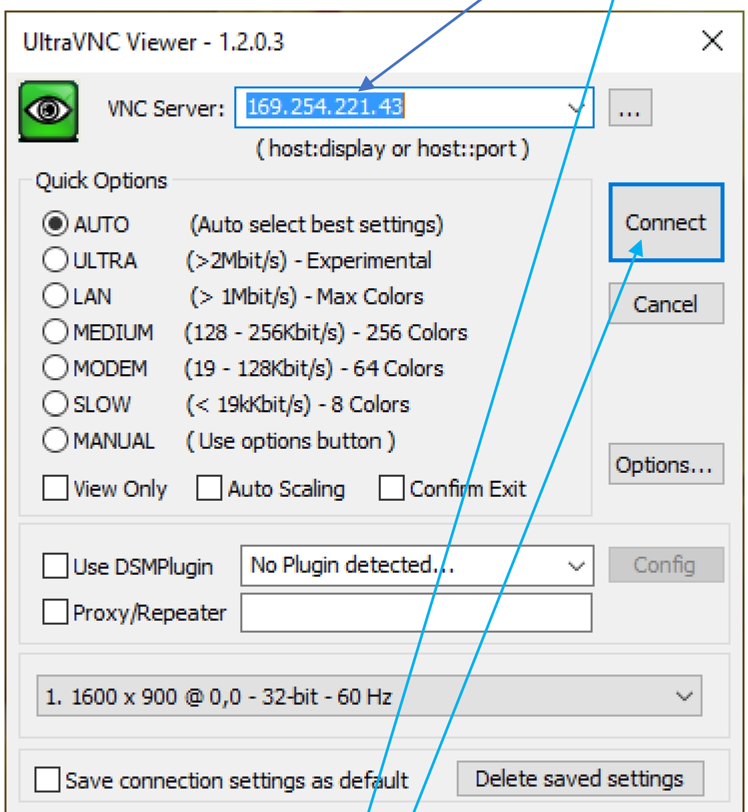
1. Connect the PC/tablet and the sampler to the LAN.
2. On the PC/tablet, bring up the "command prompt" window.
    - Type: ***ipconfig***
    - Record the IP Address that appears under the Ethernet Adapter setting: Autoconfiguration IPv4 Address. This is the "Remote IP Address".
3. On the Sampler, go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



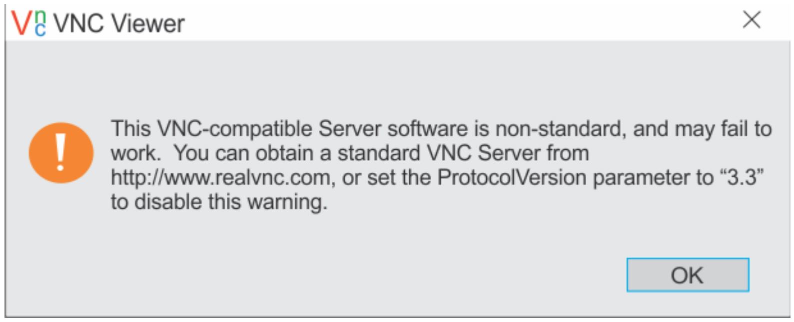
4. If the Local IP Address is invalid or needs to be changed, select the “Change IP Address” button and do the following (you will need a USB keyboard plugged into the USB port below the screen):
    a. Select the ENET1 icon.
    b. Select the “Specify an IP Address” button.
    c. Enter an IP Address, 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 or UltraVNC Viewer. Enter the “Local IP Address” in the box labeled “VNC Server:” and the encryption should be “Prefer Off”.



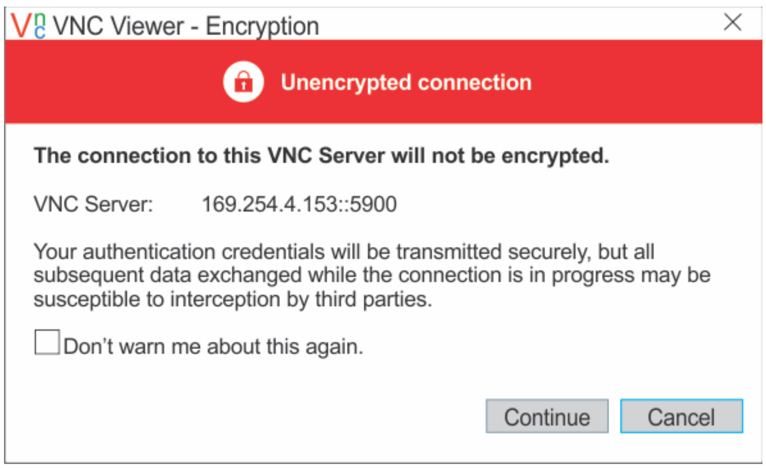
or



8. On the PC/tablet, press the “Connect” button and the following screen may appear if using VNC Viewer:



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



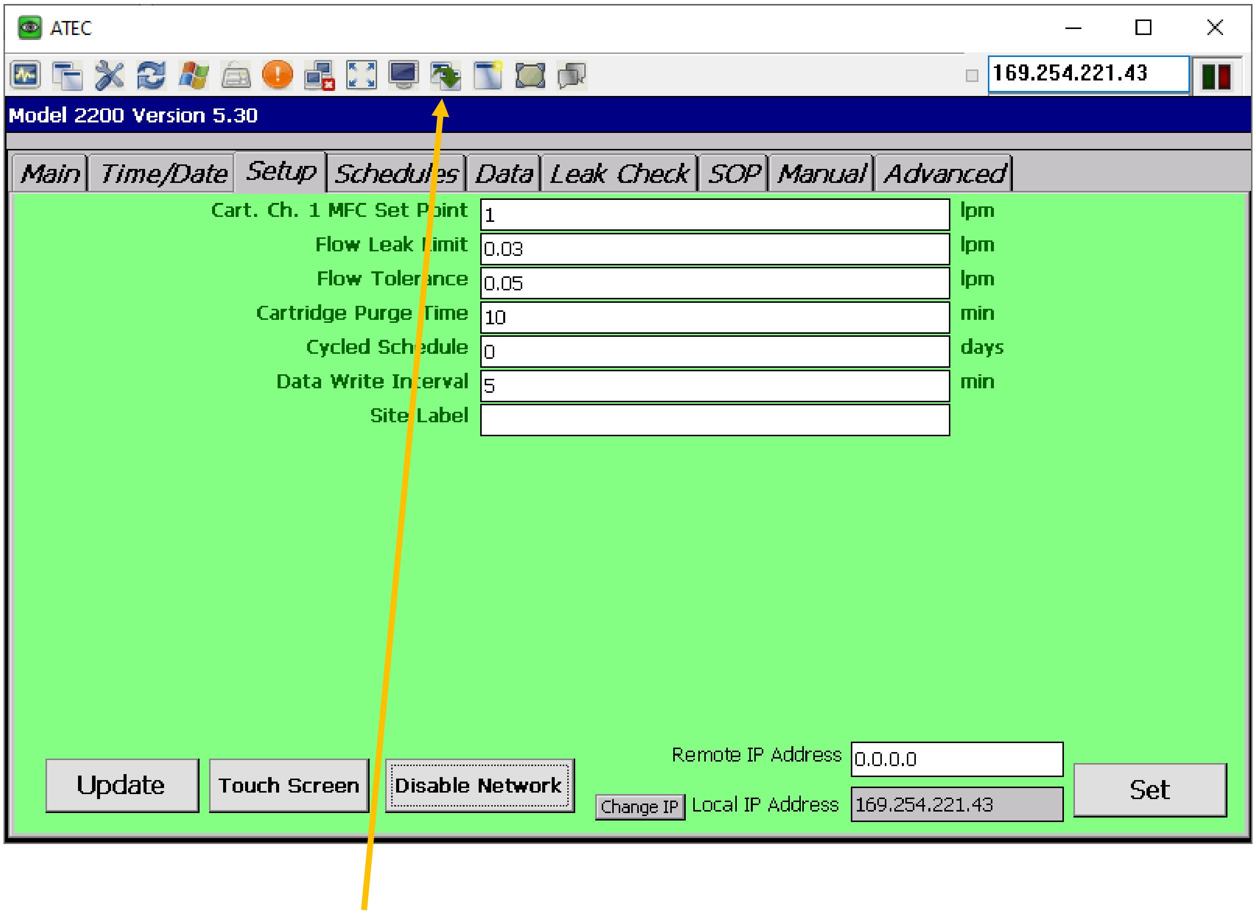
10. Press the “Continue” button and connection will be made. The “Setup” screen of the sampler should now be appearing on the PC/Tablet.

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.

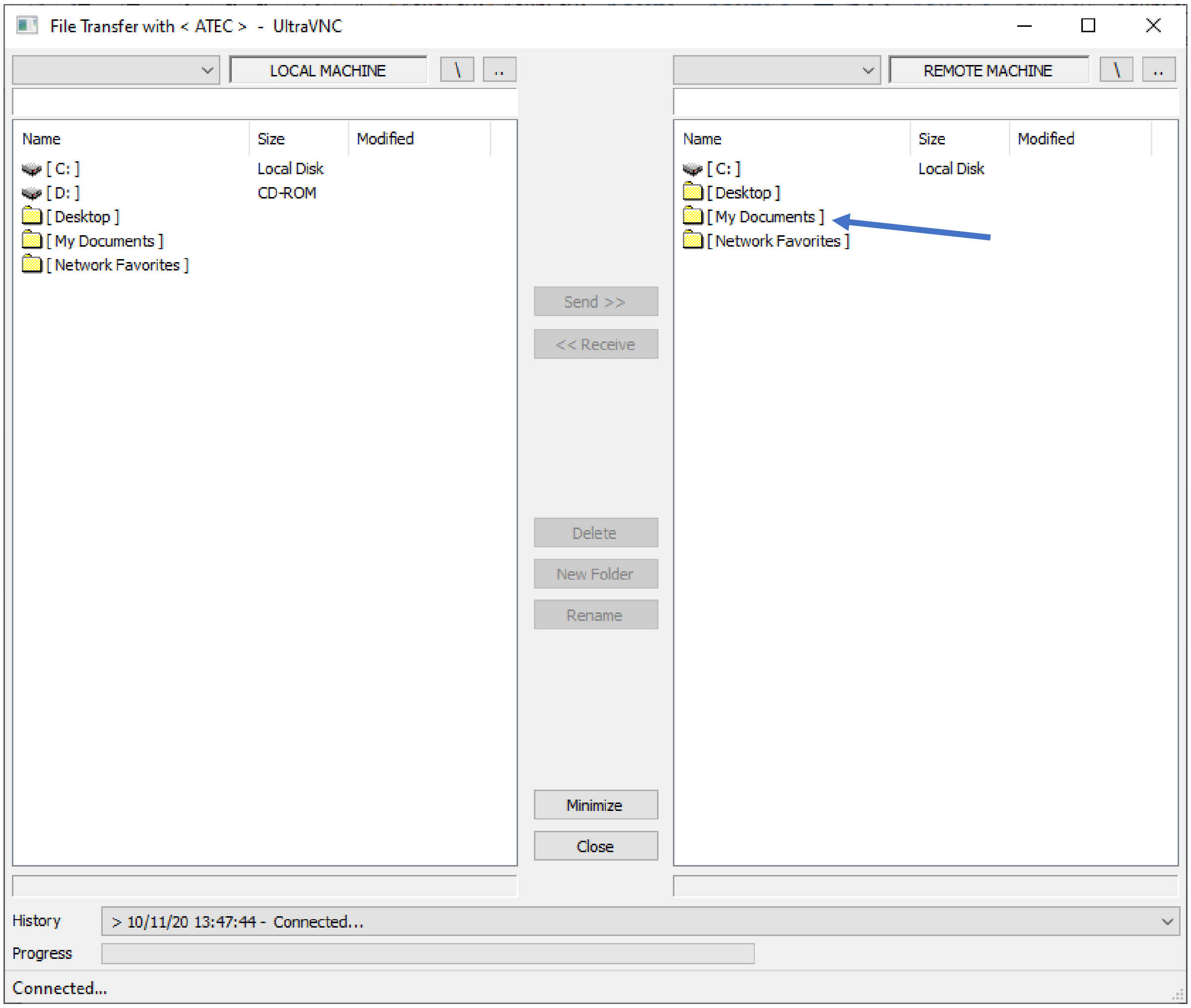
File Transfer using UltraVNC Viewer

To transfer the data files from the sampler to a remote PC/tablet, the following steps can be used.

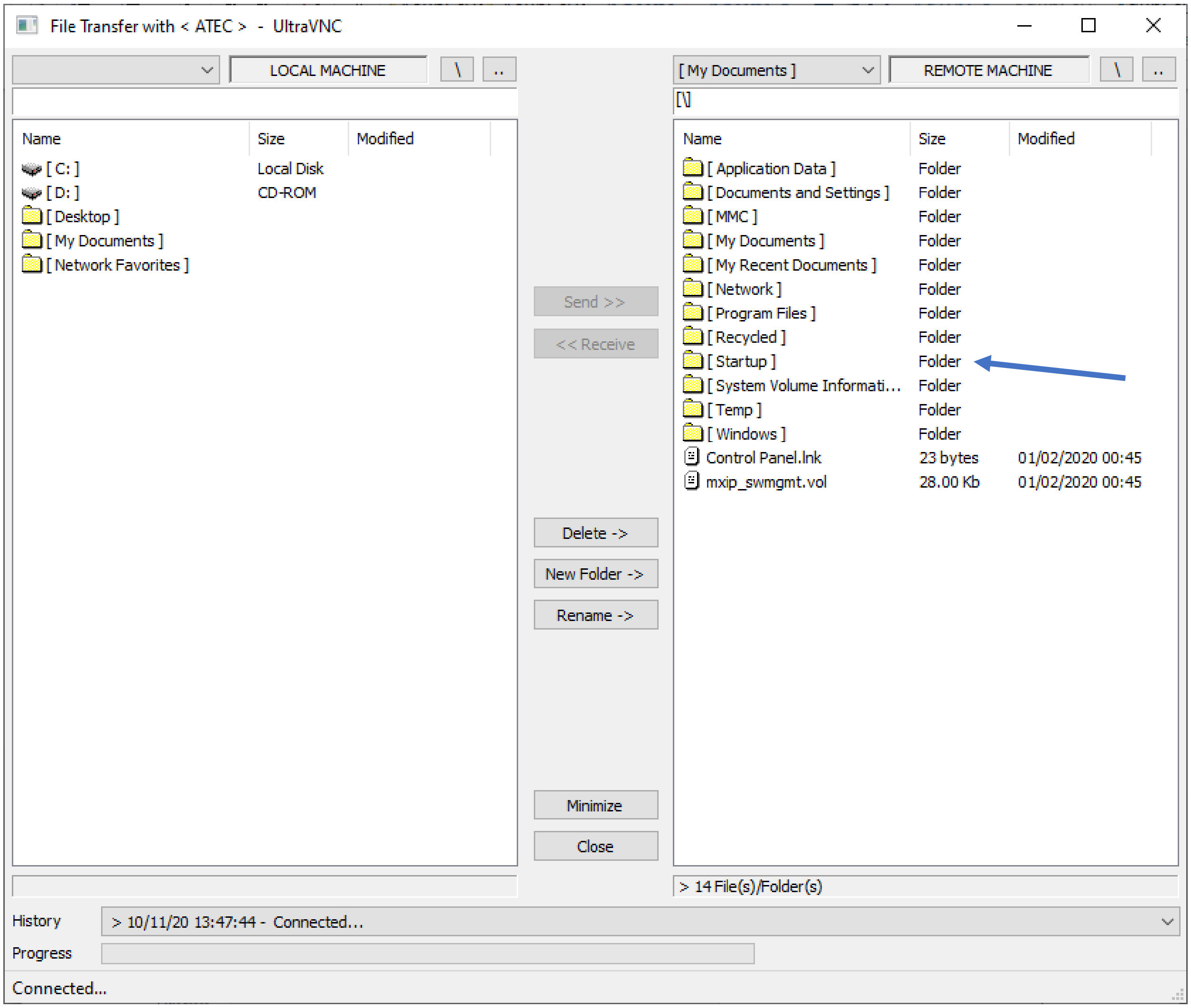
Once connected to the sampler using UltraVNC Viewer, you seen the current screen on the sampler. An example of the Setup screen is shown here.



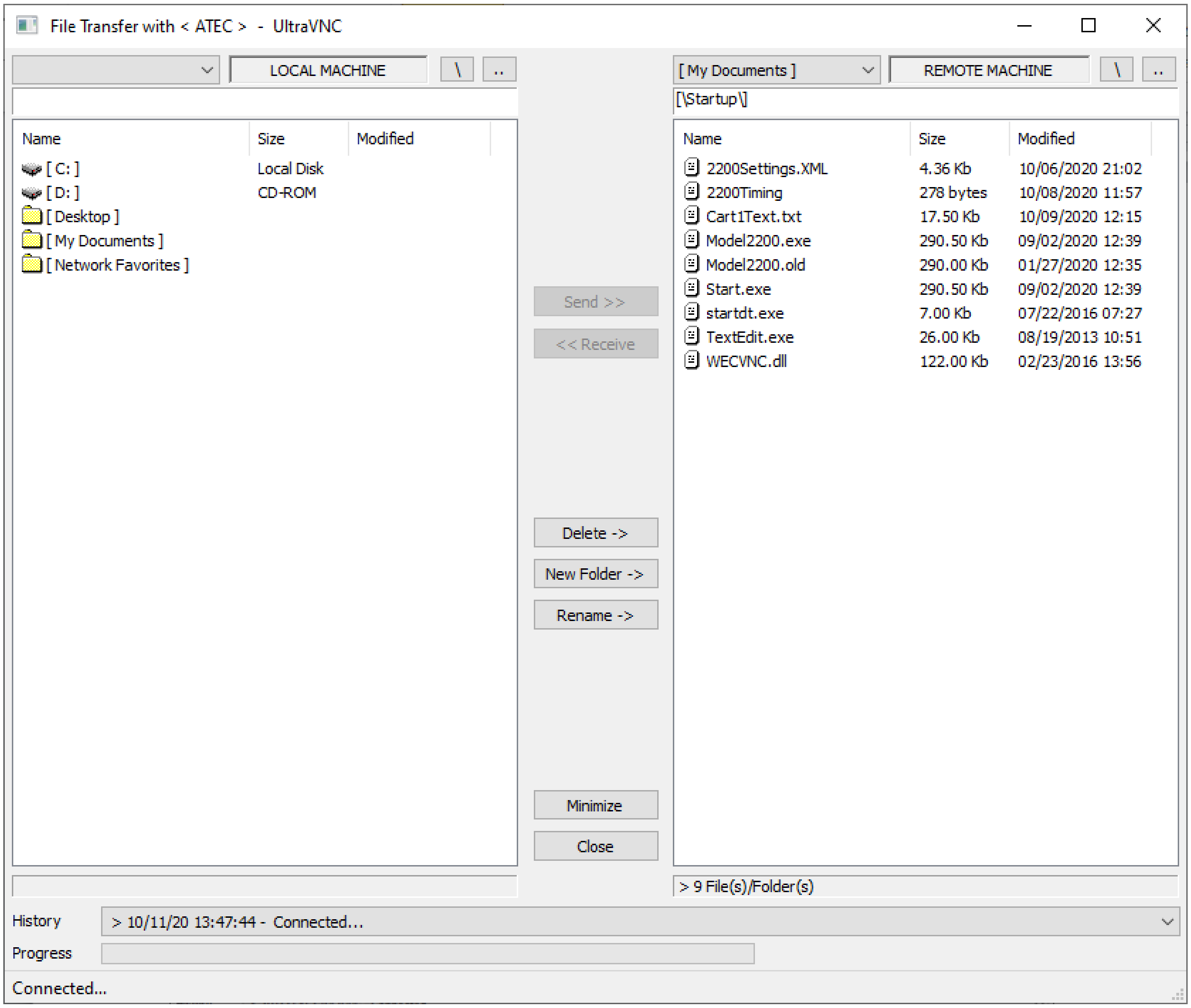
1. Select the “File Transfer” button to bring up the following screen.



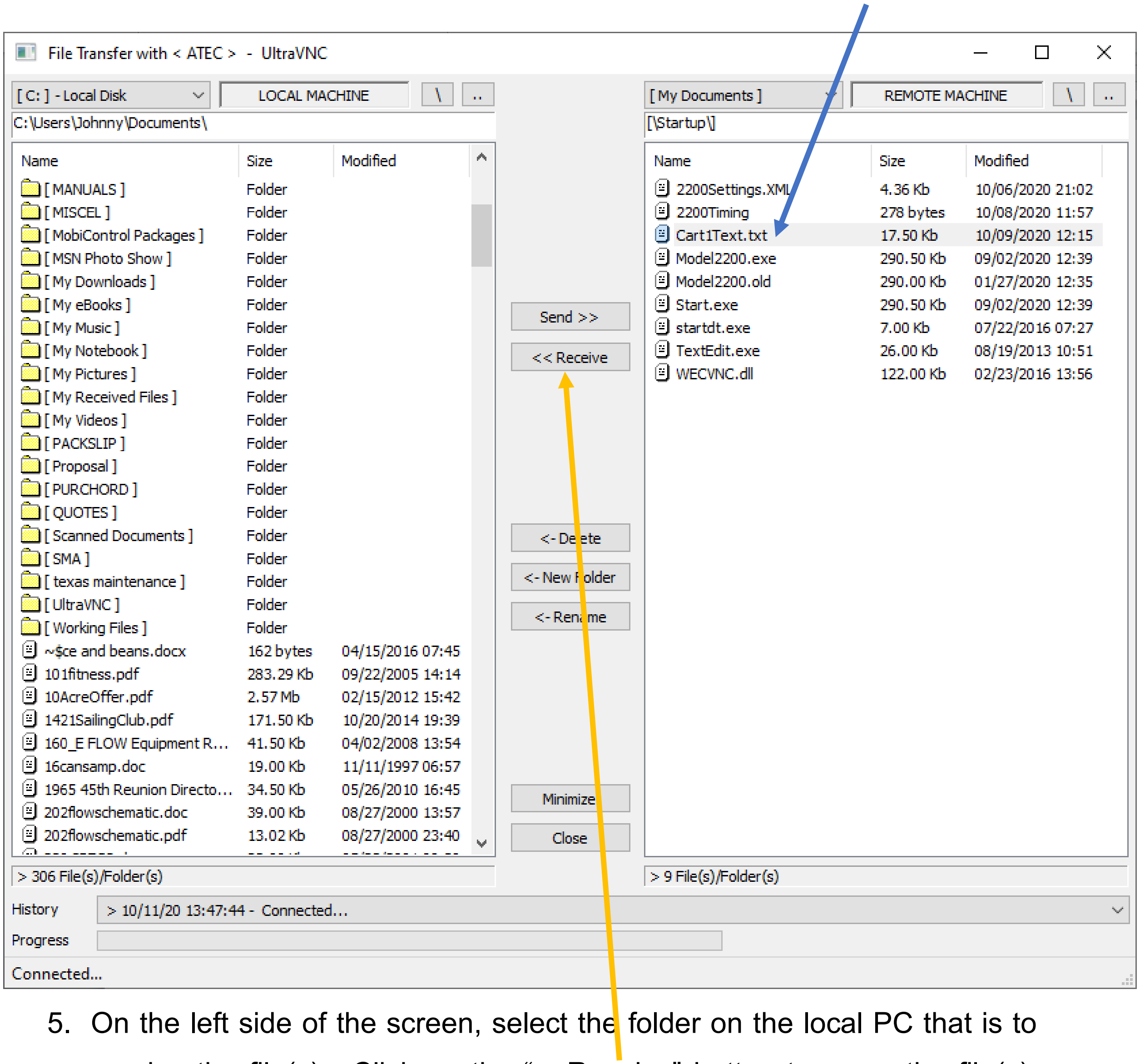
2. The left side of the screen is the local PC file structure. The right side of the screen is the file structure on the ATEC sampler. On the right side of the screen, double-click on [My Documents] to expand the folder. The following should appear.



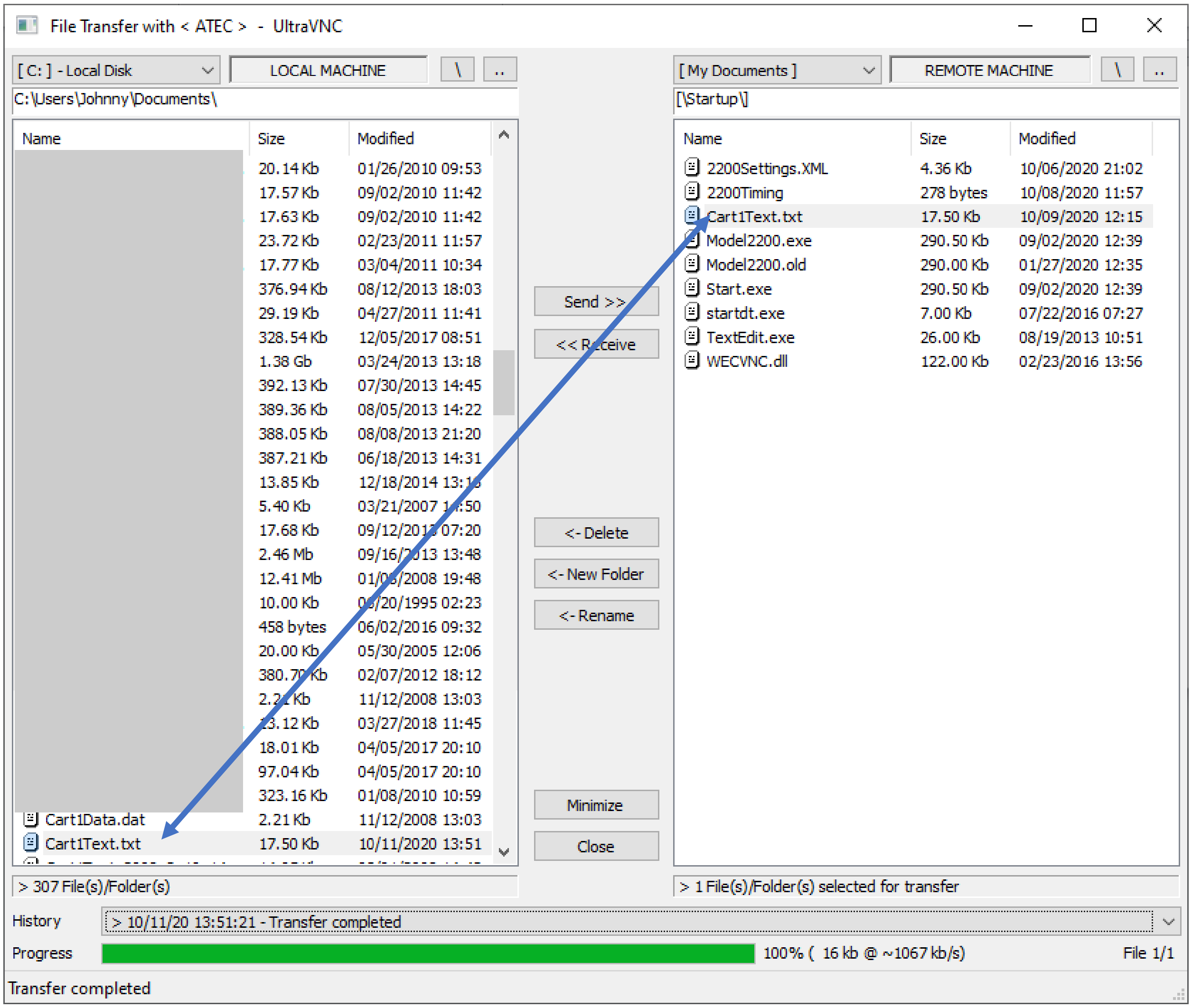
3. Double-click on the [Startup] folder to access the data files. A screen similar to the following should appear.



4. The data files have the extension ".txt". The files have names such as Can1Text.txt, Can2Text.txt, Cart1Text.txt, and Cart2Text.txt. Highlight the file(s) to be transferred. NOTE: when you store the data on a jump drive, the file names are given a time stamp so that their name is always unique and you will not overwrite existing data. This is not the case when you transfer the files remotely. They always have the same name for a channel/port. So, care must be taken to store them in unique folders or renaming them after they are transferred so that existing data is not overwritten.



5. On the left side of the screen, select the folder on the local PC that is to receive the file(s). Click on the "<<Receive" button to move the file(s). The file(s) should be transferred as shown here:



6. Close the file transfer screen by clicking the X in the upper right corner. This will return you the UltraVNC Viewer showing the sampler screen.

Maintenance

This section describes routine maintenance procedures for the Model 2200 Toxic Air Sampler. All other repair work should be performed by trained personnel.

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.

<u>Cartridge Filter</u>

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 5 to 10-micron Teflon filter and replace the filter housing in the sampler.

<u>Canister filter</u>

The operator should periodically replace the 2-micron sintered stainless steel filter in the canister flow path. The filter must be replaced when the canister flow rate cannot be maintained. Site conditions will determine the replacement frequency. Remove the Filter assembly in the sample line at the ¼" Swagelok "T" fitting on the canister side of the "T" (Refer to Figure 1). Using a wrench, disassemble the assembly to expose the pressed-in filter disk. Using a small punch or rod, push the filter disk out the end of the fitting and replace with a new disk. The new disk may need to be tapped into the fitting with a clean hammer.

<u>Ozone Scrubber</u>

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. Leak check the sample path by using the procedure described in the Sampler Leak Check Procedure section.

Mass Flow Controller Calibration

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 using a reference flow standard. The potentiometers can be accessed on the side of the flow controller housing. Electronic calibration can be performed by inserting the appropriate calibration constants into the advanced portion of the setup screen. Note that the canister mass flow controller calibration should be based on the average ambient sampling temperature as specified in the section on End Pressure under Programming the Model 2200.

Procedure for Calibrating the Canister Mass Flow Controller

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. Where the calibrator is attached will vary depending on the sampler model (see table below) and the design of the calibrator.

Model - MFC	Calibrator Location
2200 Canister MFC	Main inlet
2200 Cartridge MFC	Cartridge Outlet tube
2200-2 Cartridge MFCs	Cartridge Outlet tube of MFC being calibrated
2200-2 Canister MFCs	Remove stainless-steel tubing from main inlet to MFCs. Cap the MFC that is not to be calibrated and put the calibrator on the inlet of the MFC that is being calibrated.

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:

$$\text{Slope} = \frac{0.392 \text{ x } 740 \text{ mmHg x } 4.1 \text{ ccpm}}{292^{\circ}\text{K x } 3.8 \text{ ccpm}} = 1.072$$

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:

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

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.

Pressure Transducer Calibration

Pressure transducers should be calibrated on an annual schedule. The pressure transducers can be calibrated either electronically or manually. Since manual calibration requires removal of the transducer from the sampler, it is recommended that the pressure transducers be calibrated electronically. Appendix A provides a worksheet to calculate these constants using a calibrated pressure reference standard.

Model 2200 Parts List

Components of the Model 2200 are shown in the following Parts List. This list does not include common parts such as fuses, fittings, or fasteners.

Chassis	2200-100-1
Front Panel	2200-100-2
Rear Panel	2200-100-3
Canister Mass Flow Controller (0-20ccpm)	2200-200-1A
Carbonyl Mass Flow Controller (0-2 lpm)	2200-200-1B
3-Way Solenoid Valve	2200-200-2
Canister Tubing Set	2200-200-3
Cartridge Tubing Set	2200-200-4
Cartridge Filter Holder	2200-200-5
Cartridge Filter (47mm Teflon)	2200-200-6
Canister Filter Assembly	2200-200-7
Canister filter (7 micron)	2200-200-8
Pressure Transducer	2200-200-9
Ozone Scrubber Heater (Complete)	2200-200-10
Ozone scrubber (KI copper coil)	2200-200-11
Heater Relay	2200-300-1
Vacuum Pump	2200-200-12
Vacuum Pump Relay	2200-300-2
2-Way Solenoid Valve	2200-200-13
*Canister Pressure Pump	2200-200-14
*Pressure Gauge	2200-200-15
*Pressure Adjusting Valve	2200-200-16
Single Board Computer	2200-400-1
GPIO Board	2200-400-2
Interface Board	2200-400-3

PC Power Supply	2200-400-5
Temperature Probe	2200-400-4
Power Supply	2200-300-3
Cooling Fan	2200-300-4
Power Switch	2200-300-5
Fuse Holder	2200-300-6
Pump Fan Guard	2200-500-1
Cooling Fan Guard	2200-500-2
Vacuum Line Tubing Set	2200-200-16
Check Valve	2200-200-17
MFC Canister Ch.1 Cable	2200-700-1
MFC Canister Ch.2 Cable	2200-700-2
MFC Cartridge Ch.1 Cable	2200-700-3
MFC Cartridge Ch.2 Cable	2200-700-4
GPIO Cable Set	2200-700-5
*Canister Pump Relay	2200-300-2
*Canister Pump Relay Cable	2200-700-9
Vacuum Pump Relay Cable	2200-700-10

*Pressurized Canister Option

Appendix A – Procedure for Pressure Transducer Calibration

Pressure Transducer Calibration Procedure

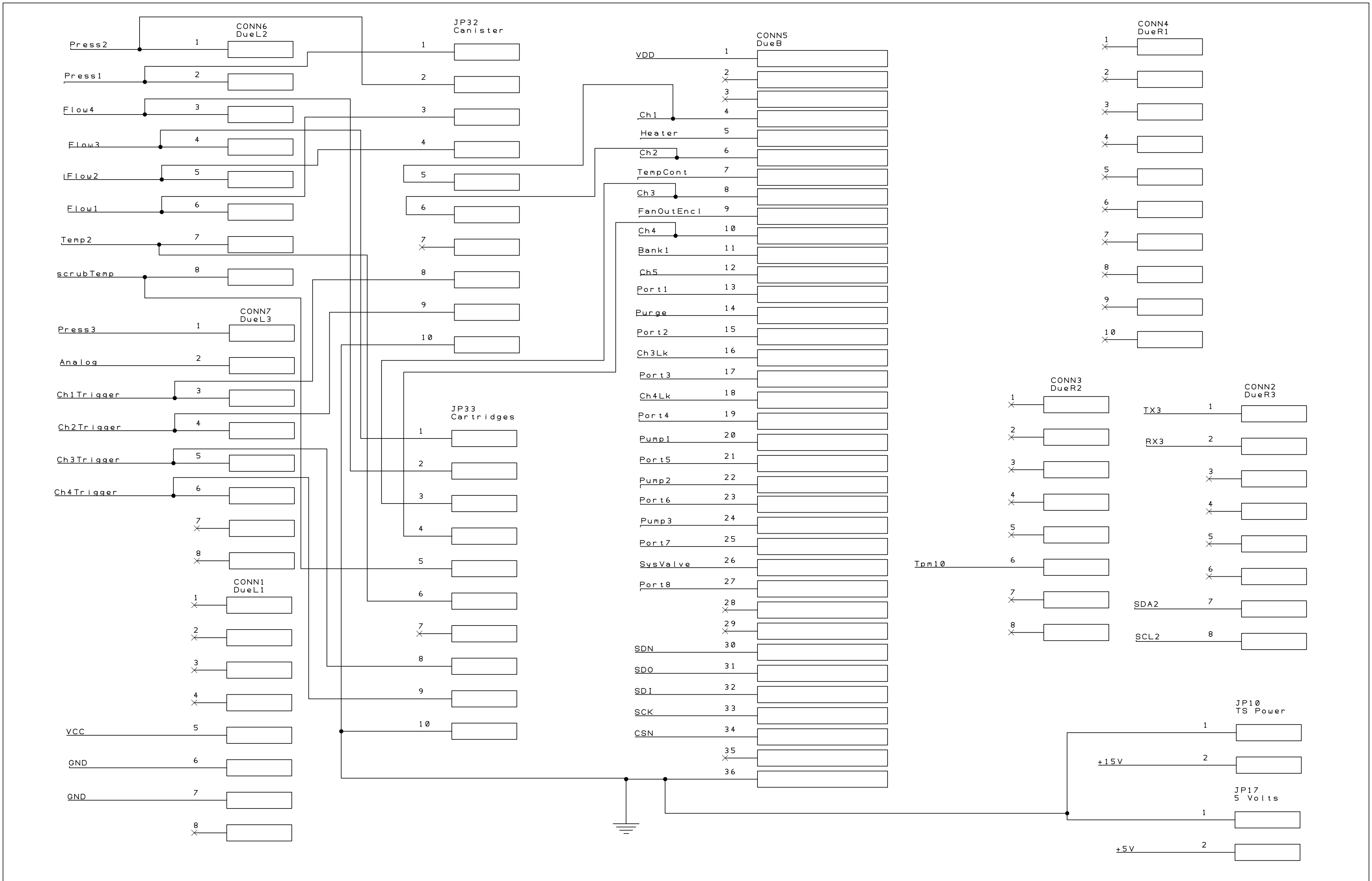
1. For the pressure transducer to be calibrated, set the slope to ***1.0*** and the intercept to ***0.0*** in the Advanced option.
2. Attach an evacuated canister (absolute pressure < 0.05 psia) to the canister inlet.
3. Record the pressure and enter the negative of this value for the intercept (e.g. recorded value = -0.1, the intercept = +0.1) in the Advanced screen.
4. Disconnect the evacuated canister from the channel inlet.
5. Accurately determine the ambient pressure (P1) within ±0.05 psi.. **P1:** ☐
6. Enter the main screen, and observe the average pressure (P2) displayed. **P2:** ☐
7. The slope is calculated by:

$$Slope = \frac{P1}{P2}$$

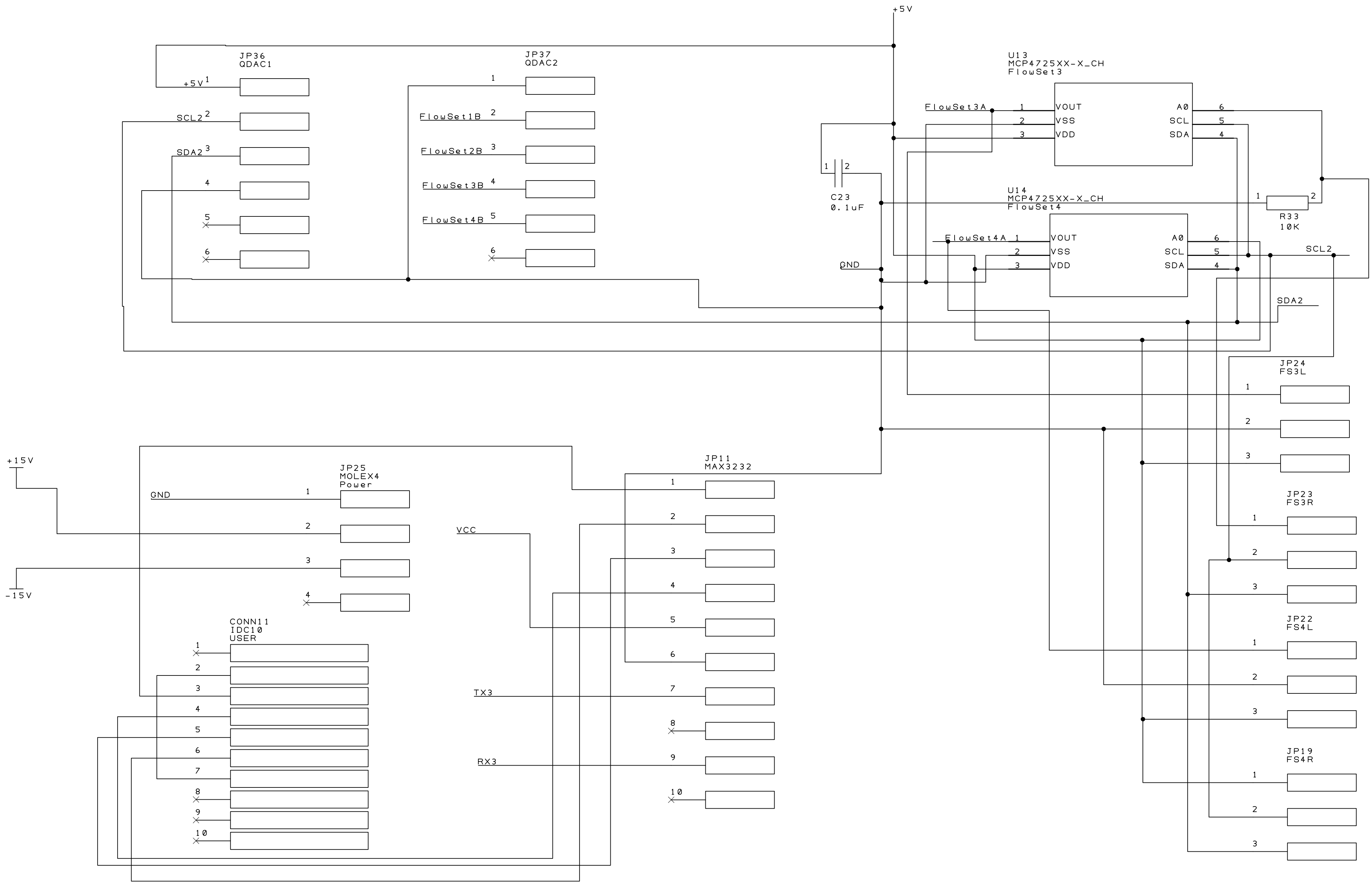
Slope: ☐

8. Enter the slope value for the pressure transducer in the Advanced screen.
9. Repeat Step 6 to verify that the pressure displayed is the same as the atmospheric pressure (P1).
10. If the pressure is different by more than ±0.1 psi, enter ***1.0*** for the slope in the Advanced option and repeat Steps 5 to 10.

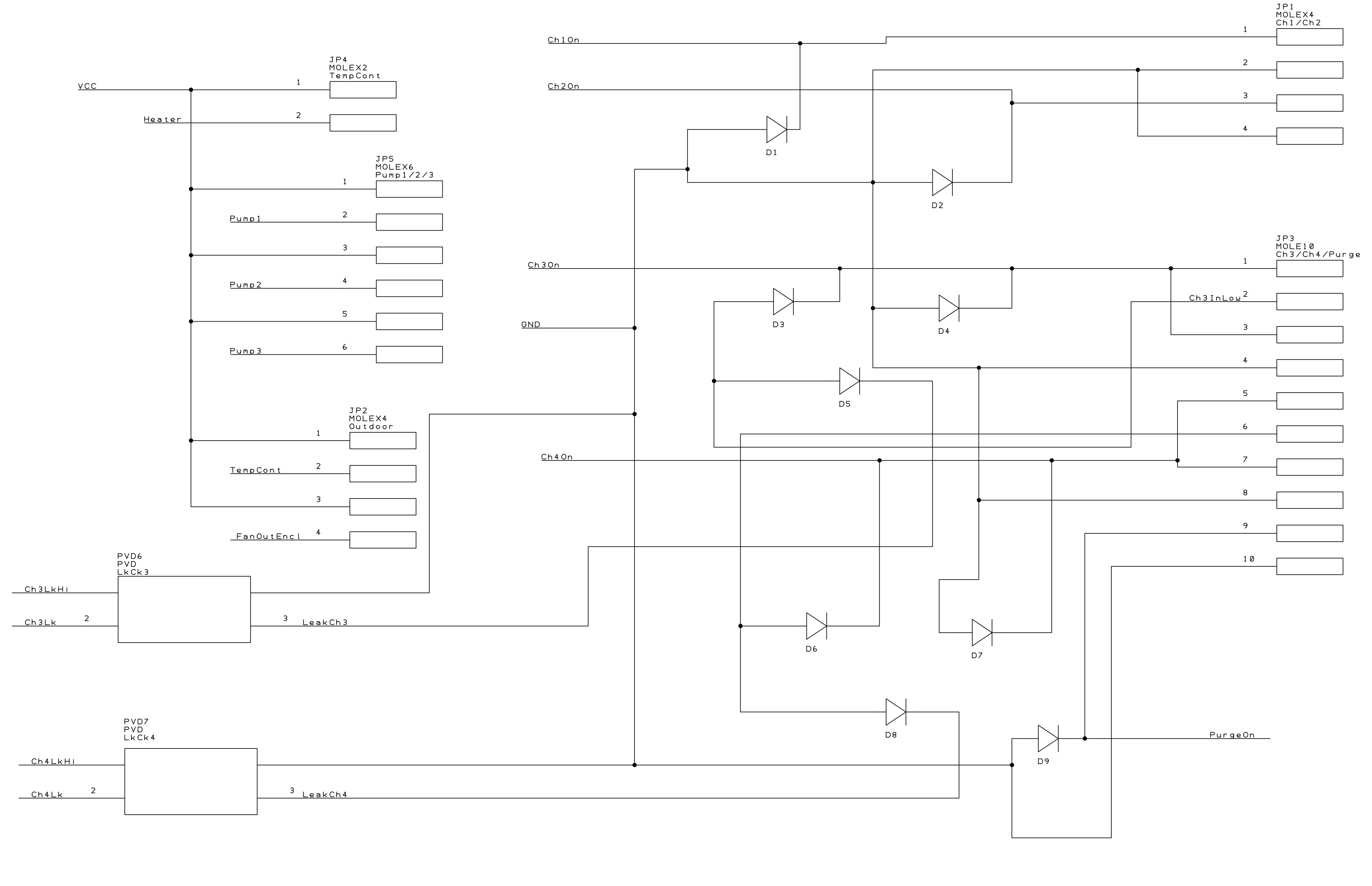
Appendix B – Schematics



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title: **Model 2200V13 Interface Board**			Filename: **Schematic-1.sch**	Drawing No. — Sheet 1 of 7



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title: **Model 2200V13 Interface Board**			Filename: **Schematic-2.sch**	Drawing No. / Sheet **2** of **7**



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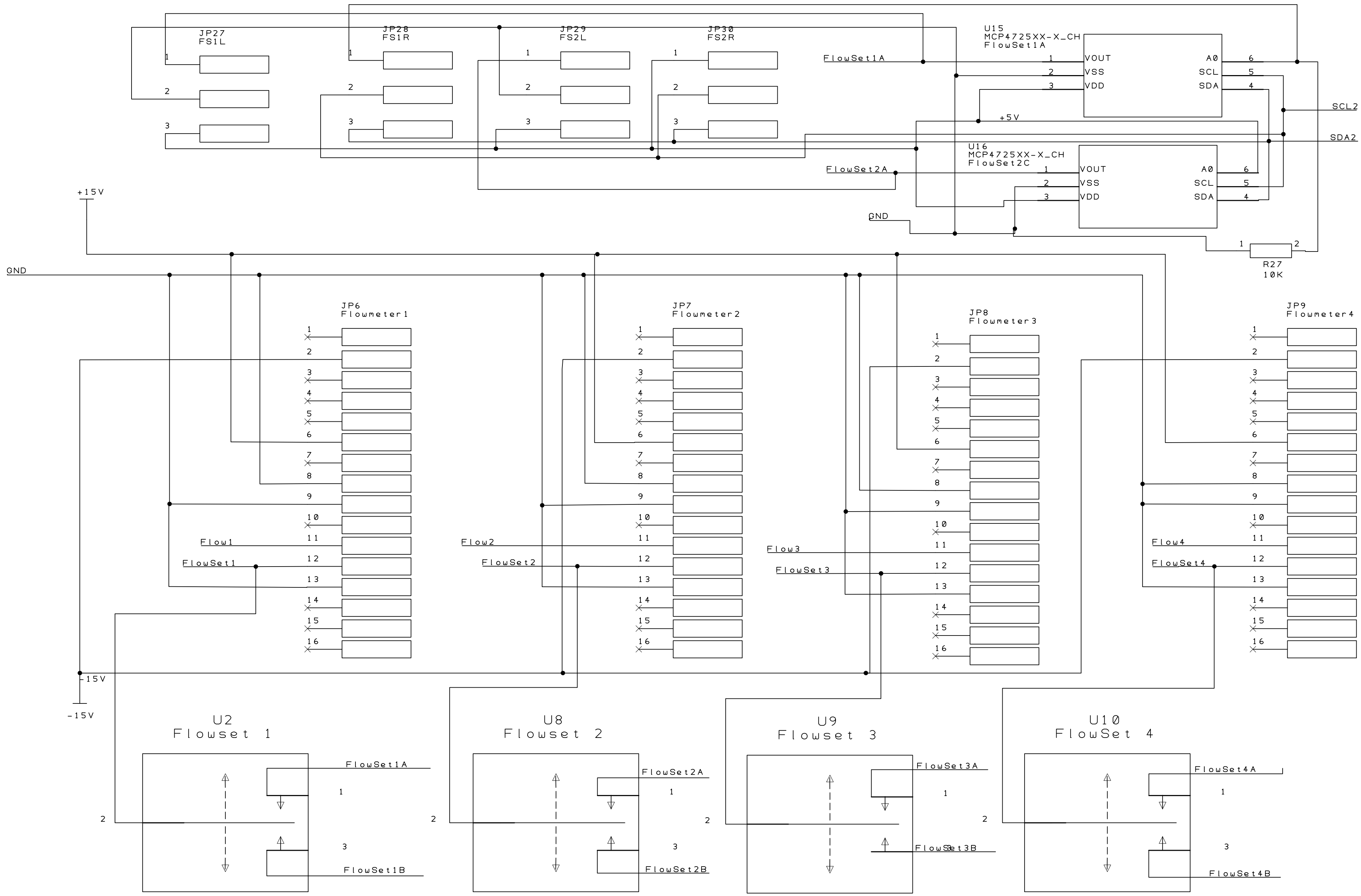
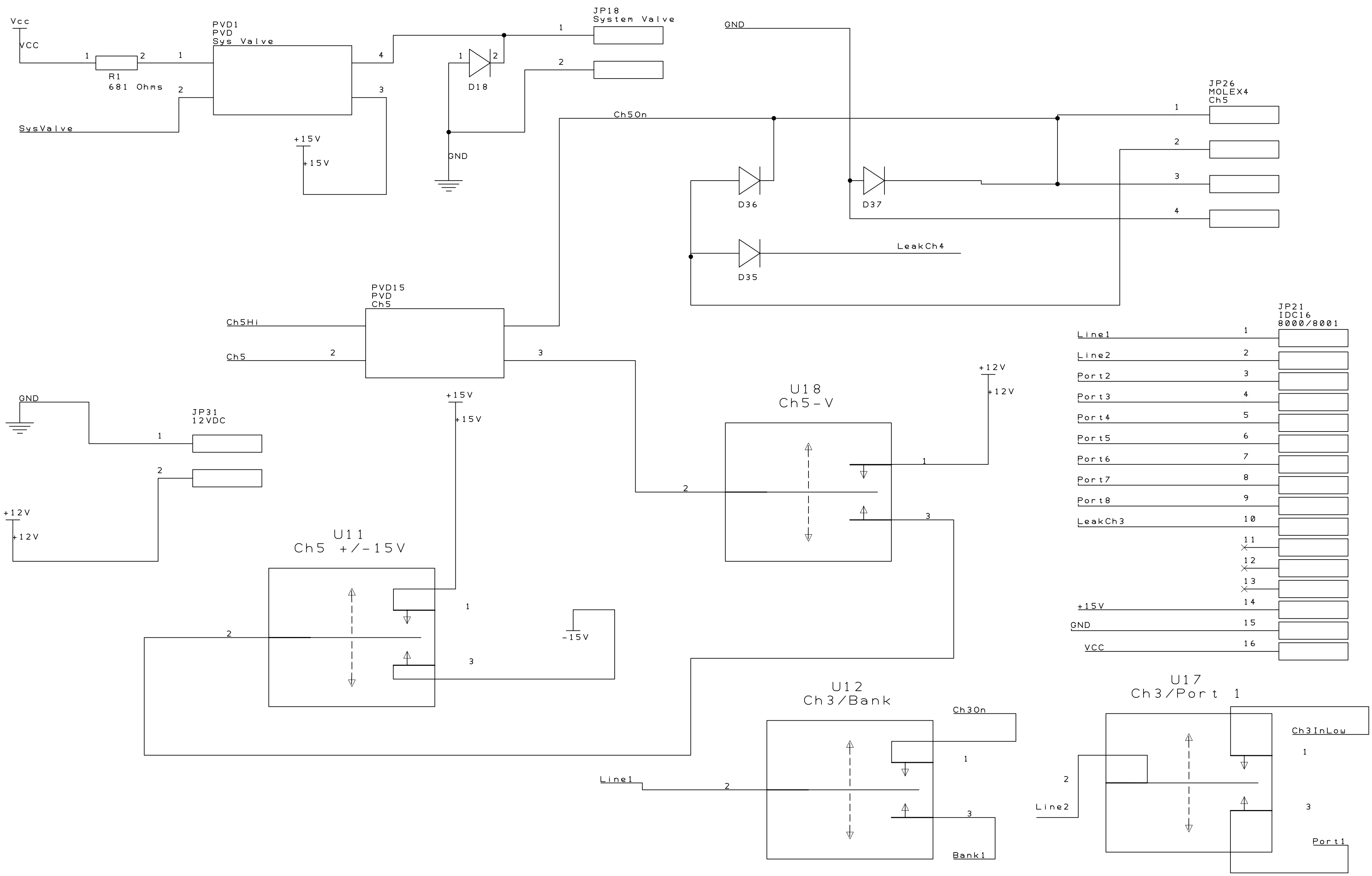
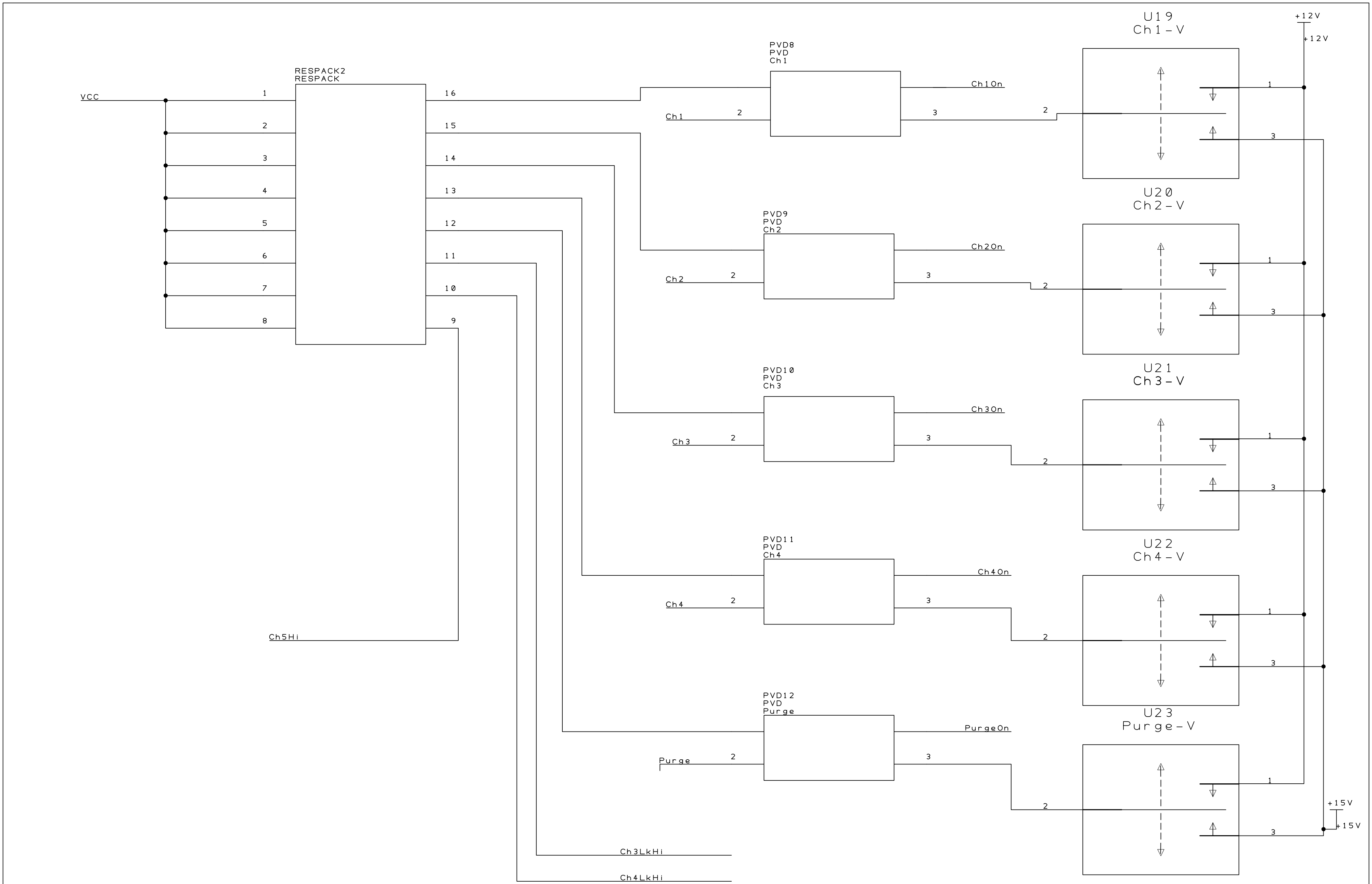


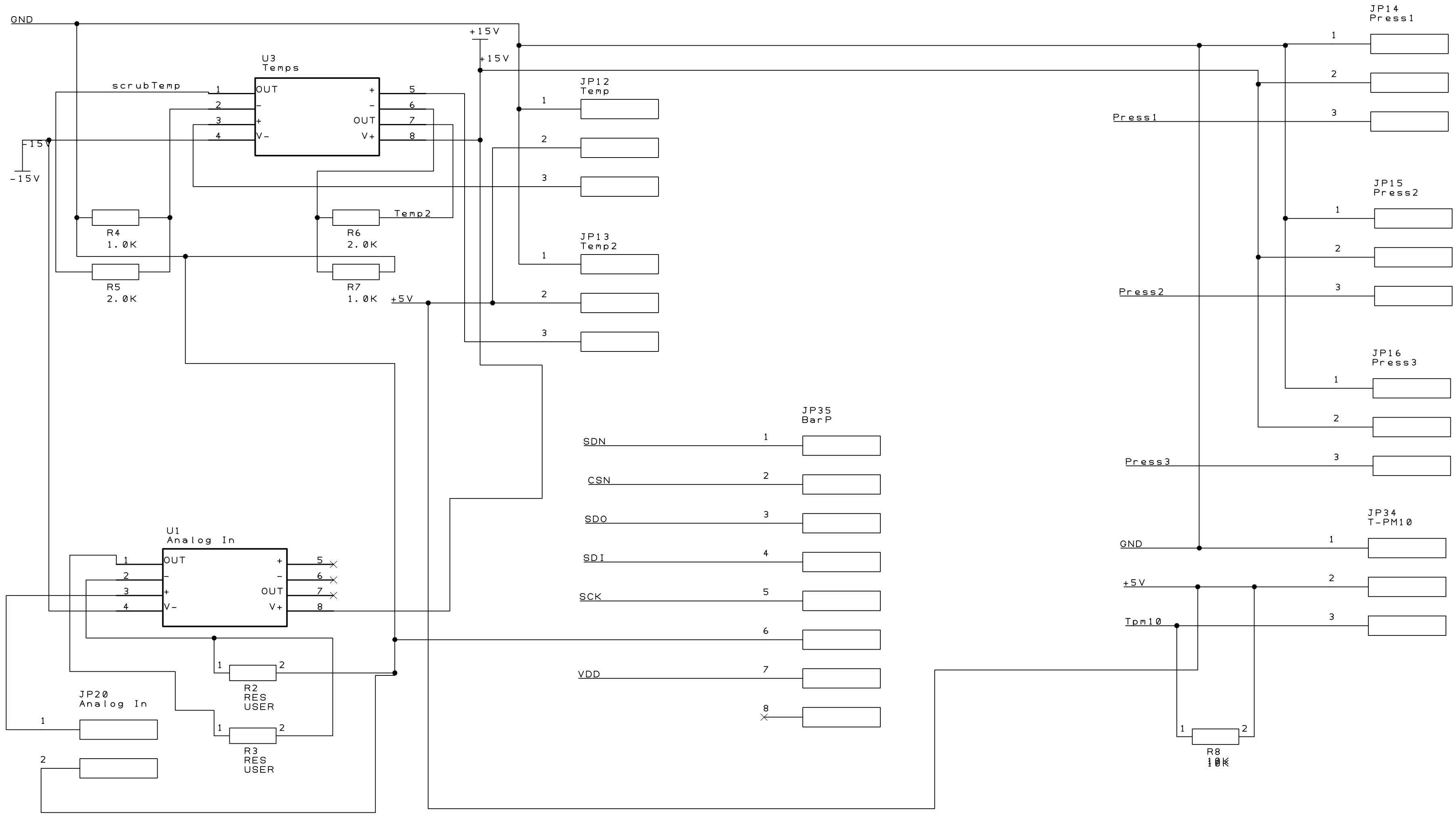
E	D	C	B	A	Drawn	Check	Projection Do Not Scale		
Drn	Drn	Drn	Drn	Project			Client		
Chk	Chk	Chk	Chk	Title **Model 2200V13 Interface Board**			Filename **Schmatic-4.sch**	Drawing No.	Sheet **4** of **7**



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title **Model 2200V13 Interface Board**			Filename **Schematic-5.sch**	Drawing No. / Sheet **5** of **7**



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title **Model 2200V13 Interface Board**			Filename **Schematic-6.sch**	Drawing No. / Sheet **6** of **7**



E	D	C	B	A	Drawn	Check	Projection Do Not Scale	
Drn	Drn	Drn	Drn	Project			Client	
Chk	Chk	Chk	Chk	Title **Model 2200V13 Interface Board**			Filename **Schematic-7.sch**	Drawing No. / Sheet 7 of 7

Appendix C – 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.

Revision A (Document Number 140-0999) .... September 1999
Revision B (Document Number 140-1199) .... November 1999
Revision C (Document Number 140-102002) .... October 2002
Revision D (Document Number 140-082005) .... August 2005
Revision E (Document Number 140-112007) .... November 2007
Revision F (Document Number 140-062008) .... June 2008
Revision G (Document Number 140-082008) .... August 2008
Revision H (Document Number 140-022009) .... February 2009
Revision J (Document Number 140-102009) .... October 2009
Revision K (Document Number 140-102009A) .... October 2009
Revision L (Document Number 140-082010) .... August 2010
Revision M (Document Number 140-072011) .... July 2011
Revision N (Document Number 140-072013) .... July 2013

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.

Table of Contents

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)

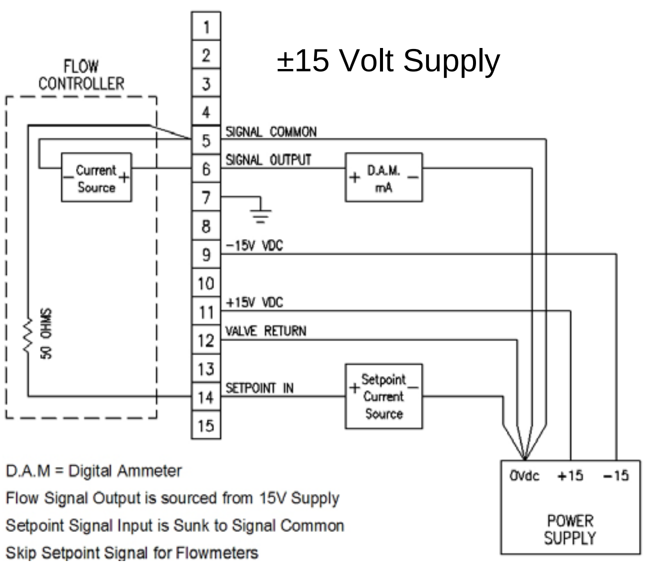
1 Stated accuracy is for nitrogen or other gas specific calibration and using this gas only.
2 Other materials are available. Viton is the standard O-ring option.
* Specifications may vary for instruments with ranges greater than 10 slm.

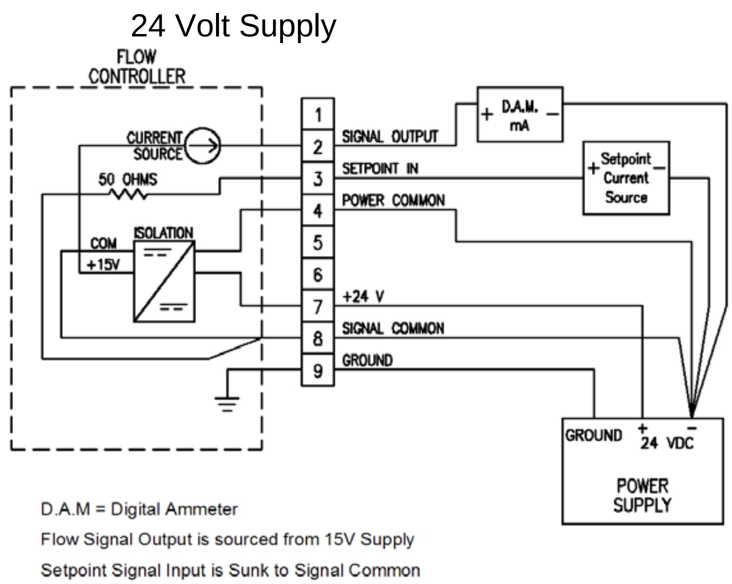
1.4. Optional 4-20 mA Current Output

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 minimum 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.

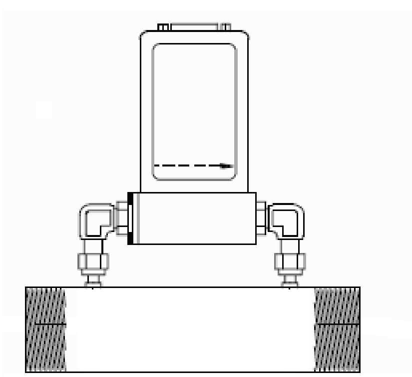
The smallest of the internal passageways in the HFM-200/HFC-202 series is the diameter of the sensor tube, which is 0.0125" (0.31 mm), so the instrument requires adequate filtering of the gas supply to prevent blockage or clogging of the tube.

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

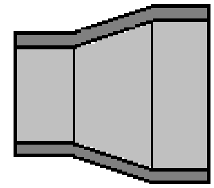


The installation of a Laminar Flow Element (LFE) in a flow circuit requires sufficient conductance before entering and after exiting the LFE sensor taps to allow the flow to fully develop with a minimum of turbulence. This provides the best conditions for accurate sampling of the flow by the sensor branch (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:



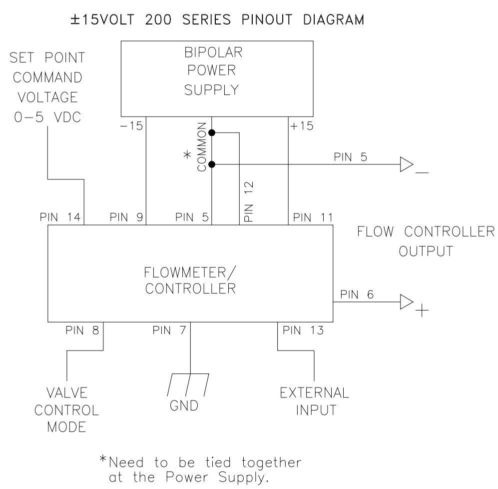
Suppose a 4" LFE is selected. The length of 4" diameter tubing or pipe, upstream of the sensor inlet tap, will be a minimum of 20". The minimum length of 4" tubing or pipe downstream from the sensor outlet tap will be 4". The length of additional 4" inlet tubing required for the 4" LFE is 20" – 2.5" = 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



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.

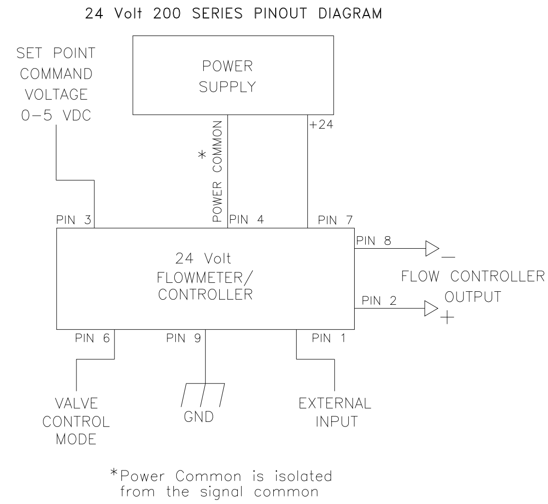
The power supply used must be meet the power requirements delineated in section 2.2 (Power Requirements) above. If a bipolar supply is required the voltages must be referenced to a common ground.

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.

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.



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

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/High density Operation

When operating at high pressure or with high density gases, 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. This zero shift can be corrected by adjusting the zero potentiometer after mounting the flow controller in its final operating position. See section 2.4.1 and 2.6.2.

Additionally, because the specific heat of a gas changes with pressure, an associated error is introduced with increased pressure. It is directly proportional to the change in specific heat versus pressure for that particular gas. For helium, there is virtually no change in indicated output; for nitrogen, the indicated output will increase at approximately 0.0067%/psi, which is the pressure coefficient. Thus,

Actual flow = indicated flow / (1 + pressure * pressure coefficient)

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 slm range with a 5.00 Volt output at full scale. Flow controller B has 0 - 10 slm range with a 5.00 Volt output at full scale. If flow controller A is set at 80 slm, its output voltage would be 4.00 Volts (80 slm/100 slm 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 slm (2.00 Volts/5.00 Volts x 10 slm = 4 slm).

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

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

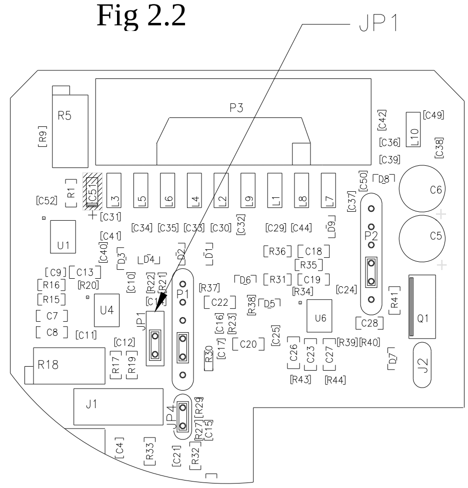
2.7.2. Operation with a Power Supply other than a Hastings

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)

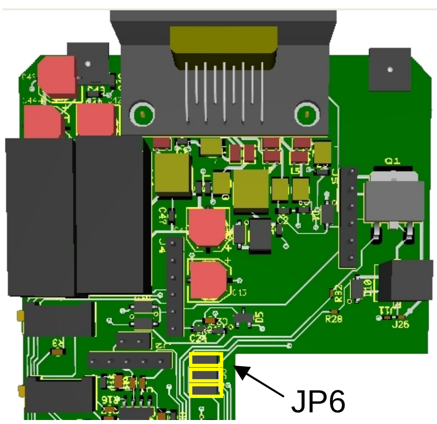
In some instances, it might be desirable to use an external sensor to provide process information to the control circuitry in the flow controller. For example, you might want to control the pressure in a vacuum system by adjusting the rate at which the system is backfilled with a gas. The new, enhanced 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

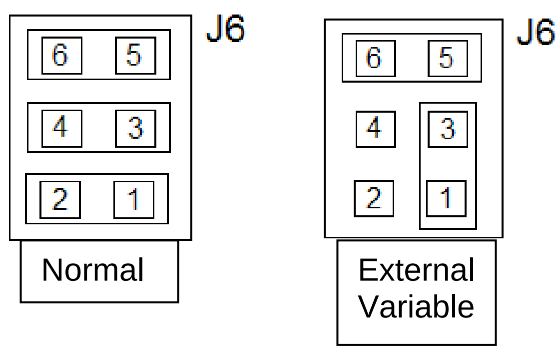


For the 15 Volt units, JP1 is a three pin jumper block located just below the “D” connector. In the normal operating mode, the jumper covers the bottom two pins. To select “External Sensor”, move the jumper to the upper two pins. This swaps the flow input to the controller circuit from the flow meter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

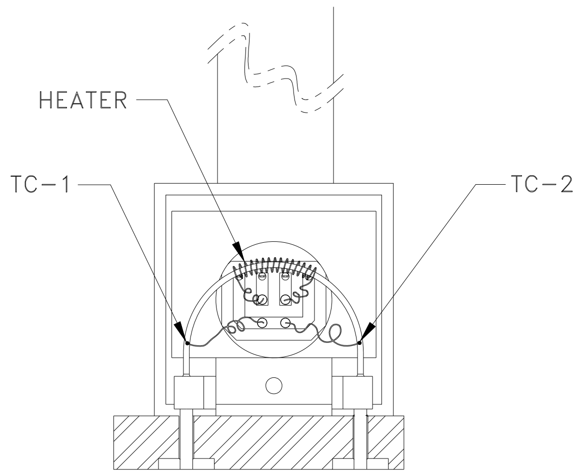


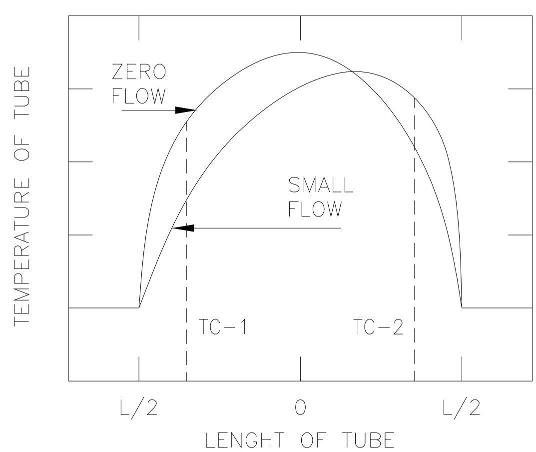
Figure 3.1

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.

Figure 3.2



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 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.

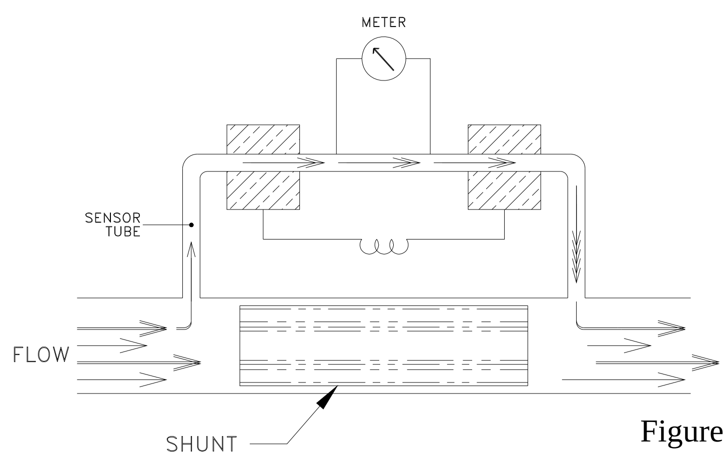
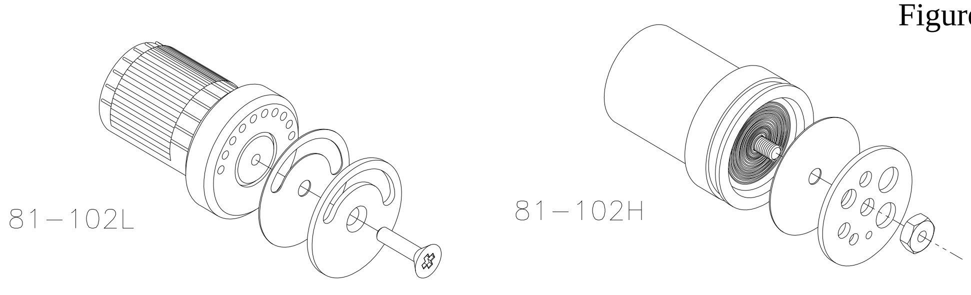


Figure 3.3

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.

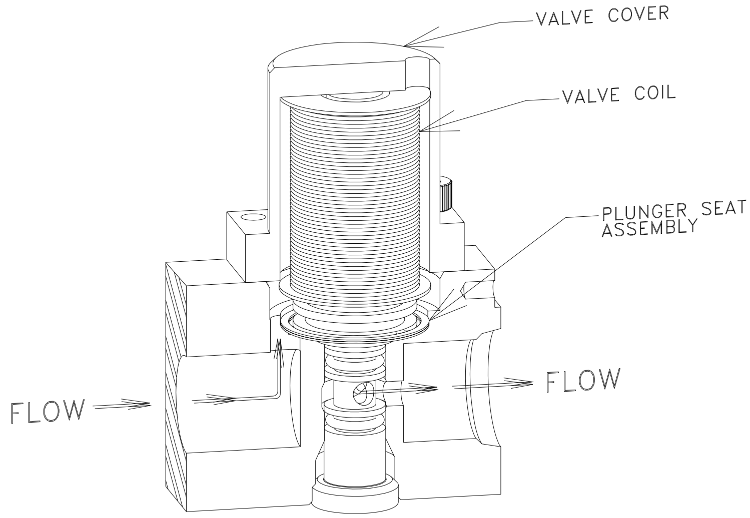


Figure 3.5

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).

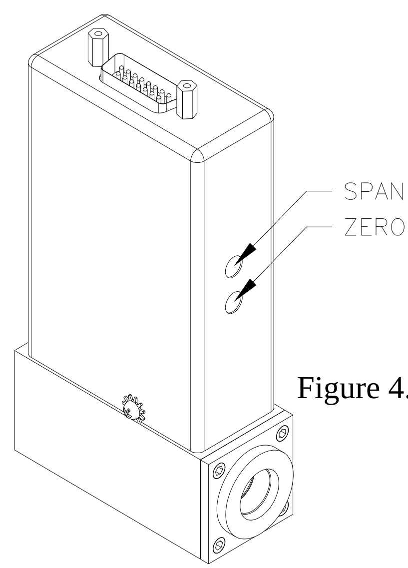


Figure 4.1

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.

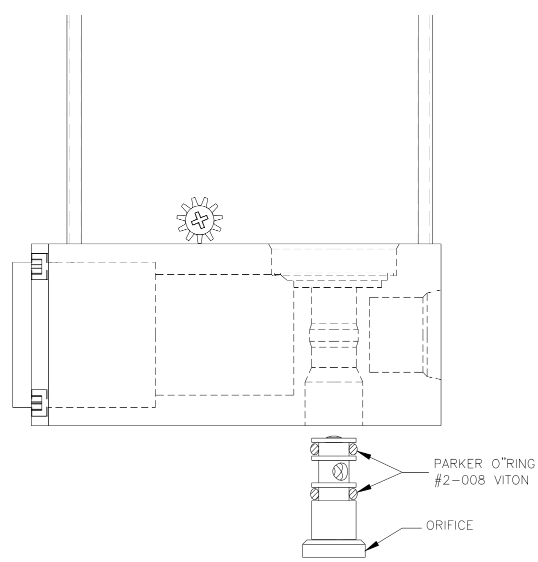
Remove the screw that holds the PC board to the sensor. Troubleshoot or replace as applicable. Installation is the reverse of the above procedure. Recalibrate if any components were changed or if any potentiometers were adjusted.

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.

TELEDYNE HASTINGS INSTRUMENTS
804 NEWCOMBE AVENUE
HAMPTON, VIRGINIA 23669 U.S.A.
ATTENTION: REPAIR DEPARTMENT

TELEPHONE	(757) 723-6531
TOLL FREE	1-800-950-2468
FAX	(757) 723-3925
E MAIL	hastings_instruments@teledyne.com
INTERNET ADDRESS	http://www.teledyne-hi.com

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