The HIAPER Advanced Whole Air Sampler (AWAS)

Guide to Operation

Version 1.1
July, 2008

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I. <u>Introduction</u>

This guide to operation describes the functional operation and specifications of the HAIS Advanced Whole Air Sampler (AWAS). The AWAS was designed to collect ambient air samples for later analysis of trace gas composition. As with other whole air samplers, the system is able to collect and store a wide range of trace gases with minimal artifacts from collection and storage. Still, the user should understand the limitations of the whole air sampler for the analysis of potentially difficult trace gases, e.g. those that are thermally labile and have chemical or surface reactivity. A suite of trace gases that are commonly measured is given in Table 1, though others are possible.

Table 1: Partial list of target gases commonly available from whole air sample collection. Other species can be added for specific tracer studies or for qualitative identifications using full scan mass spectrometry

Ethane	2-Methylpentane	DMS	CCl_3F (CFC-11)
Ethene	3-Methylpentane	OCS	CCl_2F_2 (CFC-12)
Ethyne	Benzene	Methyl Nitrate	CCl_2FCClF_2 (CFC-113)
Propane	Toluene	Ethyl Nitrate	$CClF_2CClF_2$ (CFC-114)
Propene	o-Ethyltoluene	n-Propyl Nitrate	CH_3Cl
n-Butane	p-Ethyltoluene	i-Propyl Nitrate	CH_2Cl_2
i-Butane	m-Ethyltoluene	2-Butyl Nitrate	$CHCl_3$
1-Butene	1,2,4-Trimethylbenzene	2-Pentyl Nitrate	CCl_4
cis-2-Butene	1,3,5-Trimethylbenzene	3-Pentyl Nitrate	CH_3CCl_3
trans-2-Butene	o-Xylene		$CHCl=CCl_2$
Isobutylene	m-Xylene	Nitrous Oxide*	$CCl_2=CCl_2$
1,3-Butadiene	p-Xylene	SF6	CH_3Br
n-Pentane	Ethylbenzene	Methane*	CH_2Br_2
i-Pentane	δ-Limonene	CO	$CHBr_3$
Isoprene	α-Pinene	HFC-134a	CH_3I
n-Hexane	β-Pinene	HCFC-141b	$CHClF_2$ (HCFC-22)
		HCFC-142b	$CBrClF_2$ (H-1211)
		*and isotopes	

The basic principles of AWAS operation are simple. Air is sampled from a suitable inlet through one or more compressor pumps into a sample manifold where previously evacuated cans are mounted. The current AWAS can hold up to 60 canisters (separated into 5 modules of 12 canisters each). Each canister is isolated from the manifold with an air-actuated valve; the manifold exhaust line also contains an automatic valve. On command from the computer controller (DSM), the exhaust valve is closed, and the manifold is pressurized to a pressure limit set by a manual relief valve in the exhaust manifold. Following this pressurization, the control program opens the next canister in line and then closes the canister when manifold pressure reaches a pre-specified value. After a preset time, or on command from an operator, the next canister in sequence is filled until the predetermined maximum number of canisters are filled (or until the system is otherwise shut down). The details of the mechanical and

electrical connections are presented later in this guide. This guide will present a typical mode of operation, but the system is sufficiently flexible to modify the guidelines presented here.

The guide first describes each component or module of the AWAS (Section II). Mechanical installation and checkout of AWAS on HIAPER is described in the section III. A general guide to operations is provided in section IV. A brief section on troubleshooting is given in section V. Appendices provide details of parts specifications, electrical schematics, and suggested spare parts.

II. Instrument Description

The AWAS consists of 5 functional modules that are involved in the collection of air samples by AWAS. These are:

- *Canister Module*

- *Pneumatics Module*

- *Pump Module*

- *Exhaust Module*

- *Control Module*

A block diagram illustrating the functional relationships of the modules is shown in Figure 1.

Aircraft Exhaust Manifold

AWAS Exhaust module

Canister Modules

DSM

Compressor Pumps   Pneumatic Supply

Power Relay Box

Back Panel Power Distribution

Inlet

=power
= status
= control
= sample
= He or N2
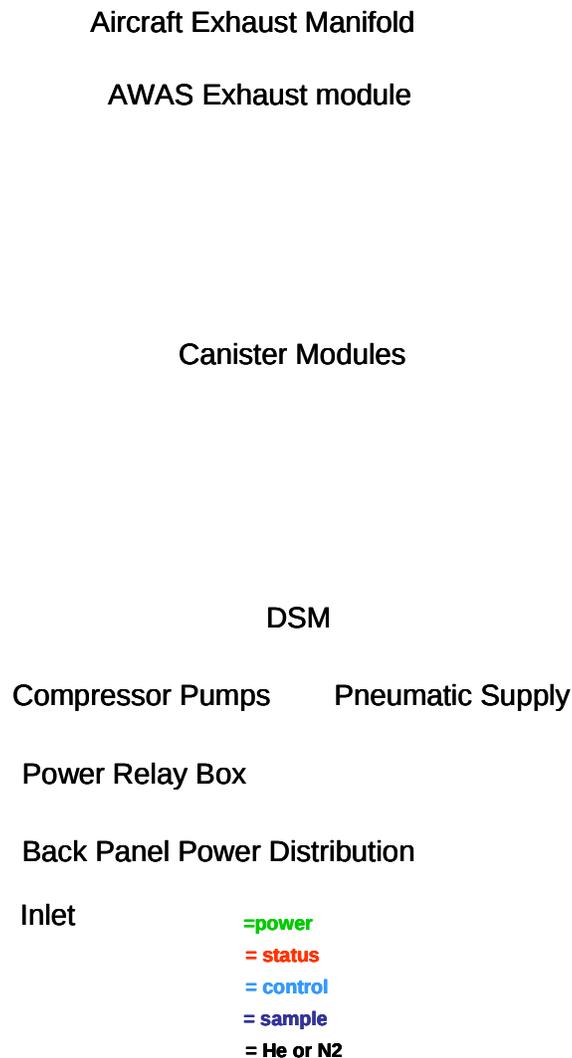
Figure 1. Functional block diagram of AWAS.

II.1. Canister module

The canister module consists of 12 stainless steel canisters (6.3 x 46 cm body, approximately 1.3 liter) mounted into a custom made support (Figure 2 and 3).
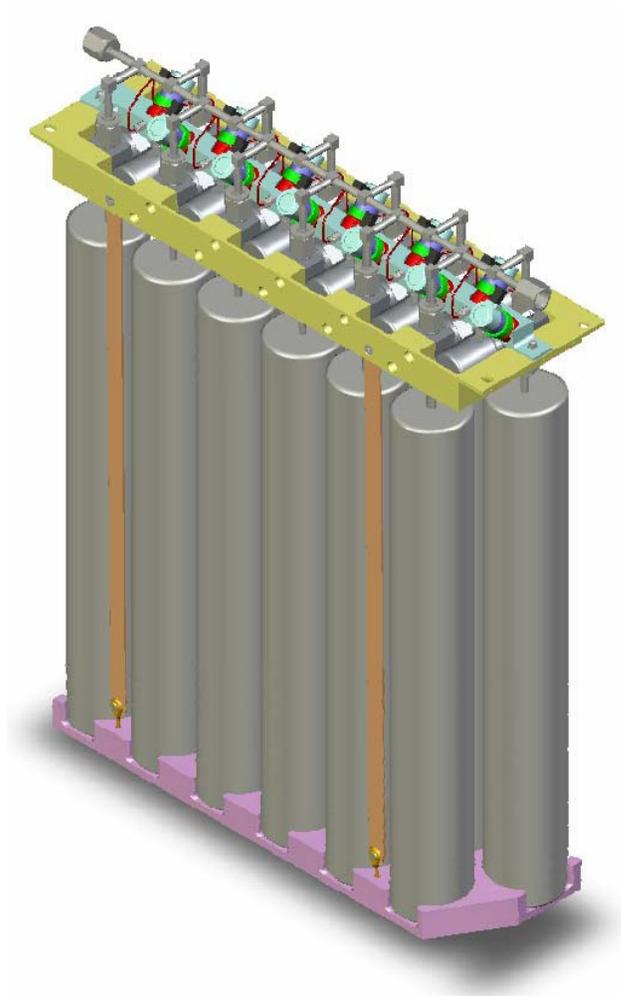
Figure 2. Schematic of AWAS canister module.
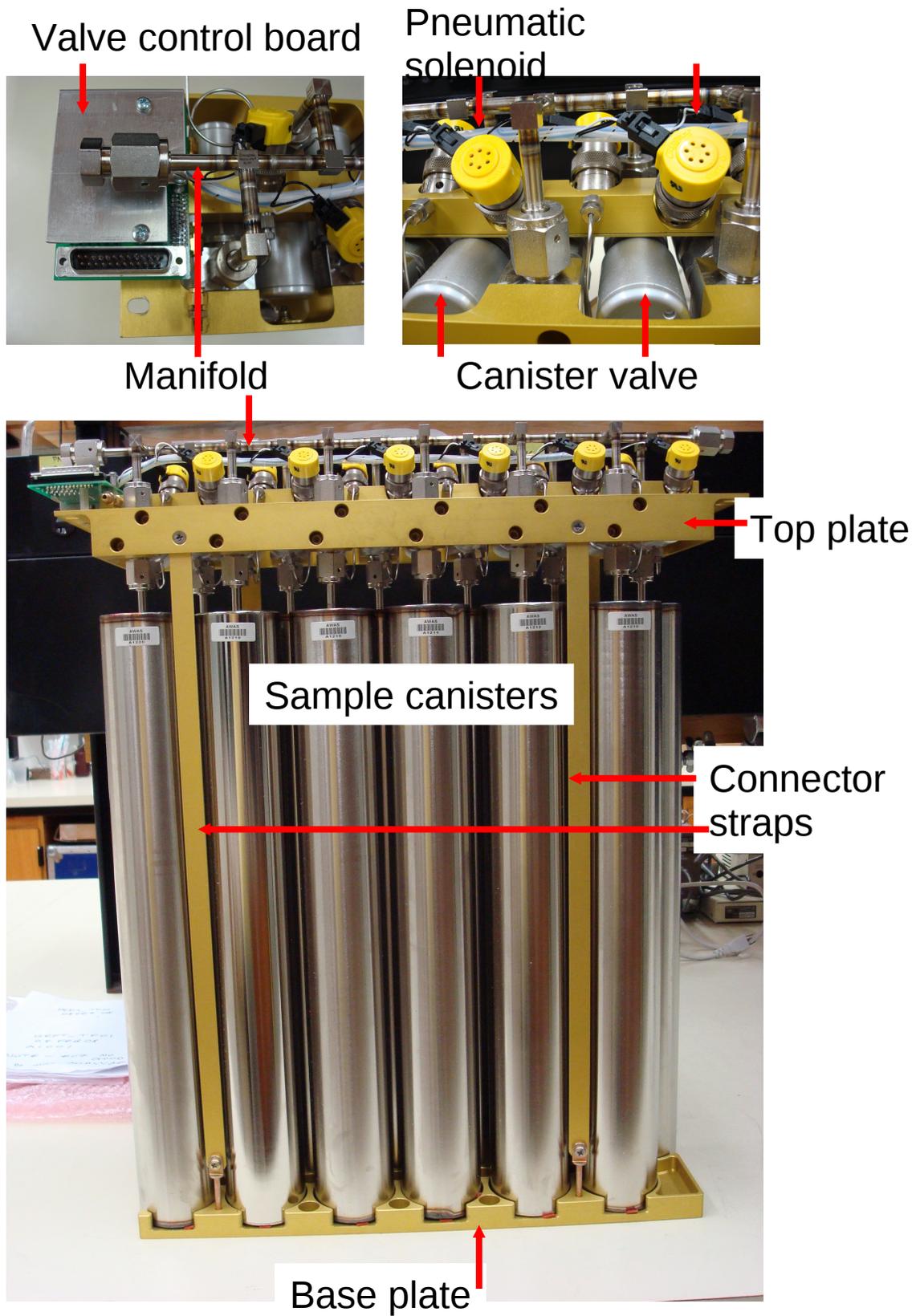
Figure 3. Photograph of single AWAS canister module with major components identified

The canisters are custom-fabricated welded stainless steel with a proprietary internal polishing treatment and conditioning procedure (C. W. Sinks and Associates, Hemet, CA). Canisters are connected to pneumatically-operated stainless steel bellows-sealed valves (Swagelok, SS-BNVVCR4-C; viton (polyimide) stem tip) that are mounted into a custom-machined top plate (J. Fox, S. Rauenbuehler, NCAR ATD). Connectors are ¼" VCR female on the canister, male on the valve. A welded stainless steel manifold (1/4" female VCR connectors) provides a path for gas flow to the cylinders. Prior to construction, each canister was vacuum and pressure tested. After the manifold was attached to the canisters, a final vacuum check was done to verify that the canister module was leak-free.

The canisters are opened by application of air pressure (60 – 100 psig) and are closed by the release of pressure applied to the bellows valves. The air pressure is supplied from a pneumatics module at the base of the AWAS rack (described later). The air pressure is delivered to a distribution manifold attached to the top plate. Solenoid valves (Clippard, EC-3M-24) are mounted on the manifold to pressurize the bellows valve via a short length of 1/16" stainless steel tubing. To open a sample canister, the corresponding solenoid is activated with a 24 volt signal. When the voltage is removed, the air pressure is released from the bellows valve, and the sample canister is closed. Choice of solenoid/canister is done with signals from the DSM transmitted via a ribbon cable that is attached to each canister module.

II.2. Pneumatics Module.

The pneumatics module contains the air supply/pressure control for operating the sample canister bellows valves. The pneumatics module is located on the base plate of the AWAS rack. A photo of the mounted parts is provided in Figures 4 and 6; a schematic of the system is shown below (Figure 5).

High Pressure Reservoir

Pressure
Transducer
behind regulator

Pressure
Regulator

Pressure
Relief valve

Pressure
Transducer

Supply valve

Fill Port   Delivery to manifolds

Figure 4. Front view of the AWAS pneumatics module.
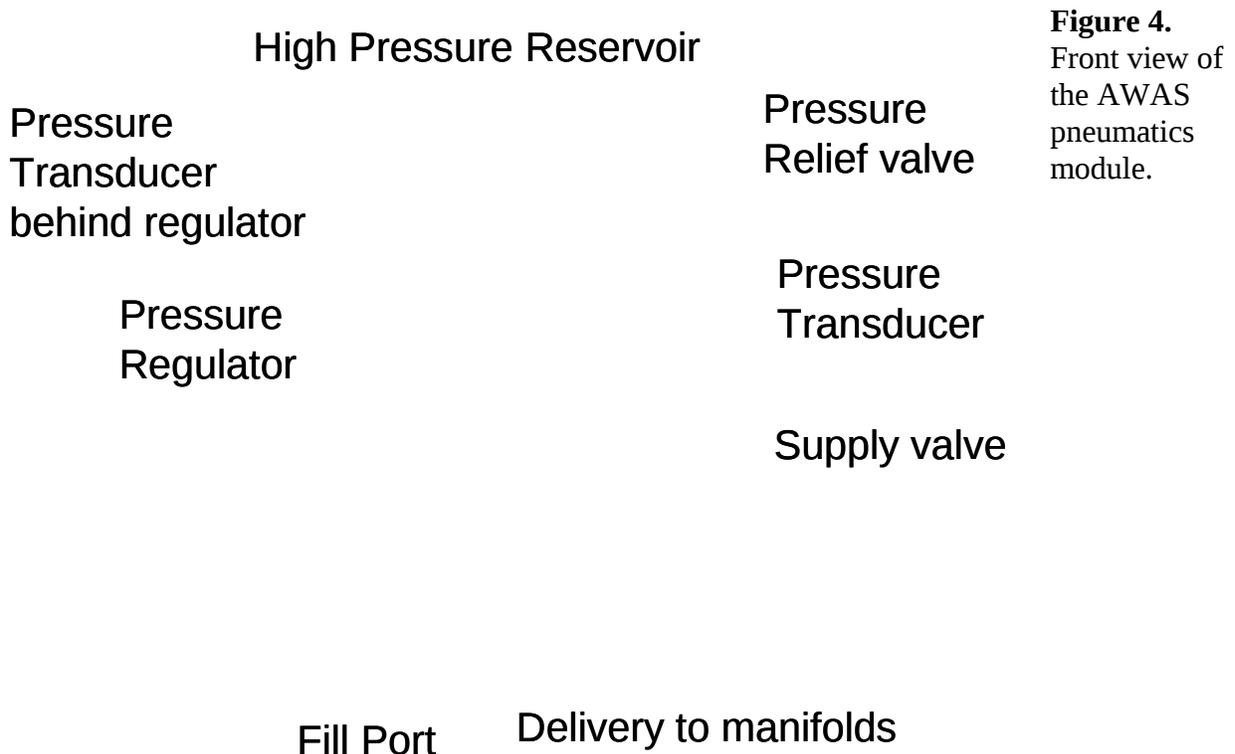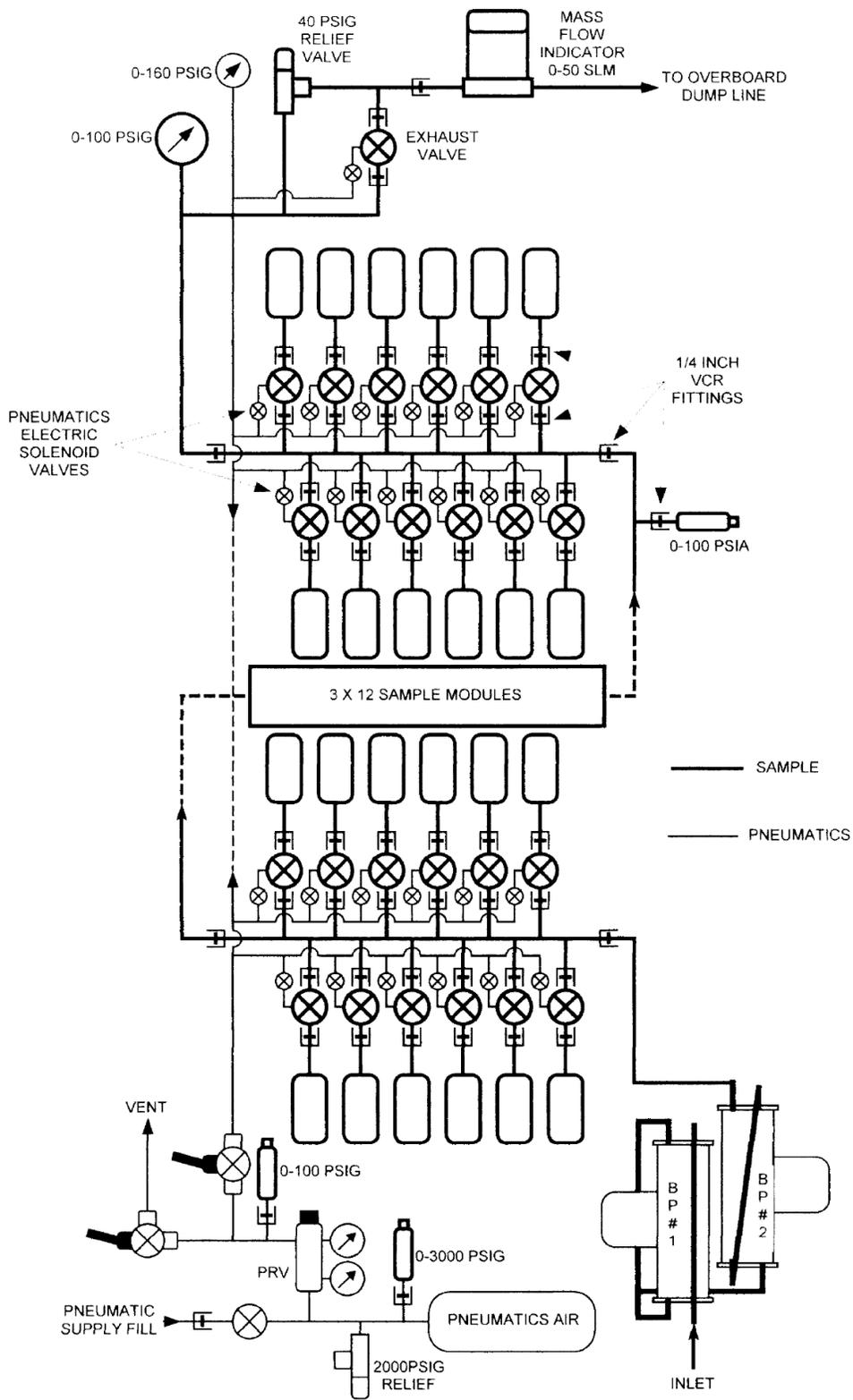
Figure 5. Schematic diagram of AWAS plumbing connections

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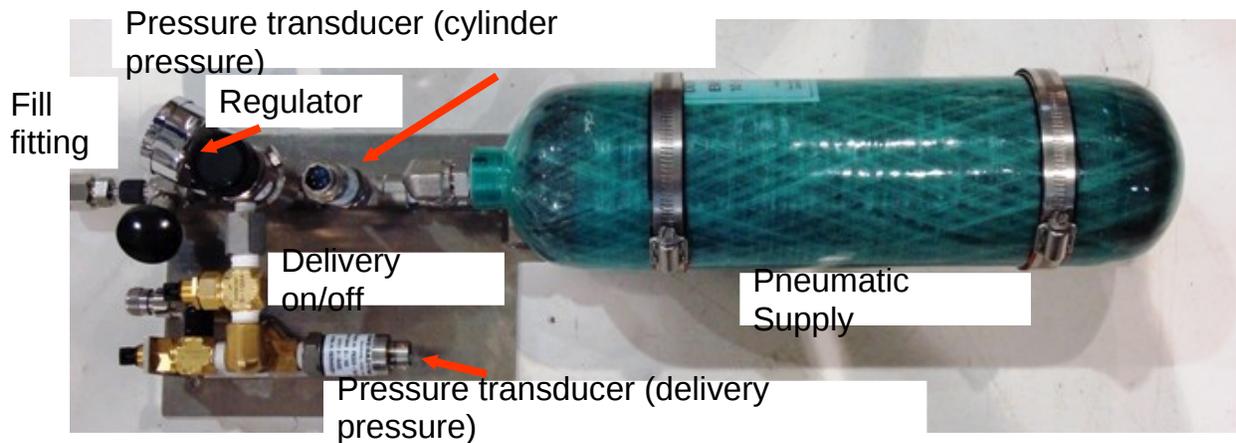
Figure 6. Top view of AWAS pneumatic module.

The pneumatics module consists of a 2.33 liter Kevlar-wrapped carbon composite cylinder (Structural Composites Industries, Model 621, DOT-E8142 spec, 1850 psi max) which contains N2 or air at about 1500 psi. The cylinder pressure is regulated with a 2-stage regulator (Scott Specialty, 51-14D-CGA590, 0 – 100 psig delivery) and both the cylinder pressure and delivery pressure is monitored by the control computer via signals from pressure transducers (Omega Engineering; PX329-3KG5V 0-3000 Psig Pressure Transducer; 28 VDC Operation; 0-5 VDC Output;   PX329-100G5V   0-150 Psig Pressure Transducer; 28 VDC Operation; 0-5 VDC Output). A high pressure relief valve (SS-4R3A5, with 177-R3A-K1-E spring kit) is included in the module as a safety precaution.

II.3 Pump Module.

The pump module is used to pressurize ambient air into the sample cylinders. The pump module utilizes 2 potable water compressor pumps (Senior Flexonics,28823-11; s/n 5301, 5302). The pumps were modified by Senior Flexonics after initial tests of the pumps showed significant leakage. The modifications included replacement of the original (incorrect) bellows with a sealed bellows and replacement of the integral ball/spring relief valve (located on the pump end plates) with plug seals. To substitute for these internal pressure relief ports, pressure relief is added to the pump module interconnect tubing and also in the Exhaust module (described next).

A photo of the pump module is shown below (Figure 7). (See also Figure 5 for schematic). The first pump is connected with a parallel inlet that feeds the second pump. The second pump is plumbed in series to allow the manifold and sample canisters to pressurize to about 35 psig. The dual pump arrangement is designed to provide reasonably short sample times near the maximum altitude of the aircraft. An example of flow rate and fill time obtained during test flights of the AWAS is given in Table 1.
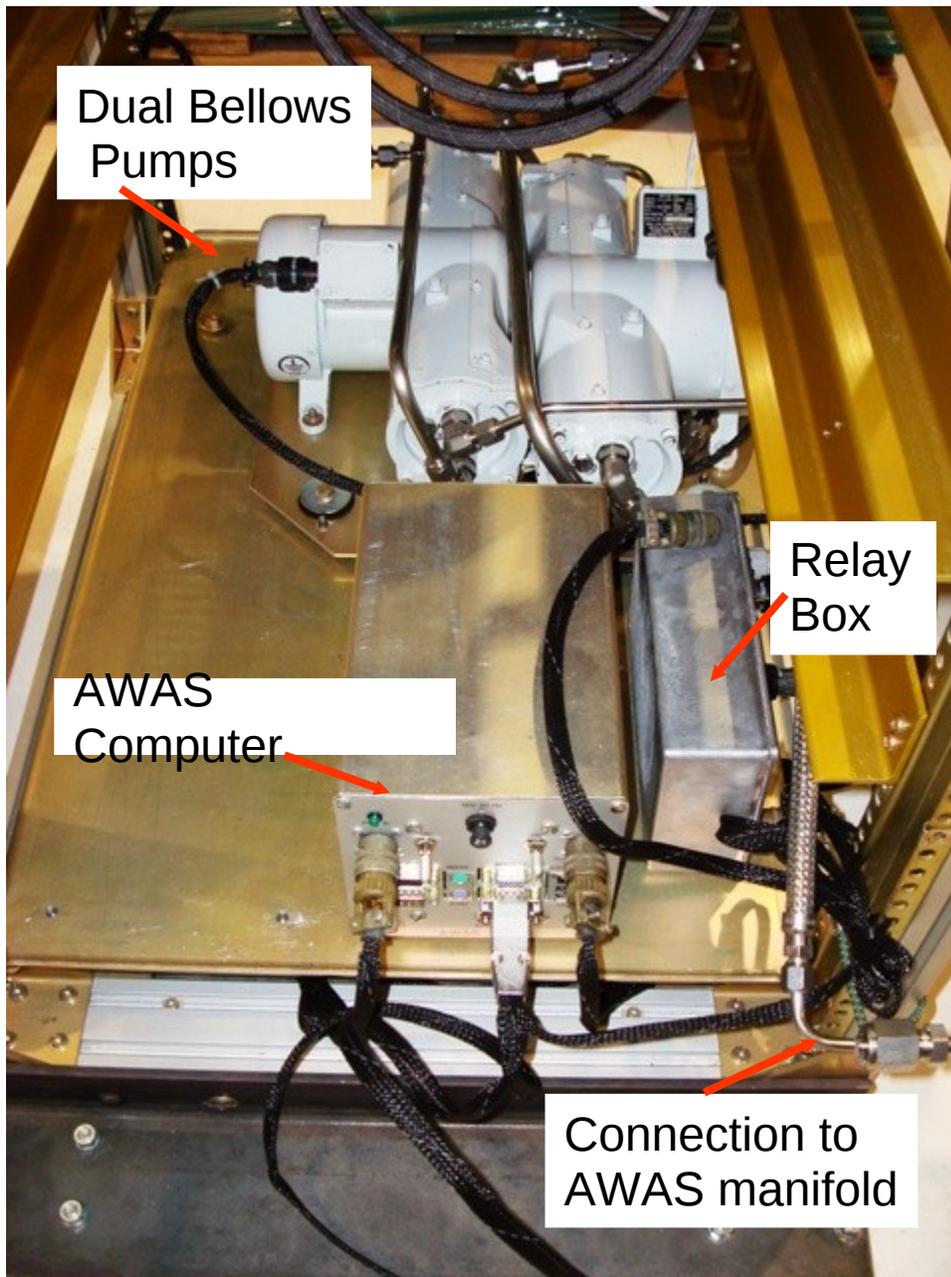
Figure 7. AWAS pump plate installed in HIAPER rack. Pneumatics module removed for clarity.

Table 1. Manifold flow rate, canister fill time, and manifold pressure of the AWAS as a function of altitude during initial test flights (February, 2008). Values interpolated graphically to altitudes shown in the table.

Altitude (ft)	Flow rate (slpm) *	Canister fill time (sec)	Manifold pressure (psia)
47000	4	36	52
45000	6	32	52
40000	10	23	52
35000	14	18	52
30000	19	13	54
25000	23	10	55
20000	27	9	56
15000	31	8	58
10000	36	7	60
5000^	40	7	62

* indicated flow on exhaust (not calibrated).   ^extrapolated values at 5000 ft.

The inlet used on the test flights of AWAS used a forward facing ¼" stainless steel tube mounted in a HIMIL housing. The connection between the HIMIL and the pump inlet may be different between missions, depending on the relative locations of the AWAS rack and the HIMIL. For the test flights, connecting tubing needed to follow a convoluted route, so lengths of ¼" flexible stainless steel hose (Swagelok, #SS-FM4SL4SL4-xx) were used. Users may choose their own types of inlet tubing that is appropriate for the measurements to be done on the collected samples.

II.4. Exhaust Module

The exhaust module controls the manifold pressure limit and allows the manifold to be pressurized or flow freely. Exhaust flow from the AWAS to the aircraft exhaust manifold is monitored with a digital flow meter (data not currently recorded). A schematic of the plumbing of the manifold is shown in Figure 5.

The manifold pressure is determined by the position of the exhaust valve and the setting of the pressure relief valve. With the exhaust valve open, the air passing through the manifold is flowing at the maximum flow for the given altitude. On command from the control computer, this valve can be closed, which allows the manifold pressure to build to the maximum set by the manifold pressure relief valve. This relief valve (Swagelok, P/N XXXXX) is set manually and should not need frequent adjustment.

II.5. Control module.

The control module provides the functions of monitoring system pressures and canister status, of opening and closing canister valves and the exhaust valve, and displaying AWAS status via the aircraft communications system or via a crossover cable connected directly to a laptop located in the AWAS rack. Interaction with the DSM is done primarily through the aircraft network (as described later). The front panel connectors are shown in Figure 8.
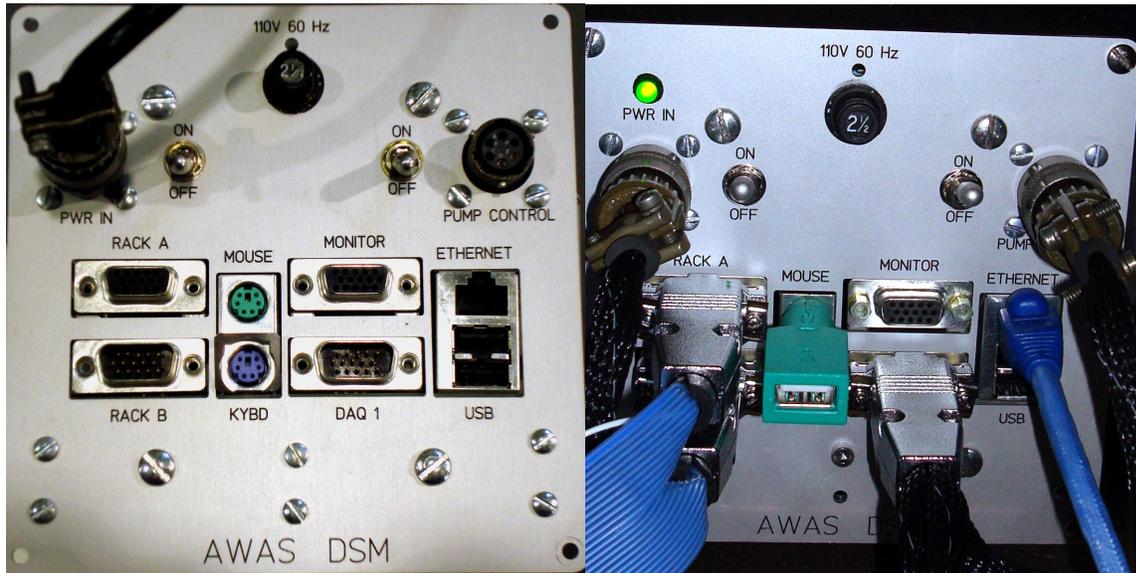
Figure 8. Front panel of the AWAS Control Computer (DSM).

A block diagram of the Control module and its interconnections to other modules in the AWAS system was shown in Figure 9. The DSM, Data Systems Module, is the core of the Control module. The DSM consists of a Pentium III level processor running LabView under Windows XP to control the operation of AWAS. Based on operator supplied parameters such as Open Time (the maximum time a can may stay open for filling), Wait Time (the time between can openings) and Maximum Pressure (the maximum pressure in an open can before closing), the DSM monitors various system parameters and controls the filling of the canisters automatically. There is also provision for the operator to initiate immediate canister sampling through a laptop terminal program accessed through an Ethernet connection to the DSM. Other aspects related to the DSM operation can be accessed through this terminal interface. The LabView screen accessed through this interface is shown in Figure10.

The physical components of the DSM consist of the CPU (Kontron MOPSlcd7), a multipurpose I/O module (DMM-32X-AT) used for analog inputs and digital I/O, a 20 channel relay module (IR104) used to control solenoid valves and pump operation, a hard disk drive and power supplies all mounted in a PC/104 enclosure as shown in Figures 7 and 8.

Figure 9. AWAS System Block Diagram showing DSM connections to system modules.
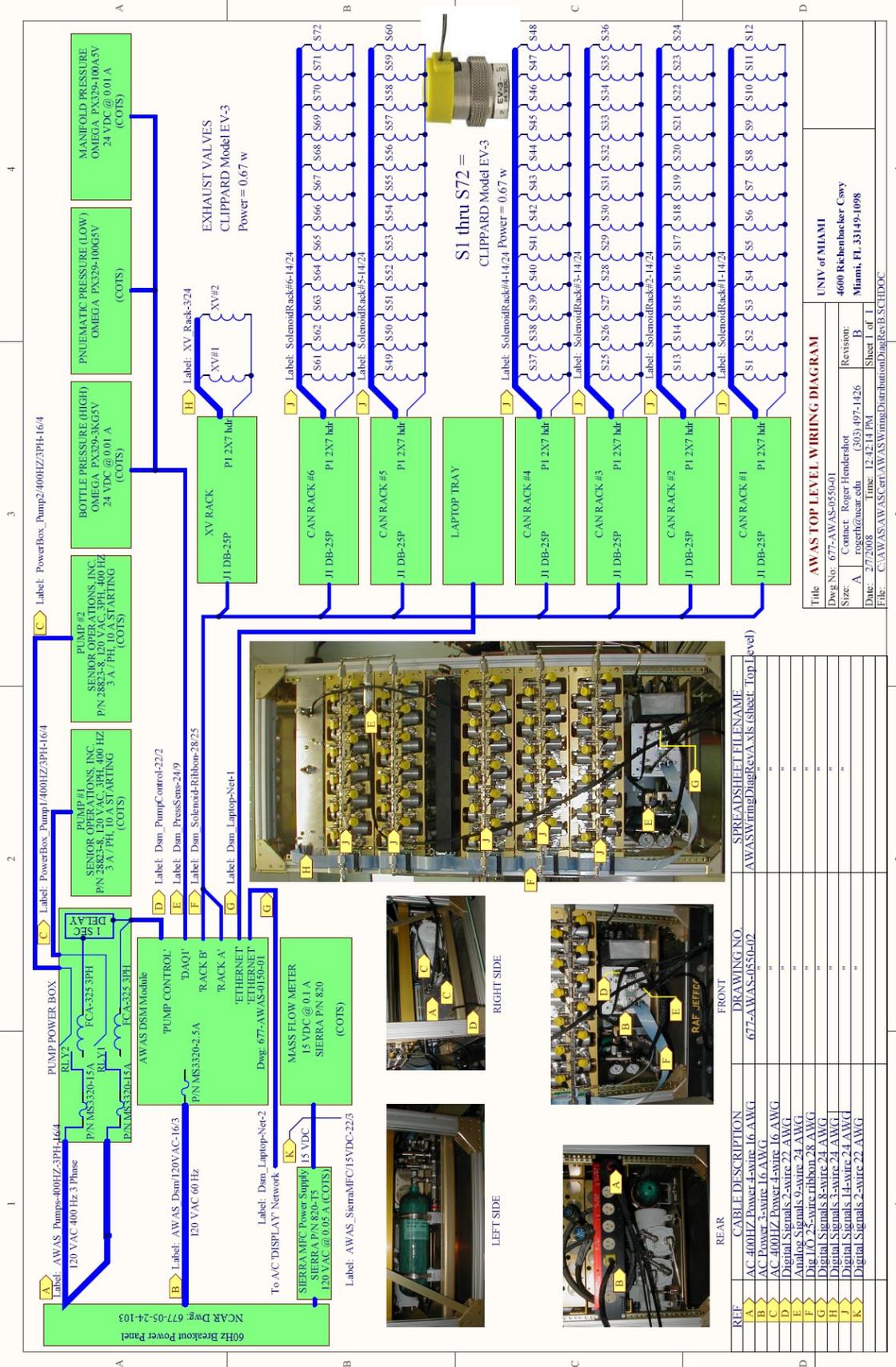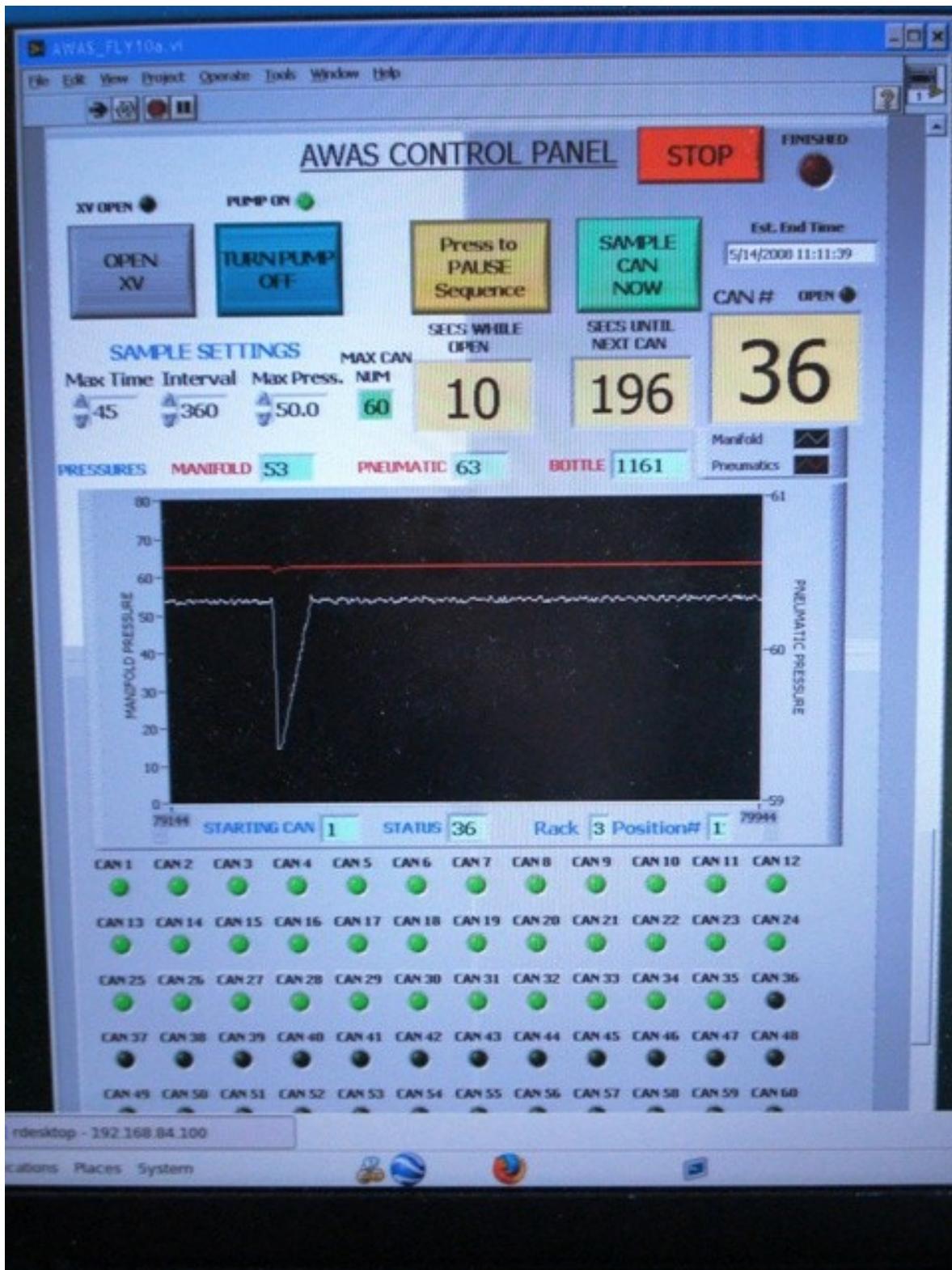
Figure 10. LabView Front Panel seen from Laptop Computer

III. INSTALLATION PROCEDURE.

Installation of the AWAS modules and components is described in this section. The description assumes starting with an empty HIAPER rack, except for one power panel installed in the rear of the rack by RAF personnel (See Figure 11 below).
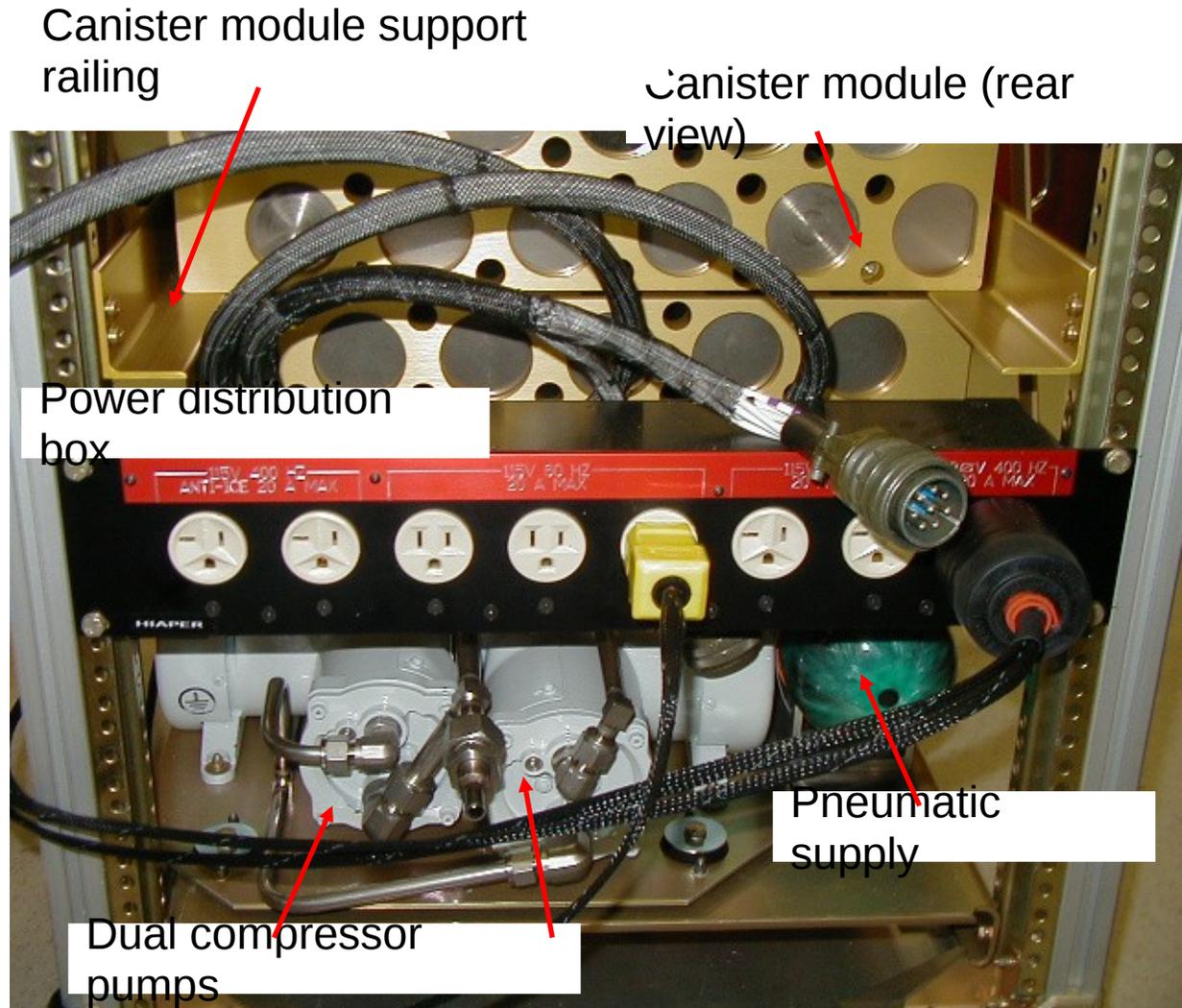
Figure 11. Rear view of AWAS rack showing power distribution panel and other components.

1) Installation of inlet

The AWAS inlet currently utilizes the standard HIMIL housing. Consult the appropriate RAF personnel to discuss options and installations. RAF personnel will install the necessary hardware inside the HIMIL based on specific requirements. For the AWAS test flights, we specified a forward facing ¼" OD stainless steel tube. A larger diameter inlet might allow more flow to the pump, but this was not tested. The largest tubing allowed is recommended, though. Prior to installation, the tubing and HIMIL should be cleaned as appropriate by the PI. Standard cleaning by RAF is an acetone and distilled water rinse. For the initial HEFT08 test flights, we used additional rinses with dichloromethane, methanol, and water.

After the HIMIL is installed on the aircraft, suitable inlet tubing is connected between the HIMIL and the compressor inlet. Since the location of the inlet and the AWAS are not fixed, each installation will be unique. Preferred connection is with 3/8" – ½" stainless steel tubing. The tubing connection to the HIMIL highly recommends nylon or Teflon ferrules, otherwise all metal connectors (Swagelok and VCR) are used for the connections. For the HEFT (and START08) flights, we used a ¼" all-metal flexible stainless steel hose (Swagelok SS-FM4SL4SL4-36 or equivalent) to connect between the HIMIL and the pump inlet. If the connection to the HIMIL is in a location that is difficult to access, use extra precautions to secure the connection to keep it from loosening during the mission. With the HIMIL as the inlet, it is difficult to locate small leaks on the inlet side of the AWAS.

2) Installation of base plate.

The base plate will contain the pump module, the pneumatics module, the control module, and the power box. Figures 6 – 7 show the orientation of the different components on the base plate. The base plate will typically have all of the modules mounted to the base plate prior to installation in the rack. Prior to mounting the base plate, all connections to the compressor pumps should be secure, and their tightness verified. Also prior to installation of the plate, it is recommended to recharge the high pressure pneumatic supply. This is accomplished by connecting a tank of helium or nitrogen to the pneumatics inlet fitting on the front of the pneumatics module. The connection is via a ¼" VCR fitting. The connecting tubing should be rated to hold pressures up to 1800 psi or more. The supply tank is opened, and the gas is metered into the pneumatics reservoir through a control valve mounted to the tank fittings. The pressure is monitored by the Scott regulator. The fill pressure should not exceed 1800 psig.

To install the base plate, locate the plate in the rack with DSM and the pneumatics fill-tube facing the front of the rack. Align the plate with the mounting holes and secure the plate with 4 aircraft screws. Connect the compressor inlet to the interconnect tubing from the HIMIL.

2) Installation of the exhaust plate.

For a full set of 5 canister modules, the exhaust plate is mounted at the topmost location in the rack (Figure12).   The module is secured with 4 aircraft screws. The outlet from the exhaust manifold is connected to the aircraft gas exhaust manifold through a section of approved Teflon tubing (3/8" OD). Figure 12 shows this connection.
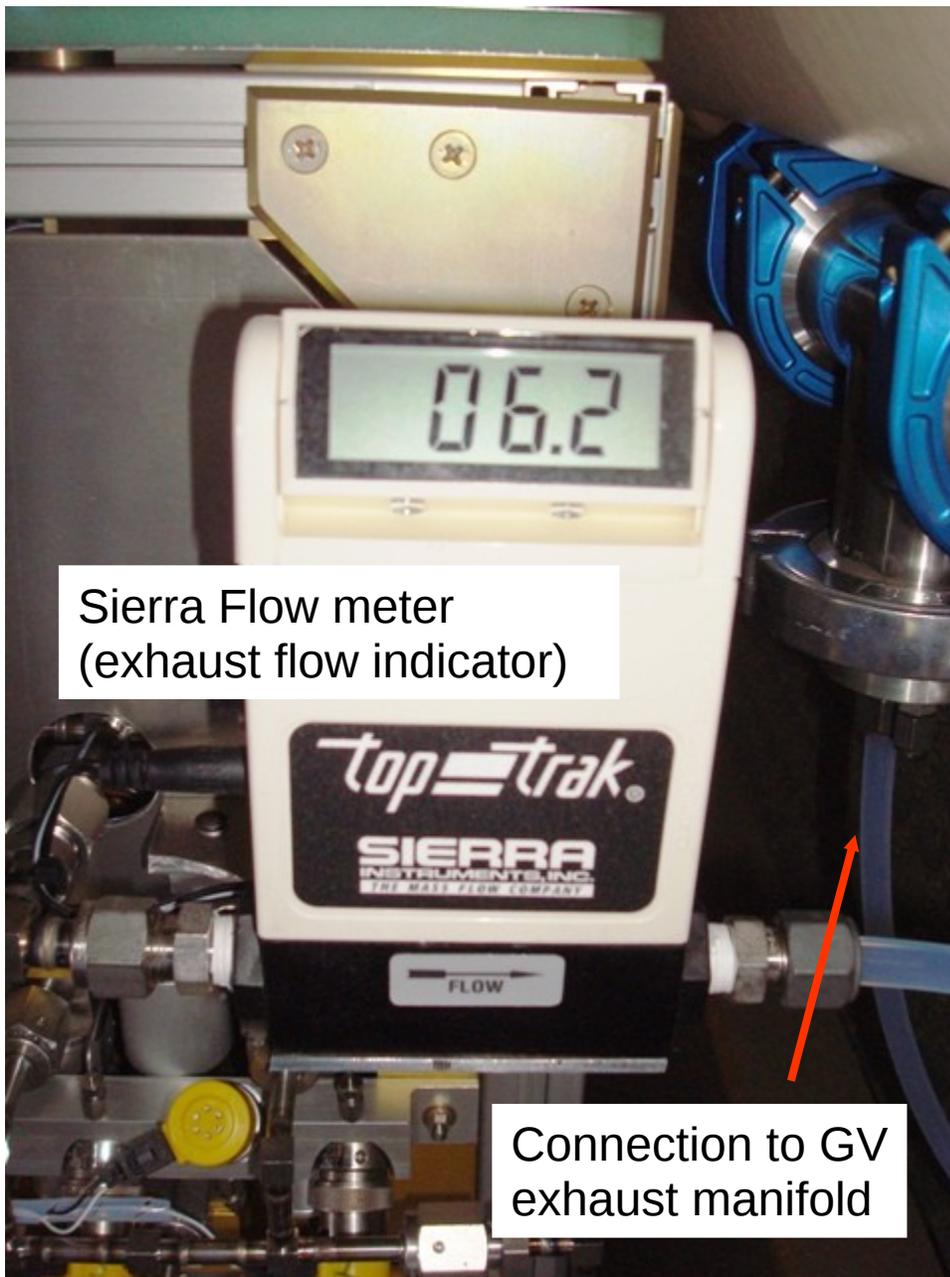
Figure 12a. Flow meter exhaust display and connection to GV exhaust manifold.
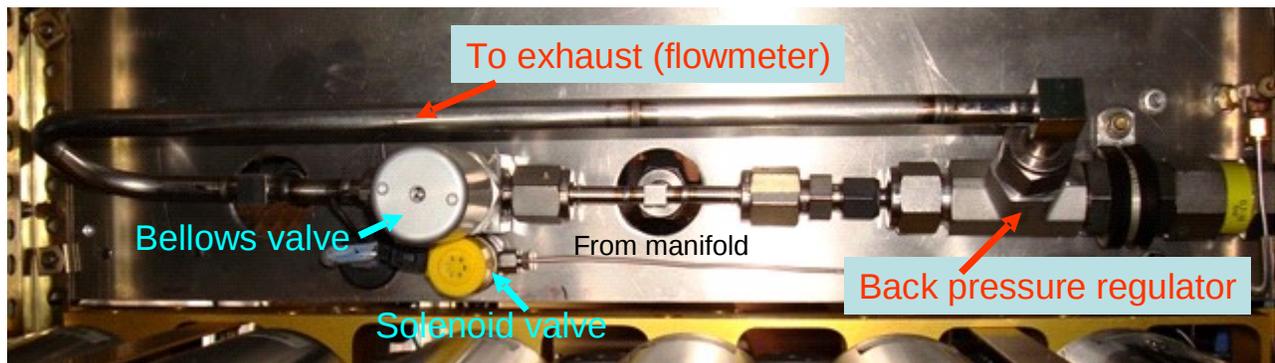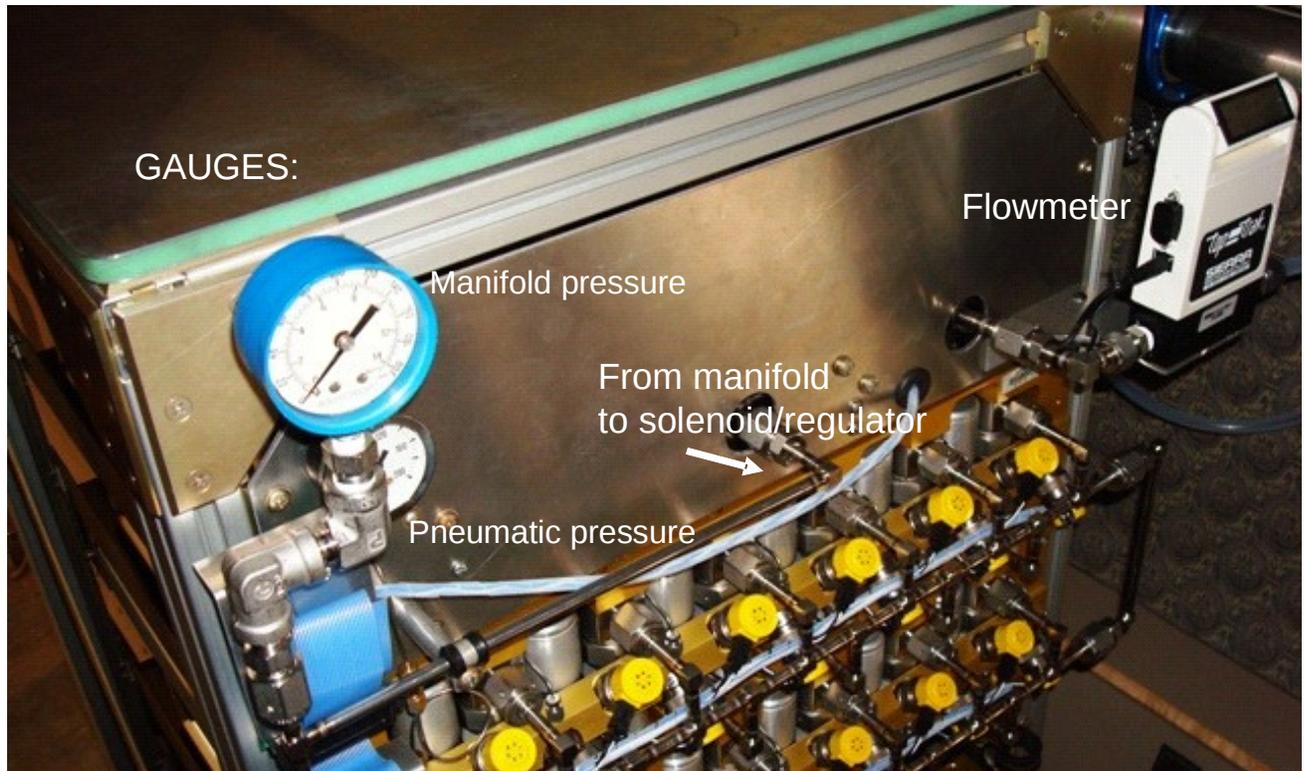
Figure 12b, c . Exhaust manifold assembly. Top: front panel shows connection from manifold and manifold pressure gauge (blue). Pneumatic pressure is indicated in lower gauge. Bottom: Back view of exhaust manifold. Shows pneumatic bellows valve on left. Manual back pressure regulator is on the right. Solenoid valve controls pressure to bellows valve actuator.

3) Installation of Computer Tray.

A computer tray (supplied by RAF) is mounted in the location between the 2nd and 3rd canister manifold (counting from the top). An RAF approved laptop computer with Windows XP operating system is mounted with appropriate clips to the computer tray.

4) Installation of canister modules.

It is most convenient, though not mandatory, that the canister modules are installed from the lowest to the highest in the rack. This is also the order that canisters are filled during sampling. Each module is slid into the rack along side rail supports. Some adjustment is necessary to align the mounting holes with the rack prior to securing the module with 4 aircraft screws. For the first (lowest module), the connecting tubing from the pump needs to be moved out of the way. Similarly, to mount the topmost module, the connecting tubing and fittings must be actually removed from the exhaust manifold. As the modules are installed, connect the 1/16" pneumatics tubing between modules (see Figure13). One longer section of 1/16" tubing is used to bridge the gap across the computer tray. After canister modules are installed, reconnect the exhaust manifold section to the exhaust module and connect it to the top canister module. Similarly, connect the tubing from the pump to the bottom canister module.

5) Installation of manifold connectors/finalize connections

Final connections between canister modules are with welded tubing sections with VCR ends. With the exception of 2 special connectors, all connectors are identical. The special connectors are: 1 longer connector to bridge the extra space occupied by the laptop tray, and 1 connector containing a pressure transducer. The long connector is used between modules 2 and 3 (counting from top), and the connector with the pressure transducer is used between modules 3 and 4 (counting from top).

6) Electrical and electronic cable connections.

Final electrical and electronic cable connections are:

    a) Connect AWAS ribbon cable along left side of rack to each module and D-connector ends to DSM (Marked Rack A and Rack B on cables and on DSM)
    b) Connect DSM Power to back panel power distribution (120V)
    c) Connect DSM Pump to Power Relay box
    d) Connect 400 cycle power from Power Relay box to back panel power distribution
    e) Connect cable from Power Relay box to pumps
    f) Connect DAQ1 cable to DSM (pressure transducers, exhaust valve at other ends)
    g) Connect Internet Cable to aircraft Internet system (location assigned by RAF).
    h) Plug in 12 V Adapter to back panel power distribution and connect to Sierra Flow Meter.

Review mechanical and electrical connections.

The system is now ready for pre-flight check.

Figure 13. Photo of AWAS installed in HIAPER rack during HEFT-08.

IV. AWAS Operation (BASIC)

1) Pre-flight start-up
   a) visually inspect all electrical and mechanical connections
   b) connect LCD monitor and mouse to front of DSM, plug monitor to back power panel.
   c) Turn on DSM power
   d) Go to C: drive, check the following file:
      status.dat = 0 or last can sampled
   e) Check/set clock (currently using Dimension4, and 192.168.184.10 timeserver)

   f) Open Labview by clicking on latest version of "AWASFLY10a" (as of July,2008)

   g) Start Labview program.
   h) Check/set Open time, Wait time, and Maximum Pressure, and Max Cans as desired for flight.

2) Preflight checks:
   a) Turn on bellows pump (See Labview description)
   b) Verify exhaust flow (>40 slpm on ramp at RAF)
   c) Verify pressure readings and data recording in LabView
   d) The following steps are recommended, but will depend on specific inlet configuration and may not be possible)
      a. Seal inlet with pump running
      b. Measure and record vacuum at inlet to verify leaktight system. Expected vacuum < 30 torr.
   e) Turn off bellows pump (see Labview description)
   f) Close exhaust valve (See Labview description)
   g) If system is to sit for long periods after this check and before flight, it is recommended to purge the inlet, pump and manifold at about 500 sccm with clean gas (e.g. ullage gas from LN2 tank). Note: this purge may not be possible with all inlet configurations.

3) Flight Operations:
   a) AWAS can be controlled from the laptop computer installed in the AWAS rack or from another computer on the aircraft network. Communication with the AWAS DSM module uses TightVNC running under Windows XP or Remote Desktop. A static IP address will be assigned to the AWAS, and this will be the address used to connect via TightVNC or with Remote Desktop. A Linux version of remote desktop and tightVNC were installed on the RAF display laptops during START08. Set up of the remote control is described later.

   A screen shot of the control panel is shown in Figure 13.

Figure 13. Screenshot of AWAS Labview control program (Ver. 10a) during START08 flights.

b) After take-off (typically 3 – 5 min after take-off):
CLICK "START PUMP"
This opens exhaust valve and starts the dual bellows pumps in sequence, and button changes to "TURN PUMP OFF".

c) When ready to start the sample collection sequence:
CLICK " START Sample Sequence" ; button changes to "Press to PAUSE Sequence". Based on the current sample interval, the estimated sample end time for the indicated Max. Cans is shown in a small panel above the can number.

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d) At any time after the sequence has been started, adjustments in sample collection timing can be accomplished. The changes are described below:

   1) Sample on command: To collect a sample at any time, CLICK "SAMPLE CAN NOW" button. After this sample, the next sample to be collected automatically will take place after the normal sample interval.

   2) Pause sample sequence: If no samples are required for a period of time, CLICK "Press to Pause Sequence" button.   This will leave the pump running, but no samples will be collected. To immediately restart sample collection, CLICK "START Sample Sequence".

   3) Adjust timing of sample interval: If a new time interval between sample collection times is needed, the time interval may be modified by entering a new value or pressing the up/down arrows on the control box.

   4) Adjust sample pressure: Though this control would not normally be adjusted, it is possible to reset the maximum canister pressure. Keep in mind that in its current configuration, the maximum manifold pressure at the altitude limit of the GV is approximately 52 psia. As a precaution, the canister is closed after the "Max Sample Time" if for some reason the manifold does not reach the indicated pressure limit.

e) The last canister to be sampled is dictated by the Max Can parameter that is set prior to starting the LabView Program. This cannot be reset during a run. The program must be halted first.

f) After the last sample is filled, the program automatically shuts off the pump and opens the exhaust valve. If the sample sequence is not complete prior to landing, it is recommended to shut down the program by pressing the red STOP button on the Control Panel. This will shutdown the program, turn off the pump and open the exhaust valve.

g) After landing, transfer from AWAS folder to memory stick (in top USB port of the AWAS DSM) the AWAS data file (FlightDataYYYYMMDDHHMMSS.dat). This file has the information on manifold and pneumatic pressures as well as the times of the solenoid activation for sample collection. An example of this file is in the Appendix of this Guide.

f) After transferring the data file, the computer may be shutdown. In Remote Desktop, open DOS control window, and type "shutdown –s". In TightVNC, the normal Windows shutdown is used. After 2 minutes, turn off power to AWAS DSM and close the pneumatics delivery valve.

Procedure Page for GV used during START08:

1) After GV data system has been on for > 5 minutes:
      a) AWAS DSM Power Switch to ON (up)
          Green light in upper left panel = on
      b) Check in AWAS rack:
          Pump Control Switch Up
          Pneumatics toggle valve on

2) For operation from SID-2 computer display:
      Turn on SID-2 computer (if not already running) (SID-2 computer =Position 2 on KVM)
      a) Log in to SID-2
      b) Follow procedures for SID-2 start-up (see SID-2 instruction sheet)
      c) Start Tight VNC session (icon located in center of the screen)
          i) program comes up with AWAS IP address for START08 = 192.168. 84.100
      d) Password = awas
      e) AWAS desktop screen will appear in a new window on the SID-2 desktop screen.
Follow steps 1 – 3 in Step 2.1 below.
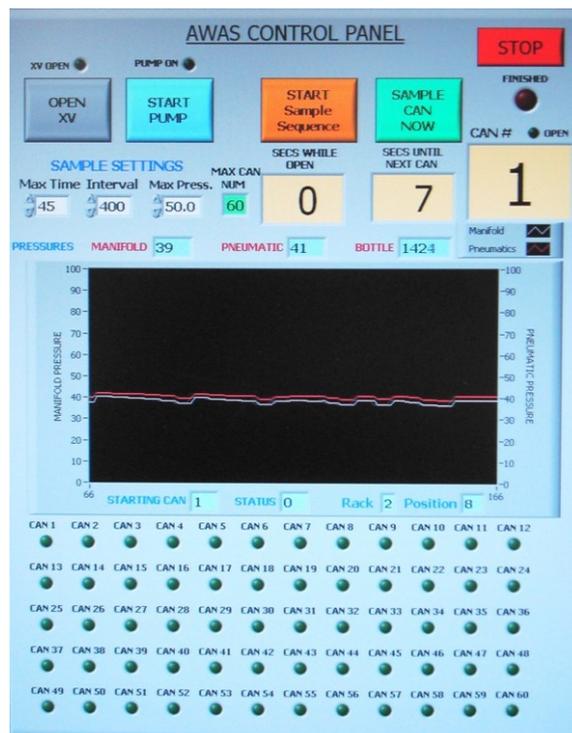
2.1) For operation using GV Display laptops running Linux:

The application rdesktop should have already been installed. It is recommended that the full command line for rdesktop to communicate with AWAS be included in the icon control that opens rdesktop. This includes the login name and password (currently rogerh and awas), and the ip address and color depth (currently 8 bit resolution). Check with RAF IT expert if help is needed for this.

Upon opening rdesktop, answer yes to the question about logging off of AWAS and logging in as a new user.

When the AWAS desktop is visible,

1) Synchronize computer time (with Dimension 4 and GV timeserver).

2) Check status.dat file and set to 0. save status. dat.

3) Open current AWAS Labview control program (now at Ver 10a).

3) Operation:

a) Check and adjust Maxtime/max pressure/interval values as appropriate for flight. If Max Can number needs to be changed. Press Labview Stop Program icon (see figure below), change the Max Can number, and then press the Labview Start Program (arrow) icon.
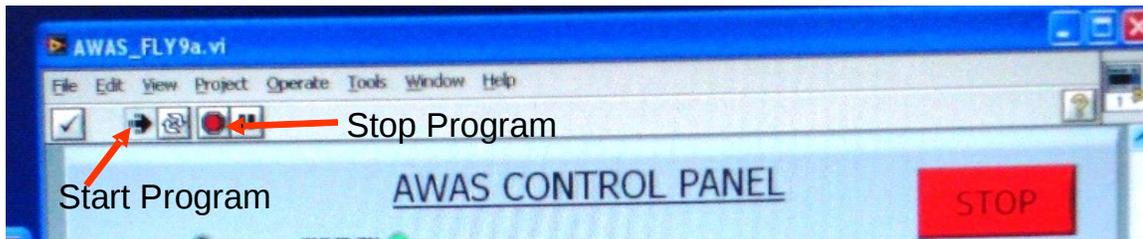
b) 3 – 5 minutes after takeoff: Press "START PUMP". XV (exhaust valve) indicator will illuminate first, then "pump on" indicator will light as pumps are turned on.

c) At the required time in the flight, Press "START Sample Sequence". This will initiate filling sample canisters using the (adjustable) parameters listed under SAMPLE SETTINGS.

d) Sample status is displayed numerically (canister open time, time until next canister starts sampling, and canister number (shows next can in sequence, then green light comes on when that canister is being filled)).

e) A time history of sample manifold pressure and pneumatic pressure is shown in the graph. A pressure drop indicates that a sample canister is being filled. This should correspond to the sample status indicators above.

f) To initiate a single sample on command, press "SAMPLE CAN NOW" button. This will immediately start sample collection if a sample is not already being collected.

g) When program reaches fills last can (based on MAX CAN NUM), the exhaust valve (XV) is opened and the pump is turned off automatically. MAX CAN NUM cannot be changed when the program is running.

h) To manually stop the sequence, press PAUSE sample sequence. Then it is possible to open XV and TURN PUMP OFF. These buttons are inactive when the Sample Sequence is running.

i) The rectangular red STOP button on the AWAS CONTROL PANEL is for fast shutdown only: This button will stop the pumps, open the exhaust valve, and exit the Labview program.

j) Sample collection data from the DSM is downloaded via USB transfer to a memory stick inserted in the top USB port of the DSM. The file is located in C:\AWAS directory and is named FlightDataYYYYMMDDHHMMSS.

4) EMERGENCY SHUTDOWN:

a) Pull breaker on the front panel (top middle) of the AWAS DSM.

APPENDICES

A.1   Parts specifications

INLET

HIML ¼" FORWARD FACING

INLET LINE

2	EA	¼" X 36" SWAGELOK STAINLESS STEEL FLEXIBLE METAL HOSE	SS-FM4SL4PM4-36
1	EA	SHORT TUBE BUTT-WELD GLAND	3166LV-4-VCR-3S-4TB7
1	EA	FEMALE NUT	SS-4-VCR-1

BOTTOM TRAY

BELLOWS PUMP PLATE

BELLOWS PUMPS

2	EA	SENIOR FLEXONICS	K097-C38184

BELLOWS PUMP FITTINGS

1	EA	SWAGELOK ¼ X 9/16-18 SAE EL	SS-400-2-6ST
2	EA	SWAGELOK 3/8 X ¾-16 SAE EL	SS-600-2-8ST
3	EA	SWAGELOK 3/8 X 9/16-18 SAE EL	SS-600-2-6ST
2	EA	SWAGELOK ½ X ¾-16 SAE EL	SS-810-2-8ST

BELLOWS PUMP RELIEF VALVES

2	EA	SWAGELOK	SS-CHS4-50

BELLOWS PUMP POWER CABLE CONNECTORS

2	EA	AMPHENOL	PT06A-10-5S

BELLOWS PUMP PLATE SHOCK MOUNTS

4	EA	LORD	150APDLQ-7

BELLOWS PUMP SWITCH BOX

BP ON SIGNAL CONNECTOR

2	EA	MALE 5-PIN KPT PANEL	

BREAKERS

2	EA	KLIXON	6TC2-15 / MS14154-15

DELAY TIMER (SET FOR 1 SECOND)

		ARTISAN	24D.1-10SST1

RELAYS

2	EA	LEACH	KC-2N-300L

PNEUMATICS SUPPLY

CYLINDER

1	EA	LUXFER DOT-SP 10015-300	EM55215

2250 PSIG RELIEF VALVE

1	EA	SWAGELOK	SS-4R3A5

FITTINGS

1	EA	SWAGELOK 3/8 X ¾-16 SAE EL	SS-600-2-8ST
1	EA	SWAGELOK ¼ NPT-3/8 ADAPTER	SS-600-1-4
2	EA	SWAGELOK ¼ NPT STREET TEE	SS-4-ST
1	EA	SWAGELOK ¼ NPT TEE	SS-4-T

TOGGLE VALVES

1	EA	SWAGELOK STRAIGHT THRU	B-1GM4
1	EA	SWAGELOK ANGLE PATTERN	B-1GM4-A

SWAGELOK QUICK CONNECT

1	EA	SWAGELOK STEM	SS-QM2-D-200
1	EA	SWAGELOK BODY	SS-QM2-B-200

REGULATOR

1	EA	SCOTT	5114D590

FITTINGS

1	EA	SWAGELOK 1/8 MPT – ¼ FPT	SS-4-RA-2
2	EA	SWAGELOK ¼ NPT STREET EL	B-4-SE
1	EA	¼ NPT 45 DEGREE STREET EL	
1	EA	SWAGELOK ¼" TUBE-1/4 MPT	SS-4-TA-1-4
1	EA	SWAGELOK ¼" VCR GLAND	6LV-4-VCR-3S-4TB7
1	EA	SWAGELOK ¼" VCR MALE NUT	SS-4-VCR-4
1	EA	SWAGELOK ¼" VCR CAP	SS-4-VCR-CP
1	EA	SWAGELOK ¼ MPT MALE ADAPTER	SS-4-TA-1-4

PRESSURE TRANSDUCERS

1	EA	OMEGA 0-100 PSIG	PX329-100G5V
1	EA	OMEGA 0-3000 PSIG	PX329-3KG5V
2	EA	TRANSDUCER CONNECTOR AMPHENOL	PT06A-10-6S

FILL VALVE

1	EA	WHITEY NEEDLE VALVE	SS-1RS4

SAMPLE MODULES

1	EA	RELAY RACK MOUNT 12-CANISTER FIXTURE/HOLDER	NCAR MADE

SAMPLE CANISTERS (12 PER SAMPLE MODULE)

1	EA	SAMPLE CYLINDER	CUSTOM MADE
1	EA	SHORT TUBE BUTT-WELD GLAND (SAMPLE CYLINDER FITTING)	3166LV-4-VCR-3S-4TB7
1	EA	FEMALE NUT (SAMPLE CYLINDER FITTING)	SS-4-VCR-1
1	EA	AIR ACTUATED VALVE / MALE ¼ " VCR PORTS	SS-BNVCR4-C
1	EA	BESWICK ENGINEERING 1/16 " VALVE AIR ACTUATOR FITTING	MCB-1016-316

MODULE SAMPLE MANIFOLD
    SWAGELOK AND CAJON MICRO-FIT FITTINGS

14	EA	90 DEGREE MICRO-FIT UNION ELBOW	6LV-4MW-P
12	EA	MICRO-FIT UNION TEE	6LV-4MW-3
16	EA	SHORT TUBE BUTT-WELD GLAND	3166LV-4-VCR-3S-4TB7
14	EA	FEMALE NUT	SS-4-VCR-1
2	EA	MALE NUT	SS-4-VCR-4
14	EA	SILVER PLATED GASKET / RETAINER	SS-4-VCR-2-GR

MODULE PNEUMATIC MANIFOLD

1	EA	12-PORT MANIFOLD	NCAR MADE
12	EA	CLIPPARD MINMATIC PNEUMATIC SOLENOID VALVE	EC-3M-24-VDC
12	EA	CLIPPARD MINMATIC SOLENOID VALVE CONNECTOR (18 INCH LEADS)	C2-RB18
12	EA	BESWICK ENGINEERING 1/16 " SOLENOID PORT FITTING	MCB-1016-316
2	EA	SWAGELOK 1/16 TUBE-1/16 MPT CONNECTOR	B-100-1-1

PNEUMATICS INTERCONNECTIONS
1/16" OD X .030" ID STAINLESS STEEL TUBING

GENERAL SYSTEM PARTS

SAMPLE MANIFOLD PRESSURE INDICATORS

1	EA	OMEGA 0-100 PSIA	PX329-100A5V
1	EA	TRANSDUCER CONNECTOR AMPHENOL	PT06A-10-6S
1	EA	0-100 PSIG ASHCROFT BOURDON GAUGE ¼" MPT PORT	40-1008S-02L-100#

SAMPLE MANIFOLD PRESSURE CONTROL

1	EA	SWAGELOK ADJUSTABLE RELIEF VALVE (SET 40 PSIG)	SS-RLS8
1	EA	AIR ACTUATED VALVE / MALE ¼ " VCR PORTS; EXHAUST VALVE (RELIEF VALVE BY-PASS)	SS-BNVCR4-C
1	EA	BESWICK ENGINEERING 1/16 " VALVE AIR ACTUATOR FITTING	MCB-1016-316
1	EA	CLIPPARD MINMATIC PNEUMATIC SOLENOID VALVE	EC-3M-24-VDC
1	EA	SOLENOID VALVE CONNECTOR	
1	EA	BESWICK ENGINEERING 1/16 " VALVE AIR ACTUATOR FITTING	MCB-1016-316
1	EA	0-100 PSIG ASHCROFT BOURDON GAUGE 1/8" MPT PORT	40-1008S-01B-100#

A.2. Electronic Schematic Diagrams
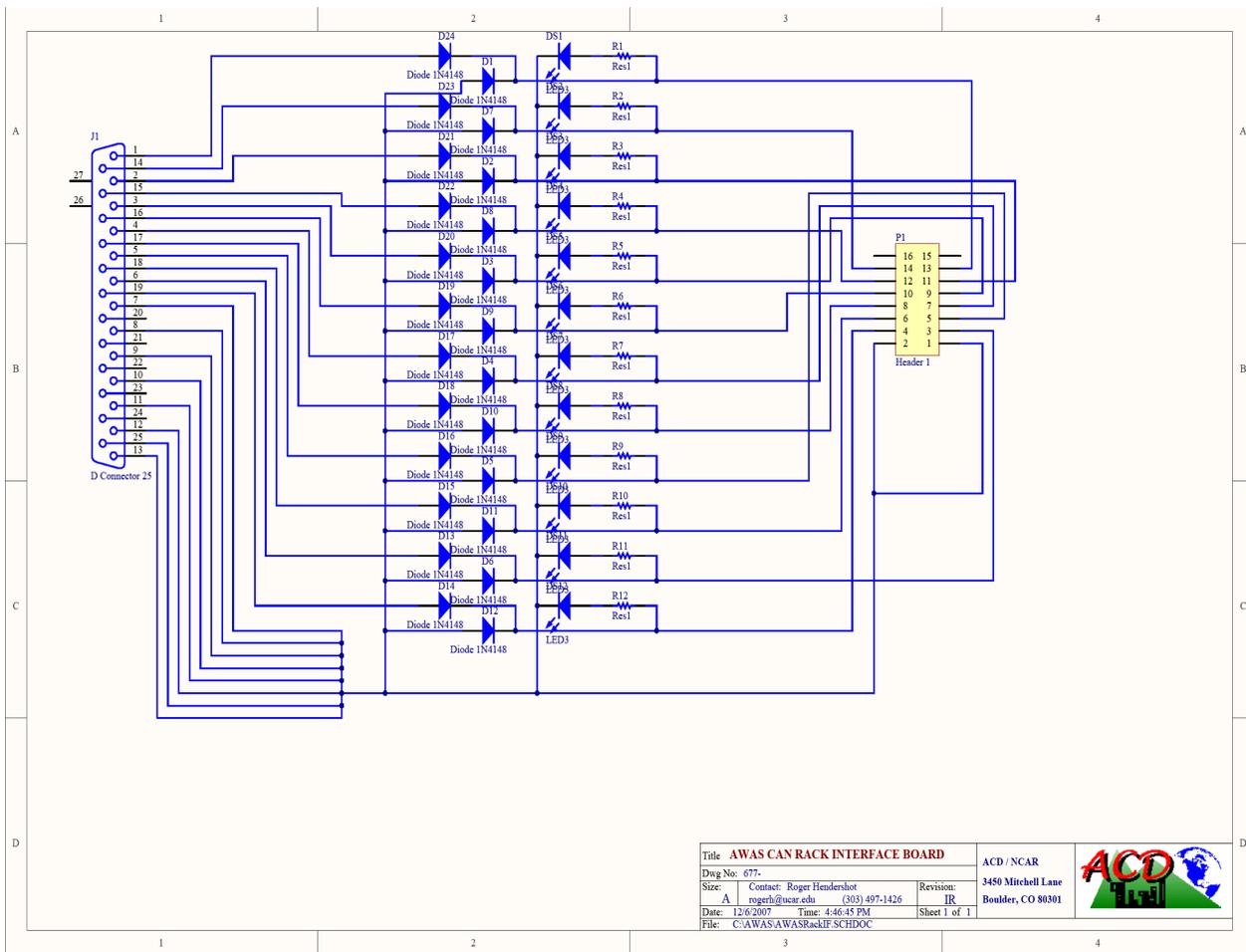
AWAS CAN RACK INTERFACE BOARD

AWAS RIBBON CABLE

COLUMNS ⟶

ROWS

6   EXHAUST VALVE   *7,8,9,10,11,13,25

5   SAMPLE MODULE #5   *7,8,9,10,12,13,25

4   SAMPLE MODULE #4   *7,8,9,11,12,13,25

3   SAMPLE MODULE #3   *7,8,10,11,12,13,25

2   SAMPLE MODULE #2   *7,9,10,11,12,13,25

1   SAMPLE MODULE #1   *8,9,10,11,12,13,25

*PINS REMOVED

Figure A.1. Ribbon connector cable wiring. .

A.3   LabView Control Program

1 Example of internal data file (sent as attachment)
2. Current working program loaded onto AWAS DSMs and provided on CD..

A.4   Suggested spare parts and support equipment for field use (not supplied as part of contract).

1) ¼" VCR gaskets for manifold connections
2) 1/16" unions, nuts, and ferrules for pneumatic connection
3) Torque wrench for VCR manifold connections
4) Memory stick for transferring data files from DSM

5) Prep system for AWAS modules:
       Oven
       Vaccuum system
       Plumbing for flushing tubes with clean gas (air or N2)
       Electric and pneumatic connections for open/close AWAS canisters

6) Transfer system for AWAS canisters is probably necessary until additional AWAS modules are constructed. (NOTE: current contract for 15 modules (17 delivered) is sufficient for 3 "typical" research flights only).
       Similar to prep system but no oven needed.
       Large dewars for canisters needed if transfer is done with cryogen.

7) Additional spares (provided)
       Clippard solenoid valves
       Spare cylinders (18)
       Spare pneumatic valves (10)
       Spare DSM (1)

A5. Hazardous Materials.

     The AWAS contains one high pressure cylinder that needs to be refilled on a routine basis. (Figure 6) The cylinder is rated at 1800 PSIG. Metal high pressure tubing and appropriate gas cylinder (supply) and tubing connector (VCR) that are rated at or above this pressure are necessary. Proper precautions for handling high pressure gas should be reviewed.

A6. Canister Preparation.

     As noted above, the preparation of the AWAS canisters will depend on the analytes that are measured from the canisters. This section is a brief description of the techniques used for the HEFT and START08 missions, and these techniques should be appropriate for many typical trace gas research studies.

     The preparation system consists of 1) a vacuum/leak detector cart connected to 2) AWAS modules that are placed in 3) a mobile oven (Figure A2 and A3).   The mobile oven has the switches and power supply necessary to activate the AWAS sample valves. For START08, house air was used as the pneumatic supply. The vent gas from a liquid nitrogen dewar is used as the pure purge gas during the processing. [Other high purity gases are also possible.]

START08 Procedure:

1) Place AWAS sample modules in oven and connect to pump system with custom made manifold connector.
2) Connect pneumatic supply (80 psi) air and connect the 1/16" pneumatic tubing between the individual modules. The last fitting is sealed with a Swagelok cap.
3) Connect ribbon cable between control switches and AWAS modules.
4) Evacuate system with AWAS canisters all closed.
5) Use helium leak detector to check for leaks. Close leaks if any are found.
6) Turn on oven heater and fan. Cover modules with insulation.
7) While heating, open/close each canister in series to verify that canister valves are opening/closing. Monitor system pressure as each canister is evacuated.
8) After all canisters have been individually checked, open all canisters.
9) Evacuate to approximately 30 mTorr or less as oven heats to about 80C.
10) Backfill canisters with N2 to approximately 1 atmosphere.
11) Repeat 9 and 10 two more times.
12) Evacuate to <30 mTorr while cooling oven.
13) If dry canisters are required, skip the next 2 steps.
14) When oven is near room temperature, add 5 Torr water vapor from previously treated reservoir. (Pretreatment may include heating, purging, and vacuum treatment prior to using water vapor in canisters).
15) After water vapor is added, close all cans.
16) Remove from manifold/oven and the modules are ready to use.

Figure A2. Bakeout system used to prepare AWAS module sampling. Also shown is part of the system used to transfer air from AWAS canisters to individual canisters.
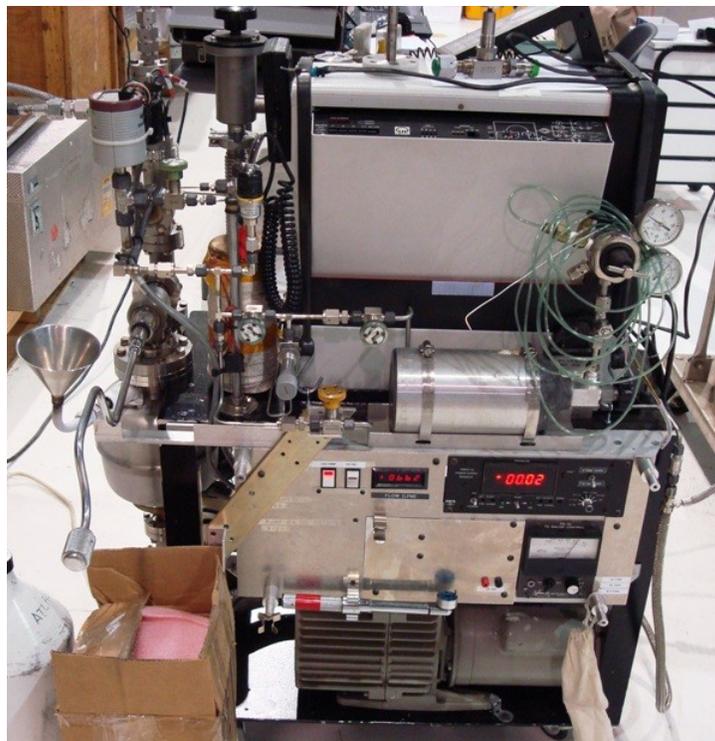
Figure **A3**. Pump system/leak detector used to prepare and check sample canisters.