Instruction Manual

Model 8050

Automated Flowing *p*CO_2 Measuring System

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January, 2007

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Chapter 1. INTRODUCTION

The thermodynamic driving force of CO_2 gas exchange between the ocean and atmosphere is often expressed as the difference in the fugacity of CO_2 (fCO_2) in seawater and overlaying marine air (ΔfCO_2). The flux (F) is expressed as:

$$F = k\ s\ \Delta fCO_2$$

where the gas transfer velocity (k) is a function of wind speed and the solubility (s) is a function of seawater temperature and salinity. fCO_2 is directly related to the partial pressure of CO_2 (pCO_2). Accurate measurements of pCO_2 with adequate spatial and temporal resolution is of essential importance in order to better constrain the seasonal and geographical variations of F. An underway (UW) pCO_2 instrument is the best tool currently available to reach towards that goal.

1.1. System Overview

This UW- pCO_2 system is designed to operate fully automatically.

Seawater is circulated through a closed chamber (*the main equilibrator*) at a flow rate of about 2 L/min and a pressure around 4 psi. The water enters the equilibrator via a *spiral nozzle*, creating a conical spray which enhances the CO_2 gas exchanges between the water and the overlying air (*headspace*) in the equilibrator. The water is then gravity drained out of the system. An "*inverted cup*" system with a siphon break in the middle of the equilibrator effectively isolates the headspace gas from the outside air and greatly minimizes any gas loss due to air entrainment from the water flow. A smaller *secondary equilibrator*, where seawater flows at about 0.5 L/min and which is opened to the ambient air, is the replacement source for the minimal air loss that might still occur in the main equilibrator.

The headspace gas is circulated through the system and back to the equilibrator with a pump *(headspace pump)* at about 100 ml/min. It is first dryed by going through a Pelletier cooling block (*the Condenser)* operating at about 5 ^{o}C, then a Permapure Nafion tube. The dry gas is then sent to the Infrared LICOR analyzer (*the LICOR*) where its CO_2 and H_2O mole fractions (xCO_2 and xH_2O) are measured.

Atmospheric air is also being measured alternatively by the system. A dedicated pump (*ATM pump*) constantly draws outside air, a portion of which is dried in a second channel of the condenser and flushes the content of a small reservoir (*the ballast*), a short length of PVC pipe open to the ambient air. The dry ballast atmospheric air is circulated through the LICOR for analysis. Accessorily, the ballast air is also used for the countercurrent flow in the outer chamber of the Perma Pure Nafion® dryers and is pulled by a dedicated pump (*the vacuum pump*).

An 8-port 16-position VALCO multiposition valve (*the VALCO valve*) selects the gas being circulated through the LICOR. A set of CO_2 gas standards (supplied by the user) is measured regularly during normal operations in order to calibrate and correct for any drift of the LICOR.

A full array of analytical and diagnostic parameters (see SOFTWARE chapter), including gas flows, water flows, various temperatures and pressures, time, position are recorded for each CO_2 measurement. The system has the capability of sending the data at the end of each day via satellite communication using an Iridium modem.

The pressure and temperature inside the main equilibrator are constantly being measured. With a knowledge of the sea-surface temperature and salinity, along with all the parameters measured by the system, one can calculate the fugacity of the seawater and the atmosphere above it, as described in the next section.

1.2. Calculation of $f CO_2$

Details of calculations and equations

Calculation of the partial pressure of CO_2.

The first step in the calculations is to correct the LICOR mole fraction output using the measurements of the standards. The corrected xCO_2 is then used to calculate the partial pressure of CO_2 in the dry air using the equilibrator pressure (the pressure of equilibration):

$$pCO_2 = xCO_2 \cdot P_{equ}$$

Correction for water vapor pressure

Drying the gas prior to analysis actually changes the mole fraction of CO_2 in the sample and since the air in the equilibrator is assumed to be at 100% humidity, it is necessary to correct for that effect.

$$pCO_2 \approx pCO_2 (in\ dry\ air) \times VP(H_2O)$$

where $VP(H_2O)$ is the water vapor pressure at a given temperature and salinity of equilibration and is given by (Weiss and Price, 1980):

$$VP(H_2O) = \exp\left(24.4543 - 67.4509\left(\frac{100}{T}\right) - 4.8489 \ln\left(\frac{T}{100}\right) - 0.000544\, S\right)$$

Where T is the temperature in Kelvin and S is the salinity. $VP(H_2O)$ is in atmospheres.

Calculation of the fugacity of CO_2

There are several equations used to approximate the true expression of the fugacity. The most commonly used is as follows:

$$fCO_2 = pCO_2 \exp\left(\frac{\left[B_{CO2}\left(T_{equ}\right) + 2\,(1 - xCO_2)^2\ \delta_{CO2}\left(T_{equ}\right)\right]P_{equ}}{RT_{equ}}\right)$$

Where R=82.0575 $cm^3.atm.K^{-1}.mol^{-1}$, T_{equ} is the temperature of the equilibrator in Kelvin, $B_{CO2}(T_{equ})$ and $\delta_{CO2}(T_{equ})$ are the first and second virial coefficients for CO_2 , respectively and are given by ($cm^3.mol^{-1}$):

$$B_{CO2}(T) = -1636.75 + 12.0408\,T - 0.0327957\,T^2 + 3.16528\,10^{-5}\ T^3$$

$$\delta_{CO2}(T) = 57.7 - 0.118\,T$$

Correction of pCO_2 to sea surface temperature (SST)

The fCO_2 is temperature dependent. The temperature of the water in the equilibrator is, in most cases, different from the temperature at the sea surface so it is necessary to correct for this temperature change. The preferred equation to do so is given by: (Takahashi, 1993)

$$fCO_{2\,(SST)} = fCO_{2\,(Teq)} \times \exp\left(0.0423\,(SST - T_{equ})\right)$$

where SST and T_{equ} are the sea surface and equilibrator temperatures, respectively.

References:

Takahashi, T., J. Olafsson, J. G. Goddard, D. W. Chipman and S. C. Sutherland (1993). "Seasonal-Variation of CO_2 and Nutrients in the High-Latitude Surface Oceans - a Comparative-Study." Global Biogeochemical Cycles **7**(4): 843-878.

Weiss, R. F. and B. A. Price (1980). "Nitrous oxide solubility in water and seawater." Marine Chemistry **8**: 347–359.

Chapter 2. HARDWARE

The system is composed of a *Dry Box, a Wet Box and a Deck Box.* In addition, depending on the type of installation, the system requires external hardware which is user-supplied and which could include: a set of three or four *CO_2 standard gas tanks, a pump* to supply seawater, a pump to evacuate the analyzed seawater.

2.1. Dry Box

The Dry Box (see Figure 1) so called because no water is circulated through it, contains most of the electronics and the LICOR CO_2 analyzer. Its purpose is to supply power to the Wet Box, to select the gas to be analyzed and to analyze it.

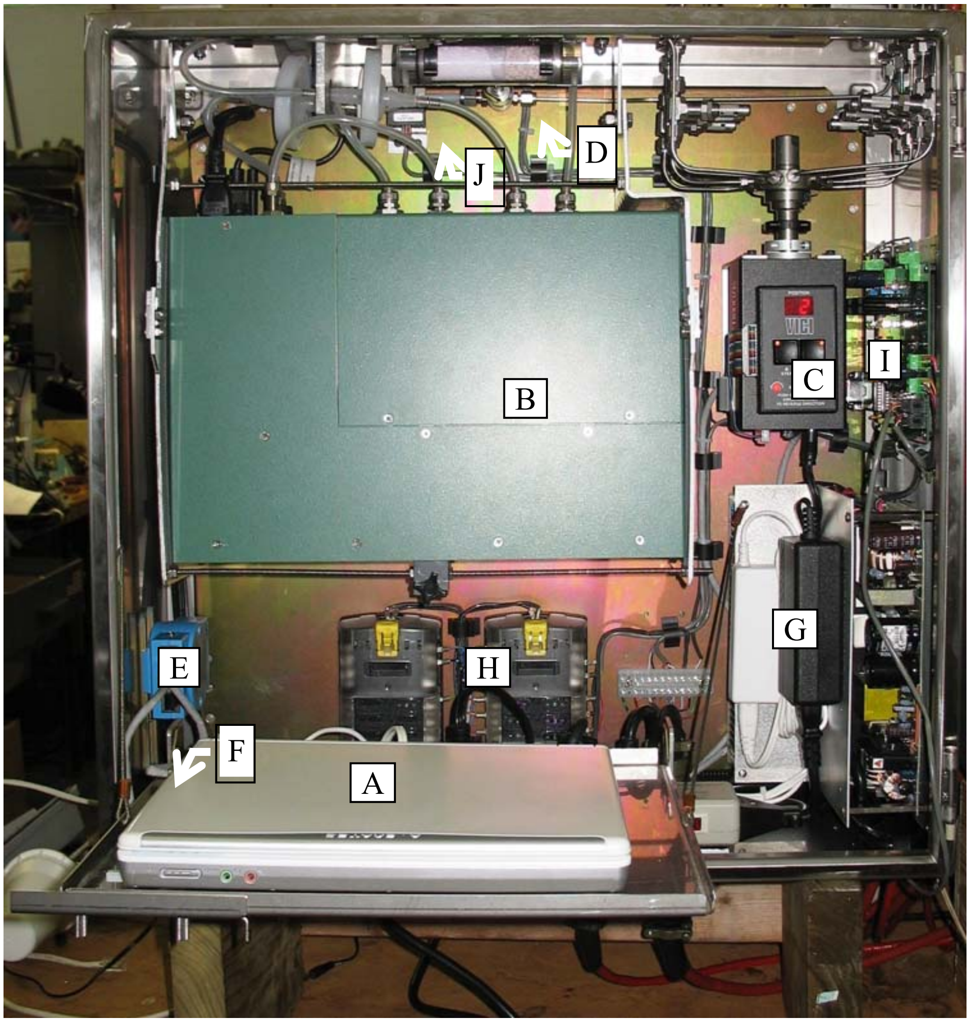


Figure 1. Picture of the Dry Box

The Dry Box connects to both of the other boxes with cables and controls the entire system.

2.1.1. Laptop Computer – A

The laptop computer can be any laptop provided it has the following components:

- Windows XP, Home or Professional editions
- 1 Ethernet port
- At least 1 USB port

It is recommended that the user supplies a USB Flash drive (128 Mb should be sufficient) to provide an external location to save the data in case of hard drive failure.
Instructions on how to setup a brand new computer to interface with the system is described in section 3.1.1.

2.1.2. Infrared Analyzer – B (User supplied)

The infrared analyzer used in the system is a Non-Dispersive Infrared (NDIR) Analyzer. The system is capable of accommodating three (3) LICOR models: LI-840, LI-6262 and LI-7000. All LICORs should be configured to start up automatically on power restore after a power failure. Except for the LI-840 which is secured to the back plate of the box, they are mounted on metallic brackets which allow the user to rotate the LICOR to an horizontal position by unscrewing the black knob holding it to the back plate (see Figure 2), rotating the LICOR upward and pushing the small metallic tabs on the side of the brackets (see Figure 3).

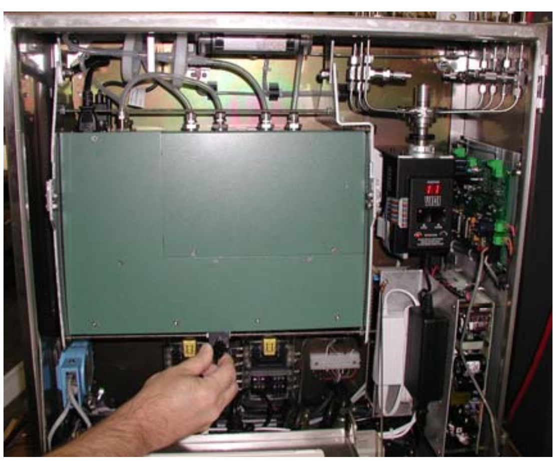


Figure 2. Rotating the LICOR - phase 1

Figure 3. Rotating the LICOR - phase 2

- LI-840

The LI-840 is a smaller, cheaper and lower maintenance model than the other two but doesn't have the same functionality nor the same accuracy. It is a good option for users who do not require high accuracy data

- LI-6262

The LI-6262 is configured to be used in absolute mode (see LICOR manual). The reference channel is connected to a closed loop in which the air is constantly being circulated by a pump through a scrubber containing Soda Lime and Magnesium Perchlorate ($Mg(ClO_4)_2$) to remove CO_2 and water vapor. It is recommended to change the chemicals in the scrubber every 6 months or so, depending on usage.
The LI-6262 used in the system also has an internal pressure transducer which measures the pressure inside the sample channel.

NOTE: the internal pressure transducer is connected to the sample cell by a short length of tubing which does not get flushed by the sample gas, as it is a dead-end path. The gas inside the tubing will most likely have a different concentration than the gas in the sample cell and will diffuse back , effectively contaminating the sample cell, when the flow is stopped to make the measurement. It is therefore recommended to limit the *Stop Flow Time* (see section 3.3.1 Run Setup) to 10 seconds or less.

- LI-7000

The LI-7000 has the same features as the LI-6262 described in the previous section and is used in the same manner. In this model, the reference channel pump and scrubber are internal but the chemicals still need to be changed with the same frequency. See the LI-7000 manual for more information.

2.1.3. Valco Multiposition Valve (MPV) – C

The VALCO valve is an 8-port, 16 positions rotary distribution valve which selects the sample gas to be analyzed and directs it to the LICOR via its outlet port. Because it has twice the number of positions as the number of ports, only half the positions corresponds to ports (the odd numbered positions 1,3,5…) whereas the other half is in-between ports and therefore closed (the even numbered positions 2,4,6…). The system stops the flow of all gases except the EQU air by placing the valve at an in-between position.

Located on the front of the valve is a manual control module which allows the manual control of the valve. Pressing the “Step” button moves the valve by one position in either direction. The direction of rotation can be changed by pressing both “Step” and “Home” buttons at the same time.

2.1.4. 3-Way Solenoid Valve– D

This solenoid directs the LICOR output to either a vent or the wet box. Only the EQU air is returned to the equilibrator. The other gases are vented out after going through the LICOR.

2.1.5. Ethernet Switch– E

The Ethernet switch connects to the computer on one end and to two Ethernet to Serial converters on the other end. One is situated in the dry box (see 2.1.6) and the other one is in the Deck box (see 2.3.1) where it connects to the Druck barometer, the GPS and the Iridium modem.

2.1.6. Ethernet to Serial Converter– F

This device provides 4 serial ports which connect to the LICOR, the VALCO valve, the GO Board and to the Wet box (where it reads the relay module, the A/D module and the Hart thermometer. It is pre-configured by General Oceanics, Inc. and cannot simply be replaced by a new one purchased from the manufacturer. To replace, contact General Oceanics, Inc.

2.1.7. Power Supplies– G

There are several power supplies which provide power to the different components of both the Dry and Wet boxes. The power to the Wet box is carried over by the 19-connector cable. See Appendix H for wiring diagrams.

2.1.8. Fuse Box– H

Details about the fuses are given in section H.2 of Appendix H

2.1.9. GO Board– I

The GO board has three functions:

- It interfaces with three temperature sensors:
  - the “box” temperature sensor located on the board.
  - the “ambient” temperature sensor located in front of the opening at the bottom of the Dry box’s door. When the fan is on, the inside air is expelled and replaced by air coming in that opening.
  - The condenser temperature sensor located inside the condenser itself.

- It controls the speed of the fan on the Dry box’s door. The user sets a minimum and maximum box temperature in the program. The fan runs at minimum speed when the temperature is less or equal to the set minimum , at maximum speed when the box temperature is more or equal to the set maximum and at a proportional speed when the box temperature is in-between the two. The box temperature can be defined by the user in the program as that measured by either the “box” temperature sensor or the “ambient” temperature sensor.
- It controls the Headspace pump speed. The speed is a number between 0 and 255.
- It controls the temperature of the condenser. The target temperature of the condenser is set in the program. The board controls the power to the condenser in order to keep it within +/- 0.5 ^{o}C around that temperature.

2.1.10. LICOR flow meter– J

This device measures the air flow out of the LICOR. The flow is output as a 0-5 V voltage which is calibrated to a flow in ml/min.

2.2. Wet Box

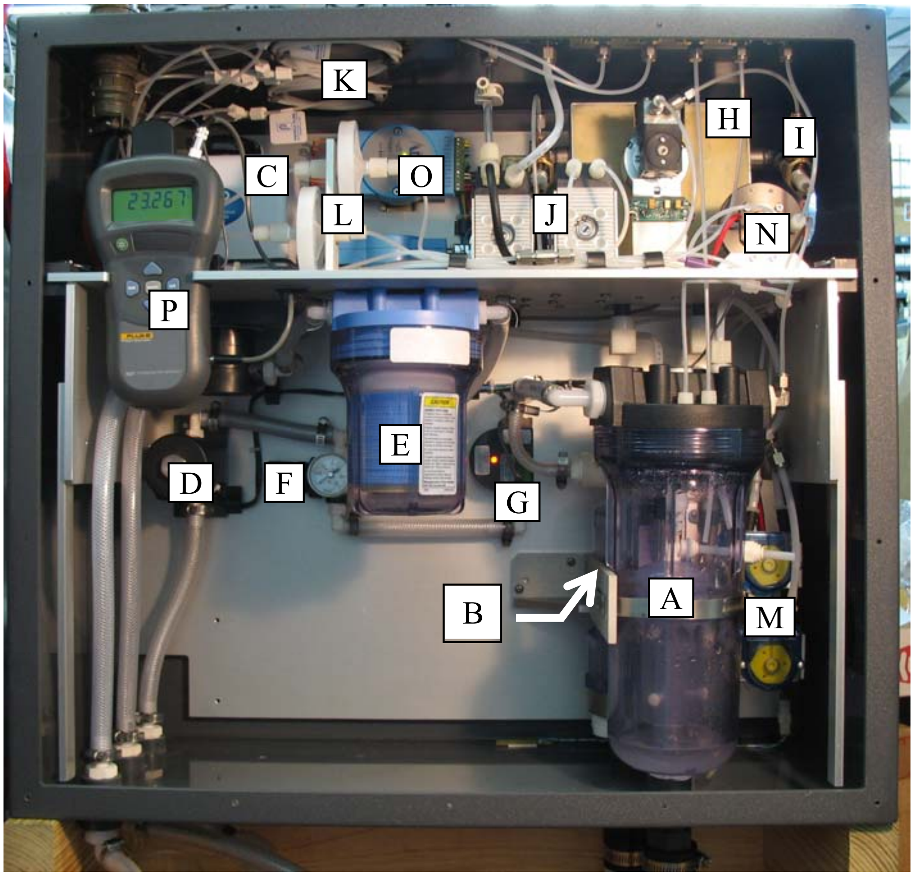


Figure 4. Picture of the Wet box

2.2.1. Main Equilibrator – A

The main equilibrator is where the seawater equilibrates with the headspace gas. Water enters through a spiral nozzle at about 2 L/min and exits through the "inverted cup" piece in the middle of the equilibrator. This "inverted cup" piece effectively seals the headspace gas from the outside air and maintains a constant and stable water level inside the equilibrator, therefore reducing fluctuations in pressure due to turbulences. It has a siphon break to prevent loss of air due to siphoning of the exiting water. Air loss is minimal but not completely prevented so it is made up by pre-equilibrated air from the secondary equilibrator. This make-up air is pre-equilibrated in order to minimize the perturbation of the intake.

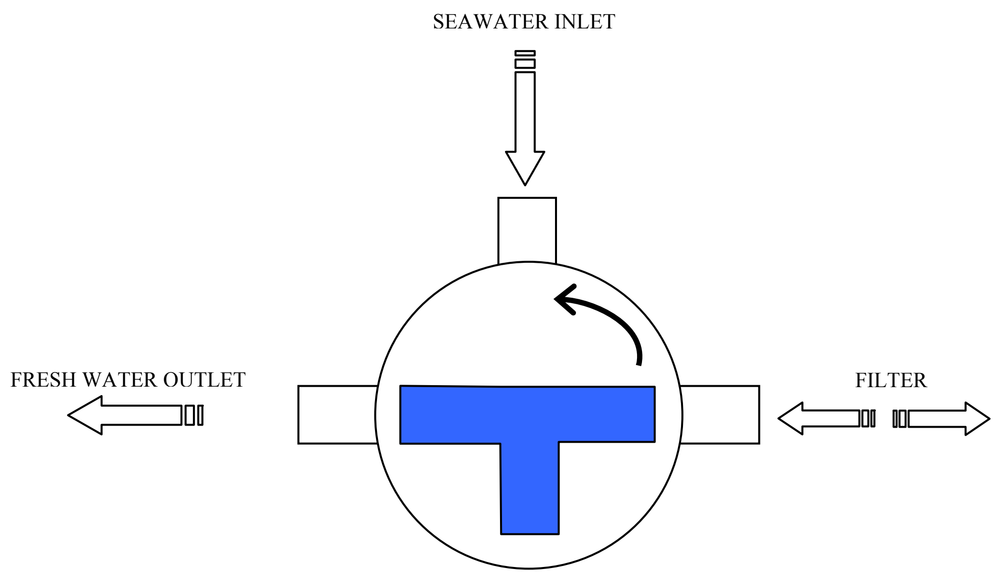
It also contains a temperature probe connected to the Hart thermometer (see 2.2.16) and a Setra Pressure transducer (see 2.2.14) to measure the temperature and pressure at the time of equilibration.

2.2.2. Secondary Equilibrator – B

This equilibrator provides pre-equilibrated air to make up for any loss of air that occurs in the main equilibrator. It is open to the air inside the Wet box via a flow meter similar to the one found in the Dry box which measures how much air is drawn in this equilibrator and, indirectly, gives an idea of how much air is drawn in the main equilibrator.

2.2.3. EVSCO Valve – C

This valve selects whether seawater of fresh water enters the system. It works in conjunction with the fresh water solenoid to back-flush the water filter during a “Filter” operation (see software).



At the start, the seawater inlet is closed as well as the fresh water solenoid. When the analysis is started, the valve is rotated 90 ^{o} counter-clockwise and seawater flows through the system. During a “Filter” event, the fresh water solenoid is opened and the valve is rotated 90 ^{o} clockwise so that fresh water flows backwards through the filter, through the valve and out of the system.

2.2.4. Fresh Water Solenoid – D

It controls the fresh water input used to back flush the filter (see 2.2.3 for a description of the event)

2.2.5. Water Filter – E

This filter is fairly coarse and is not used to clean the seawater but rather to prevent big particles (50 μ) from entering the equilibrator and clogging the system. It is back flushed at intervals selected by the user programmatically and can be cleaned manually (when the system is not running) by unscrewing the body and rinsing off the internal stack of disks.

2.2.6. Water Pressure Regulator – F

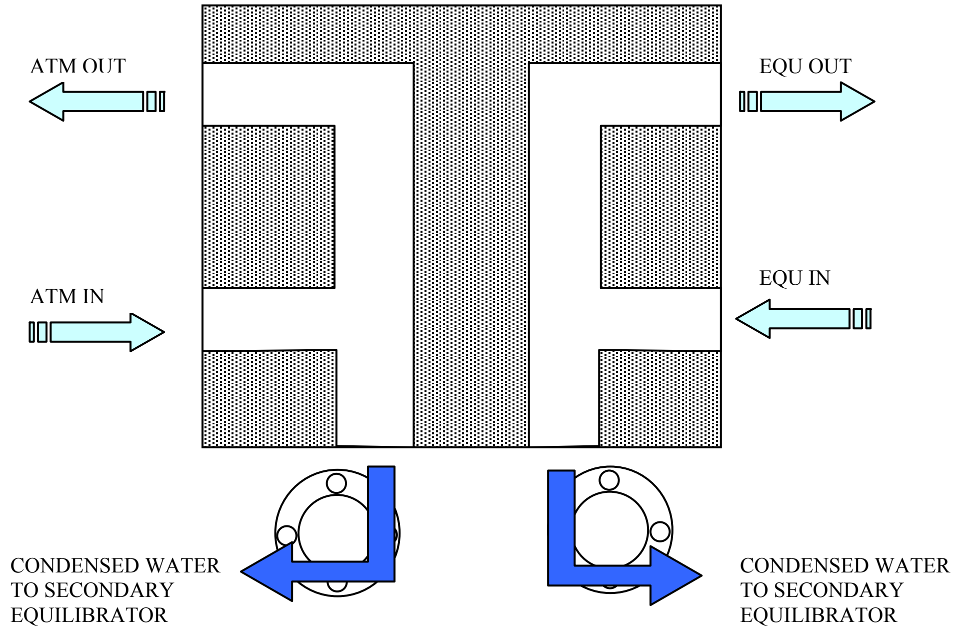
It regulates the downstream pressure of the water going into both equilibrators. To adjust it, pull the knob out. Turning the knob clockwise will increase the pressure, and therefore the flow. Turning it counter-clockwise will decrease it.

2.2.7. Water Flow Meter – G

This device measures the water flow through both equilibrators. Therefore, the appropriate flow value for the system depends on how much is going through the secondary equilibrator. A flow of about 2.6 – 2.7 L/min usually provides a satisfying spray pattern in the main equilibrator without creating too much turbulences and also a sufficient flow in the secondary equilibrator.
The water flow meter is factory calibrated and outputs a 0 to 5 V signal value equal to the flow in L/min. Its calibration coefficients in the "UW pCO_2 cals.dat" file are therefore 0 and 1.

2.2.8. Condenser – H

The condenser is a drilled-through block of anodized aluminum in contact with a Peltier thermoelectric cooling device.



2.2.9. EQU and ATM Moisture Detectors – I

These detectors are located on the outlet of both the EQU and ATM side of the condenser. The program can detect if liquid water reaches these detectors. If liquid water has accumulated there, it can be removed easily by unscrewing the nylon nut holding one of the stainless steel electrodes.

2.2.10. Air and Vacuum Pumps – J

Three gas pumps are used in the system.

- The vacuum pump draws dry ATM air from the ballast through the outer compartment of the Nafion dryers. It creates a pressure and water gradient across the membrane of the dryers which further removes moisture from the analytical gas. It is constantly on when the system is running.
- The ATM pump draws atmospheric air, a portion of which is dried in the condenser and then used as the Nafion dryers' counter-flow and also measured in the LICOR. It is also constantly on in order to flush the atmospheric line and provide for the counter-flow of the Nafion dryers.
- The Headspace pump draws the equilibrator air (the headspace) and circulate it through the LICOR in the Dry box and back to the equilibrator. It is only running when the system is measuring EQU air and is stopped for a few seconds (user defined) while the system reads the LICOR values. Its speed is controlled by the program through the GO Board (see 2.1.9).

2.2.11. Permapure Nafion® Dryers – K

They contain a semi-permeable membrane across which water vapor can diffuse. A pressure and water vapor gradient is created across that membrane by drawing dry ATM air on the outside, which dries the air flowing on the inside. The membrane is fragile and will expand and twist if it enters in contact with liquid water, which will block the air flow through it. They will most likely need to be replaced if water droplets are observed inside. Their useful lifetime has been observed to be in the order of a couple years and they should be replaced accordingly.

2.2.12. Acrodisks Filters – L

These are 1 m water filters designed to prevent liquid water from entering and damaging the Nafion dryers. They should be replaced on a regular basis every year or so.

2.2.13. Peristaltic Pumps – M

They drain the water which accumulates in the condenser. They are programmatically controlled and will turn on for 20 seconds at the start of the analysis and at regular intervals set by the user in the main program. The drain frequency will depend mostly on the moisture content of the atmospheric air in the region of analysis since the amount of ATM air going through the condenser is a lot larger than the amount of EQU air.

2.2.14. Setra Pressure Transducer – N

The Setra is a differential pressure transducer, which means that it measures the pressure difference between the equilibrator air and the surrounding air. In order to calculate the pressure inside the equilibrator, one needs to add the output of the Setra to the pressure value given by the LICOR at the time of measurement since the LICOR measurement is made at ambient pressure by opening the 3-way solenoid to the vent.

2.2.15. Adam Modules – O

There are three modules in the system which are all connected to the same COM port in the Dry box:

- An ADAM 4068 relay module which controls the pumps and valves of the system (except for the Headspace pump controlled by the GO Board)
- An ADAM 4017 A/D module which reads the voltage inputs from the various sensors, including the moisture detectors.

- An ADAM 4521 which is an addressable RS-422/485 to RS-232 converter used to convert the Hart thermometer RS-232 signal into RS-485 and transmit it to the computer.

These modules are pre-configured by General Oceanics, Inc. and cannot simply be replaced by a new one purchased from the manufacturer. To replace, contact General Oceanics, Inc.

2.2.16. Hart Thermometer – P

This device reads the temperature probe located inside the equilibrator. It is factory calibrated and is stable over long periods of time. It has its own power supply and can also run on batteries if the power were to fail. A hole in the front window of the Wet box is provided to allow the user to turn this device on or off without having to remove the window. Press and hold the power button for a couple seconds to turn it on. Press and release quickly the power button to turn if off.

2.3. Deck Box

The Deck box has its own power supply (A) and is weather proof. However, the barometer opens to the outside and its inlet should therefore be protected from the elements. It contains the following elements:

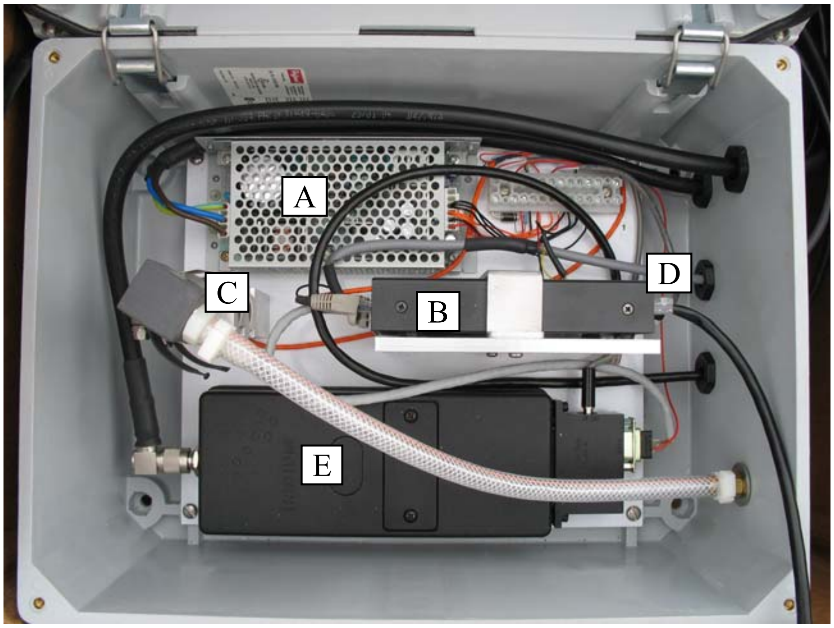


Figure 5. Picture of the Deck Box

2.3.1. Ethernet to Serial Converter – B

This converter is the same as the one in the Dry box (see 2.1.6) and connects to the Ethernet Switch (see 2.1.5). It has four COM ports, three of which are connected to the Iridium modem, the GPS and the Druck barometer. It is pre-configured by General Oceanics, Inc. and cannot simply be replaced by a new one purchased from the manufacturer. To replace, contact General Oceanics, Inc.

2.3.2. Druck Barometer – C

It measures the atmospheric pressure used in the calculation of the pCO_2 after being corrected for the height of the Deck box.

2.3.3. GPS – D

The GPS is used to record the latitude and longitude at the time of measurement.

2.3.4. Iridium Modem – E

The Iridium modem allows the system to transfer data through 2-way satellite communications. It contains a SIM card, which should be provided by the user. For more details on the Iridium communications, see section 3.7.

2.4. Power Requirements

Dry Box: 600 Watts

Deck Box: 65 Watts

The values given above are maximum power consumption values. While running, the system should consume about half of that. No optional equipment is included in the above estimates.

When plugged on a 120V AC power line, a 6 A fast blow fuse should be adequate

Chapter 3. SOFTWARE

The controlling software was developed in Labview by Craig Neill at the University of Bergen in Norway. It consists of a collection of subroutines called *Virtual Instruments* (VI). The software provided is in a compiled application form (*UW pCO2.exe*) that includes all subsidiary VIs. Also included is a configuration editor (*edit configuration.exe*) that relates to the physical configuration of the instrument. It is separate from the main program to avoid inadvertent changes. A separate software handles the satellite communications.

3.1. Overview

3.1.1. Computer Setup

The computer needs to be setup so that it can run with the lid closed, without going to sleep, and so that the only thing needed to start the system is to power up the computer. Brand new computers need to be modified as described below:

Automatic logon:

You can turn on automatic logon without editing the registry in Microsoft Windows XP Home Edition and in Microsoft Windows XP Professional on a computer that is not joined to a domain. To do this, follow these steps:

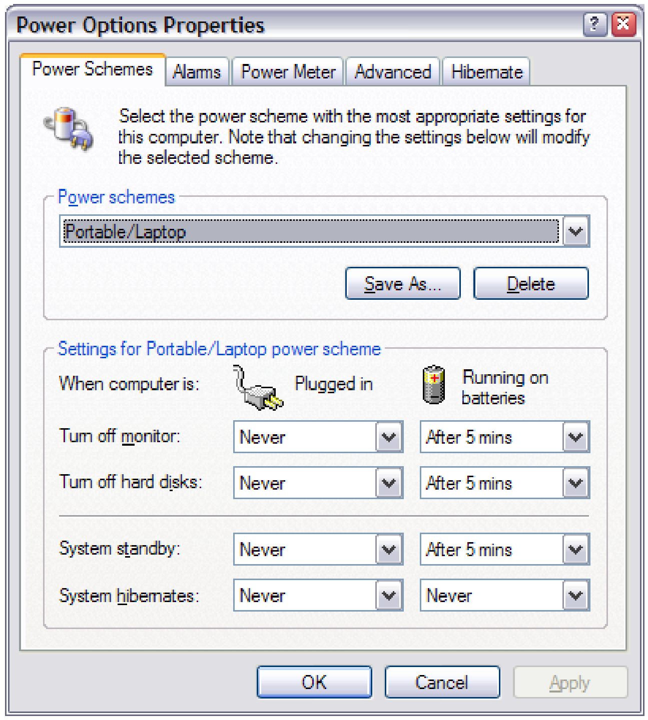
- Click **Start**, and then click **Run**.
- In the **Open** box, type "*control userpasswords2*", and then click **OK**.
- Clear the "Users must enter a user name and password to use this computer" check box, and then click **Apply**.
- In the **Automatically Log On** window, type the password in the **Password** box, and then retype the password in the **Confirm Password** box.
- Click **OK** to close the **Automatically Log On** window, and then click **OK** to close the **User Accounts** window.

For more information, go to http://support.microsoft.com/default.aspx?scid=kb;en-us;315231

Disable Sleep mode:

Click **Start**
→ **Control Panel**
→ **Performance and Maintenance**
→ **Power Options**

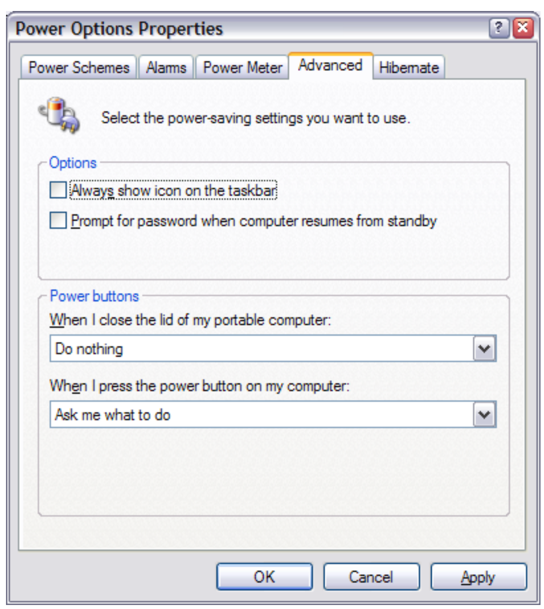
The “Power Schemes” tab should look like this. When plugged in, all the options should be set to “Never”. When running on batteries, set all options to 5 minutes except “System hibernates” which should be set to “Never”.



In the “Advanced” tab:

De-select “Prompt for password when computer resumes from standby”

Select “Do nothing” for “When I close the lid of my portable computer”



When done, click “Apply”.

DIGI COM ports Installation:

From the DIGI manufacturer CD

- Click on "SOFTWARE (install optional software)"
- Select "RealPort Driver" and click "Next"
- Select "Add New Device" and click "Next" (A list of 2 I.P. addresses for already configured devices present in the system should appear)
- Select one of the devices to setup and click "Next"
- Select the "Start COM port". The program will assign the four (4) next available COM ports to the device.
- Repeat with the second device.

The DIGI Ethernet-to-Serial devices and the ADAM modules are pre-configured by General Oceanics. Replacing them with a new device ordered from the manufacturer will not work. Contact General Oceanics for instructions on how to replace these modules.

3.1.2. Program Files

Installation:

Run the .exe files in each of the sub-directories in the "installers" directory. Do the installations by the order of the numbers in the name of each sub-directory. This will install the LabView runtime engine (1) and the NI-VISA runtime engine (2).

Copy the file visaconf.ini in the nivisa-config directory of the CD to the directory c:\vxipnp\winnt\nivisa (replace the file of the same name that is there).

Copy the file zlib.dll in the zlibDLL directory of the CD to the directory c:\windows\system.

Copy the whole directories "UW_pCO2" and "Iridium_Sea" from the CD to c:\.

To make the pCO_2 and/or Iridium program(s) start automatically when the computer boots:

In Windows Explorer, go to C:\Documents and Settings\All Users\Start Menu\Programs\Startup

Right-Click on the right pane of the window and select "New → Shortcut" in the menu.

Click on the “Browse…” button and select the pCO_2 program in its folder.
Click “OK”
Repeat for the “Iridium” program.

This is the list of files and their location on the hard drive of the computer which are necessary to run the system (except the ones copied by the “installers”).

UW pCO_2 Folder
UW pCO2.exe
Edit Configuration.exe
Calibrate Sensors.exe
Settime.dll, lvanlys.dll, uart.dll
UW pCO2 cals.dat
UW pCO2 log.dat

Iridium_Sea Folder
Inbox Folder
Outbox Folder
Config.txt
Underway_Co2_011.exe

C:\VXIPNP\WinNT\NIvisa Folder
visaconf.ini

C:\WINDOWS\system
zlib.dll

For the Iridium program to install on the land-based computer in order to receive the transmitted files

Iridium_Land Folder
Inbox
Outbox
config.txt
Irid_Land_03.exe
zlib.dll
Iridium sorter.exe

3.2. Initialization

The system is pre-configured before shipment. The user can modify the setup of the system as explained in the following section.

3.2.1. *"Edit Configuration.exe"* Program

This program sets up the physical configuration of the system (see Figure 6).

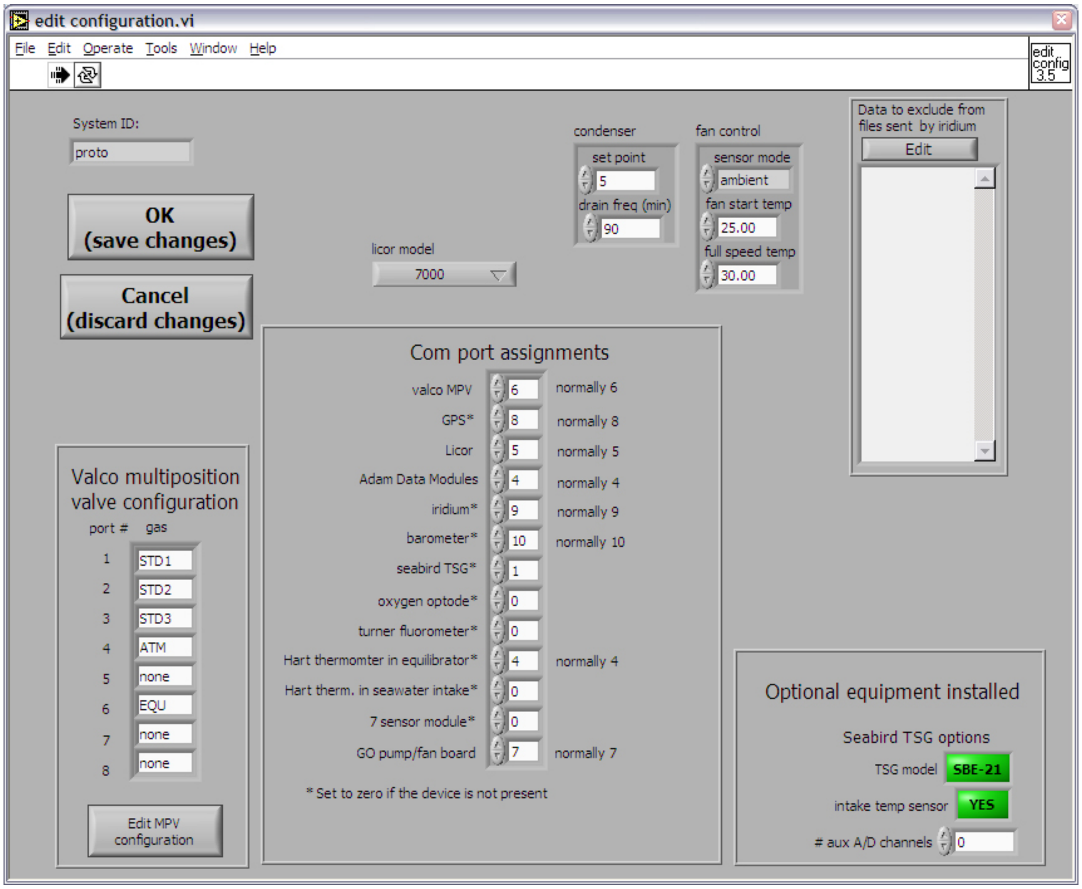


Figure 6. "edit configuration.exe" Panel

- System ID

  This is a short string of characters identifying the system. User defined. This string can only be changed from the "UW pCO$_2$.exe" program in the Setup panel. After changing the ID, stop the program and save the changes when prompted (see 3.3.1).

- LICOR Model.

  Select between 840, 6262 or 7000, depending on the model installed in the system.

- VALCO (MPV) port assignment

  Click on "Edit MPV configuration"

Assign the type of gas (STD 1-7, UNK 1-5, ATM, EQU or none) to each port of the MPV. User defined.

- COM port assignment

  Default values are:
  - VALCO MPV (6)
  - GPS (8)
  - LICOR (5)
  - ADAM data modules (4)
  - Iridium (9)
  - Barometer (Druck in Deck box)(10)
  - Hart in equilibrator (4)
  - GO board (7).

  For optional equipment not present, set value to 0.

- Condenser

  The GO board controls the temperature of the condenser to within ±0.5 ^{o}C, which is a value set in the firmware of the board. The user, however, can select the temperature at which to run the condenser. The default value is 5 ^{o}C.
  The drain frequency refers to the control of the two peristaltic pumps used to drain the water out of the condenser. The value in minutes represents the delay between two drain events. A default value of 60 min should be satisfactory for most applications except where atmospheric air is very humid, like in equatorial regions, where a slightly lower value might be desirable.

- Fan Control

The fan's purpose is to limit the temperature fluctuations around the LICOR analyzer by venting the inside of the dry box with outside air. Its speed is proportionally increased from the *Start Temperature* to the *Full Speed Temperature*. The temperature around the LICOR can be measured by one of two temperature sensors: the *internal* sensor, located in the middle of the dry box and the *ambient* sensor located at the bottom vent hole of the box's front panel.
Typical Start and Full Speed temperatures are 25 ^{o}C and 35 ^{o}C, respectively.

- Satellite Data Exclusion

Due to the high cost of satellite communications, the user has the possibility to exclude data from being sent. Clicking the "Edit" button will give access to a panel where the user can select from a list the data columns to exclude from the files that are transferred by Iridium. Using this feature in combination with the fault conditions allows one to significantly reduce the size (and cost) if iridium files without losing real time information. For example, you can set a fault condition (with no action) (see 3.3.2 Sleep/Wake) for deck box temperature greater than 55 and then remove those data from the iridium files – you will still be alerted if the temperature is too high but you don't need to pay for transferring every reading by satellite. There are many diagnostic sensor data that could be removed from iridium files in this way. No data will ever be removed from the files stored locally on the instrument's computer.

- Optional Equipment

The system can interface with the following optional equipment:

- Optode O2 sensor
- TurnerFluorometer
- Extra Hart temperature probe
- 7-parameter sensor module from General Oceanics (model I8050-7)
- Seabird TSG, model 21 or 45

If the optional equipment is present in the system, simply assign the COM port number through which it is interfaced in the "Edit Configuration.exe" program.
Assigning a COM port to the "seabird TSG" device will make three new controls appear at the bottom right corner of the panel (see Figure 7).

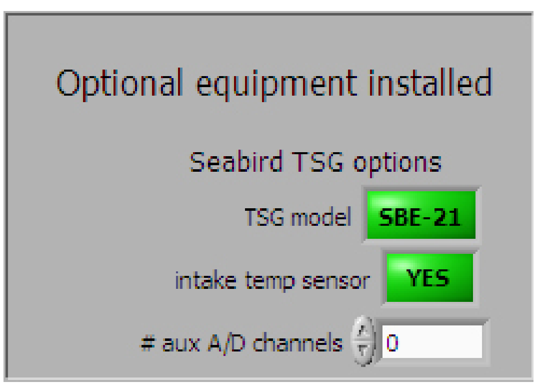


Figure 7. Optional Equipment Options

Clicking on the "TSG model" control toggles between the two SBE-21 and SBE-45 models from Sea-Bird Electronics, Inc.

Clicking on the "intake temp sensor" toggles between "Yes" and "No". This control refers to a temperature sensor that can interface with the Sea-Bird TSG models via an optional interface box (model PN 90402 from Sea-Bird Electronics, Inc.).

The "# aux A/D channels" control only appears if SBE-21 is selected with "TSG model" control and refers to the number of A/D channels available through the optional interface box mentioned previously.

3.2.2. Configuration File – UW pCO2 log.dat

This file contains all the settings that specify how the system runs. This file is accessed upon initialization and is rewritten upon completion of initialization. The main program or the log editor program can be used to create a log file. ". If a "*UW pCO2* log.dat" file does not exist or is not found, an error message will appear (error7, file not found). Acknowledge the error message by pressing "continue" and click "*View Setup Screen*" on the next popup panel that appears. The "*UW* pCO_2 *init.vi"* panel will appear on which the system configuration can be changed. A new configuration file will be generated when the user clicks the "*Start Running*" button.

Below is an example of a configuration file:

```
system ID            proto
GO board port        7
data module com port        4
iridium port         9
run timing           5,5,5,20,20,20,5
GPS com port         8
MPV      6,STD1,STD2,STD3,ATM,none,EQU,none,none
run sequence         STD1-1,STD2-1,STD3-1,ATM-3,EQU-5,filter-1,loop0-1
data path 1          C:\data
data path 2          C:\data2
graph buffer size    200
druck com port       10
standards            281.20,522.30,358.90,415.93
licor       1,5
O2 port  0
fluoro port          0
SBE-21  0,N,N,N
condenser            5.0,90
in box path          C:\iridium\inbox
out box path         C:\iridium\outbox
iridium send time    0.00
equ pump control     100,100,70
fan control          ambient,25.0,30.0
not sent
licor zero/span      1,4
7 sensor 0
equ hart  4
intake hart          0
fault condition      ATM cond. H2O,<,2.00,none,0.00
fault condition      EQU cond. H2O,<,2.00,none,0.00
```

Figure 8. Example of a configuration file

NOTE: If a new log file is moved into the INBOX subdirectory, the program will recognize the appearance of the new log file. The main program will shut down, accept the conditions within the new log file, and reboot the computer. If the compiled program (UW pCO2.exe) is in the computer's start menu, the main program will start running with the settings from the new log file. This allows the user to change the configuration of the system via satellite.

3.2.3. Calibration File – *UW pCO2 cal.dat*

It contains the calibration coefficients for the system sensors in the following order:

- Equilibrator temperature sensor (Hart Thermometer)
- Water flow sensor
- Equilibrator Pressure Transducer
- LICOR gas flow sensor
- Secondary equilibrator gas flow sensor.

The calibration equations are polynomials.

$$Y = a_0 + a_1 X + a_2 X^2 + a_3 X^3 + \ldots$$

The coefficients are listed in increasing powers of X from left to right.

$a_0, a_1, a_2, a_3 \ldots$

The user must provide this file. It can be updated using the "*Calibrate Sensors.exe*".(see 3.2.4 "*Calibrate Sensors.exe*" Program)

Below is an example of such a file:

```
0,1,,
0,1,,
0,7.4738,,
-39.3496,48.39016,-11.7368,2.306373
-31.628677,27.637729,-2.421940,0.754821
```

Figure 9. Example of a calibration file

3.2.4. "*Calibrate Sensors.exe*" Program

This utility allows to calibratre the following five sensors in the system:

- Equilibrator Temperature Probe (Hart Thermometer)
- Water Flow Sensor
- Equilibrator Pressure Transducer (Setra)
- LICOR Flow Meter
- Secondary Equilibrator Vent Flow Meter

When starting the program, the main window appears.

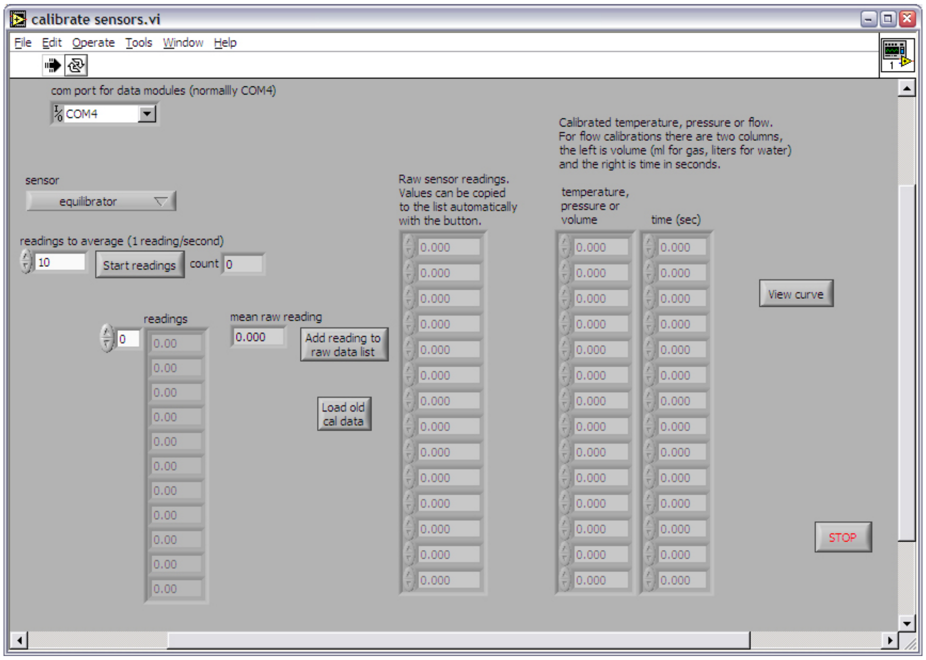


Figure 10. "Calibrate Sensors.exe" main window

Main Window.(Figure 10)

- COM port: If the COM port is wrong, Select the correct one, stop the program and restart it by clicking on the outlined white arrow (shown black here) at the top left corner of the panel.
- Sensor: Select the sensor to calibrate
- Adjust physical parameter (temperature, pressure of flow)
- Select the number of readings t average and click “Start Readings”
- If the mean raw reading is satisfactory, click on “Add reading to raw data list” button
- Enter the value of the physical parameter being measured (temperature, pressure). For flow calibrations, enter volume of air passed in ml)
- For flow calibrations, enter the time it took for the volume of air to pass.
- Repeat steps 3-7 for several different values of the physical parameter.
- Click on “*View Curve*”.
- Select the “*UW pCO_2 cals.dat*” file to update.

Fitting Window.(Figure 11)

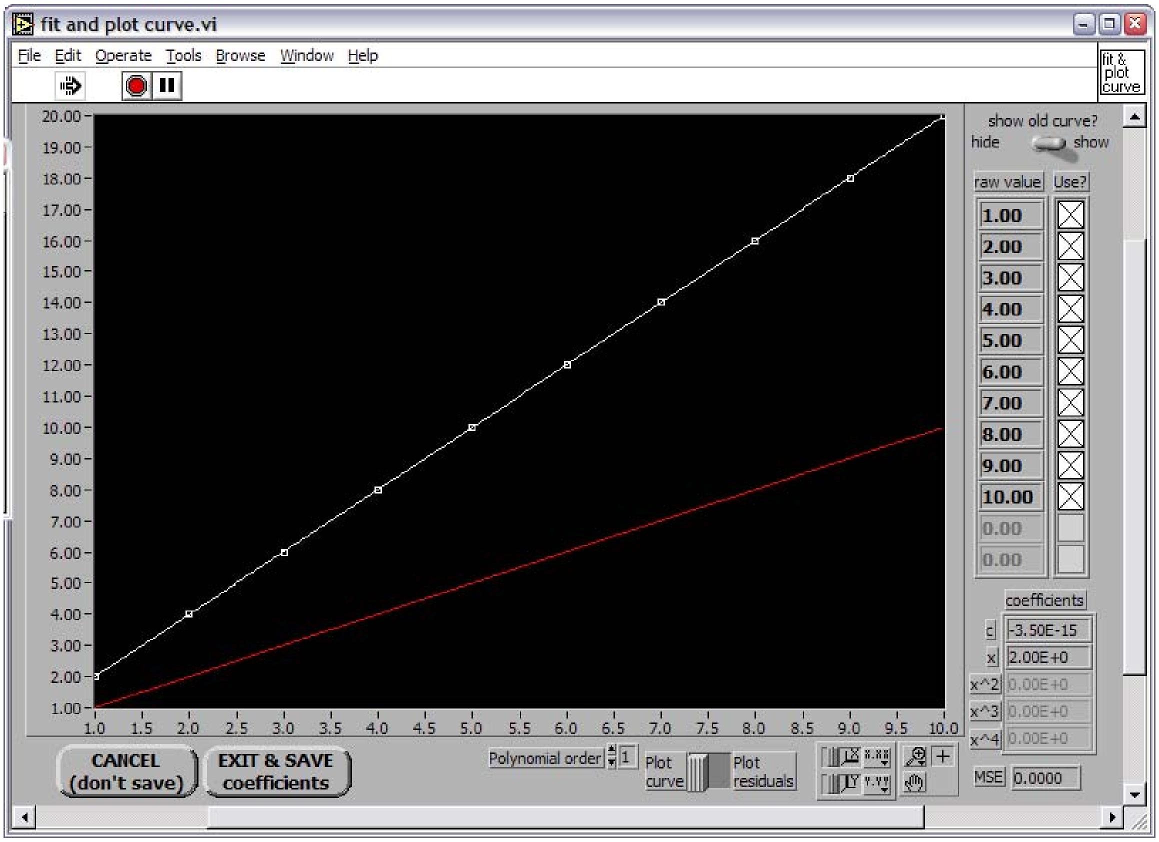


Figure 11. "Calibrate Sensors.exe" fitting window

The data is plotted on the graph at the center of the window.

- Select the points to use for the fit on the right side of the panel
- Select the polynomial order of the fitting curve at the bottom center of the panel. The coefficients and mse will be displayed at the bottom right corner
- The user can display the previous curve saved in the “UW pCO2 cals.dat” file using the toggle switch at the top right corner of the panel
- When satisfied with the fit, click on “Exit & Save coefficients” button.
- Select “Replace” when prompted to replace the old “UW pCO2 cals.dat” file.
- The program will generate a calibration file specific to that sensor. Its file name will be of the form: ‘sensor’ cal ‘date’.txt where ‘sensor’ is the name of the sensor calibrated (“equilibrator temperature”, “water flow”, “licor gas flow”…etc…), and ‘date’ is the date of the calibration. If the file already exists at that location, the user will be prompted to replace it.

3.3. Setup

The first window to appear when the main program *UW pCO_2.exe* is started is the *Autostart* popup showing a 15 seconds countdown before the analysis begins. To access the setup panel, click on the "*View Setup Screen"* button before the end of the countdown. The next window (*UW pCO_2 Init.vi*) will display the settings that were used last time the system ran.

The program will then load the calibration and configuration files and initialize the system. Green LED controls will light up as it goes successfully through the different steps. When all LEDs are green, the system is ready to be setup.
The details of the events that occur as these LED are turned on are described below:

"*log file loaded*" LED

- System ID displayed
- GO Board port - COM port is opened, communication is established until "ready" is received from the board.
- ADAM modules COM port
- Iridium port opened
- "run timing" values displayed
- GPS COM port is opened
- MPV COM port is opened
- Run sequence read and displayed
- Data path 1 displayed
- Data path 2 displayed
- Graph buffer size displayed
- Druck COM port is opened
- Standards values displayed
- LICOR COM port is opened and initialized.
  Configurations sent:
  - 7000: Polled sampling, checksum off, no timestamp, data to output is defined, pump speed slow, slow pump speed = 75, filtering = 1 second, CO_2 Ref conc. = 0, H_2O Ref conc. = 0
  - 6262: All water corrections = on, polled sampling, data to output is defined, Average time = 1 second, CO_2 Ref conc. = 0
  - 840: Polled sampling, heater on, pressure compensation on, filter = 1 second, alarms disabled, RS232 strip = true, echo = false, data to output is defined
- O_2 probe COM port is opened
- Fluorometer COM port is opened
- SBE-21 COM port is opened, calibration data loaded from file (SBE-21 only)
- Condenser settings displayed
- Inbox path
- Outbox path

- Iridium send time
- EQU pump control
- Fan control settings are sent to GO Board
- Excluded Iridium data displayed
- LICOR zero/span - one set of LICOR data are read to get the header out of the way
- 7-sensor module- COM port is opened unless it is sharing a port with the data modules
- Equilibrator Hart thermometer
- intake Hart thermometer - COM port is opened unless it is sharing a port with the data modules.
- Fault conditions displayed
- GPS sleep conditions displayed

"*Config loaded*" LED

- EQU pump speed setting is sent to the GO board.

- Condenser temperature setpoint is sent to the GO board.

- Calibration coefficients are loaded from the file "uw pco2 cals.dat".

"*Relays init done*" LED

- COM port for data modules is opened and command is sent to relay module to reset all lines.

"*MPV Home*" LED

- VALCO valve is set to position 2 (first stop positon).

"*licor vent*" LED

- Latching solenoid on LICOR outflow is set to the vent position.

"*ready*" LED

- Another set of readings is taken from the LICOR (to make sure the header has been read).

- Program starts if the autostart timer runs out or enters loop where it is waiting for commands on the initialization screen if "View Setup" is pressed (see 3.3.1)

The initialization screen has five tabs that select different pages for specifying operating configuration and conditions and which are described below:

3.3.1. Run Setup

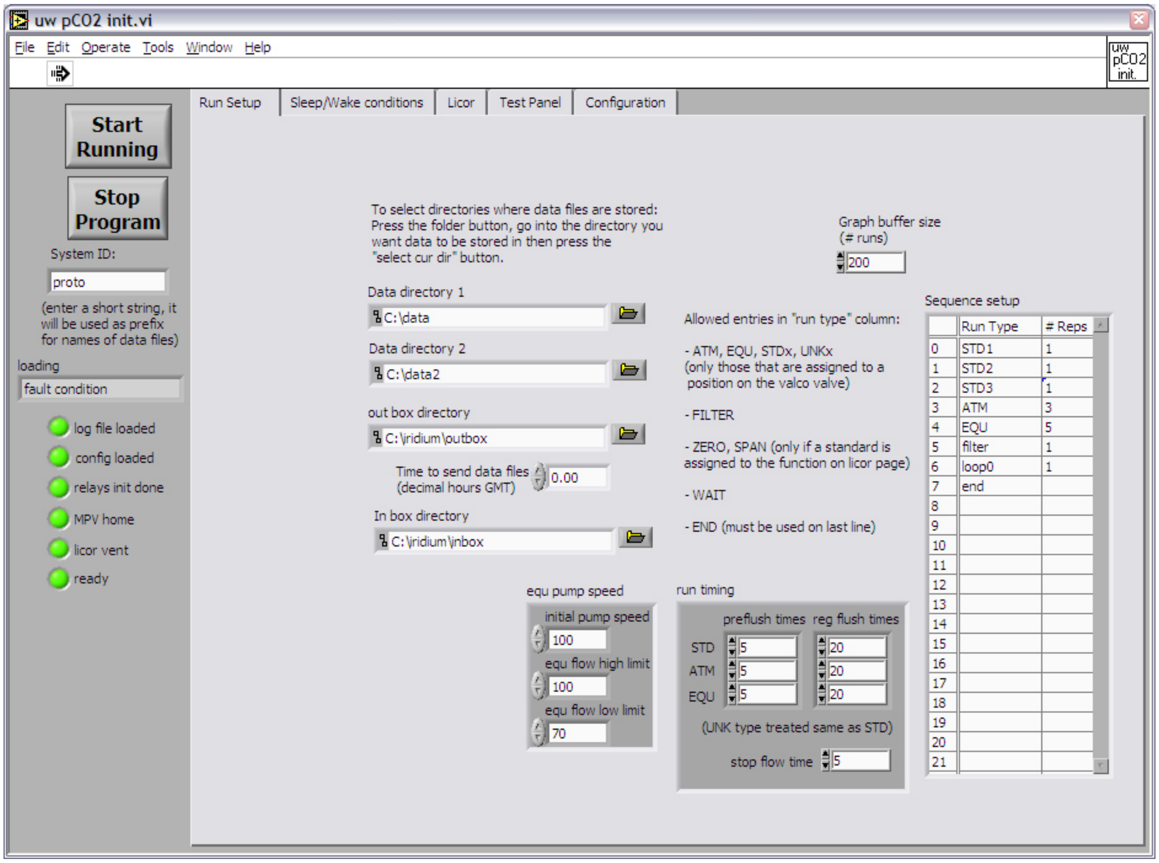


Figure 12."Run Setup" Tab

System ID

This is a short string of characters identifying the system. It is user defined. To change this string, type in the name desired. After changing the ID, stop the program and save the changes when prompted. This string is used to identify the provenance of the data files when transmitted via satellite (see 3.7)

Data Directories

The controls for data directories 1 and 2 contain the names of the two directories were data files will be stored.   The defaults are c.\data and d: (the d drive is the compact flash card).

The Iridium inbox and outbox are normally c:\iridium\inbox and c:\iridium\outbox. .

The numerical control "time to send data files" tells the program at what time of day to copy the previous day's compressed data file to the iridium outbox (see 3.5 and 3.7 for more information).

NOTE: This setting does not affect when a new data file is started (new files are always started at midnight), it only delays the sending of the files. The purpose is to allow users with multiple systems to use one land line to receive data from all systems (and avoid all of them calling at once).

The data files in data directories 1 and 2 are updated with every analysis. At the time selected by the user, the last finished data file is compressed and copied to the Iridium outbox directory from which it is immediately sent via satellite.

Graph Buffer Size

The graph buffer size determines how many (most recent) runs are available for plotting on the graph. In a lab setting, a value of 5000 run graph buffer should not create any problems. For VOS use, where there won't be anyone around to look at the graph, a smaller number (~ 200) will save memory and CPU time.

Sequence Setup

The sequence setup table determines the sequence of runs. Only the following entries in the "run type" column are valid:

ATM – atmospheric air

EQU – equilibrator air

STDx – where x is 1…n and n is the number of standards defined in the multi-position valve (MPV) setup table.

ZERO, SPAN – can only be used if they are assigned to a standard with the controls on the LICOR page (see below). The command will run the assigned standard and send the zero or span command to the LICOR. The run type that is stored in the data file will have a "z" or "s" appended to it. For example, if STD4 is defined as the span gas: entering STD4 in the sequence setup table will run standard 4 without setting the span on the LICOR and "STD4" will be the run type in the data file. Entering "SPAN" in the sequence setup table will run standard 4 and set the span of the LICOR; "STD4s" will be the run type in the data file.

UNKx – unknown gases, must be defined in MPV setup table.

LOOPx – where x is the line number of a previous line in the sequence setup table. The sequence will loop back to the specified line number (remember that the number of iterations of the loop will be (# *reps* +1), because it runs once before encountering the LOOP command. Loops may be nested.

WAIT – will turn the headspace pump off for one minute for each number of *reps* selected. Vacuum, ATM and seawater pumps will stay on.

FILTER - will backflush the water filter for 45 seconds (do this just before standardization to give the equilibrator time to recover).

END - The last line in the left column must be the word "end".

Run Timing

The run timing controls tell the program how long to flush the LICOR cell in between each measurement.
The "*preflush times*" are used only between DIFFERENT gases (i.e. when the Valco MPV has just moved from one gas to another).
The "*Reg flush times"* are used between replicates of the SAME gas.

The first measurement of each type of gas will then occur after (*preflush + reg flush*) seconds. Each subsequent measurement will occur only after (*reg flush*) seconds.
The default settings are 180 seconds of preflush and 60 seconds of regular flush. In this case, the LICOR will be flushed for 4 minutes before the first measurement is made and for 1 minute for the other replicates.

Stop Flow Time

The stop flow time is the delay in seconds after the flow is stopped before the LICOR is read. For the EQU gas, the flow is stopped by stopping the headspace pump. For all other gases, the MPV is stepped up one position (which is between two ports since there are 16 positions for only 8 ports) Ten seconds seems to be ideal. It allows the pressure in the lines to stabilize without allowing back diffusion of contaminated air in the sample cell of the LICOR.

Equ pump speed

The initial pump speed is a value between 0 and 255 which controls the speed at which the pump will be run when the analysis starts. This value is modified by the “Set Pump Speed” button located on the “Set Flow” window (see Figure 17).

The equilibrator flow high and low limits are used by the program to adjust the headspace pump speed by increments of 1, should the equilibrator air flow fall outside of those limits.

3.3.2. Sleep/Wake

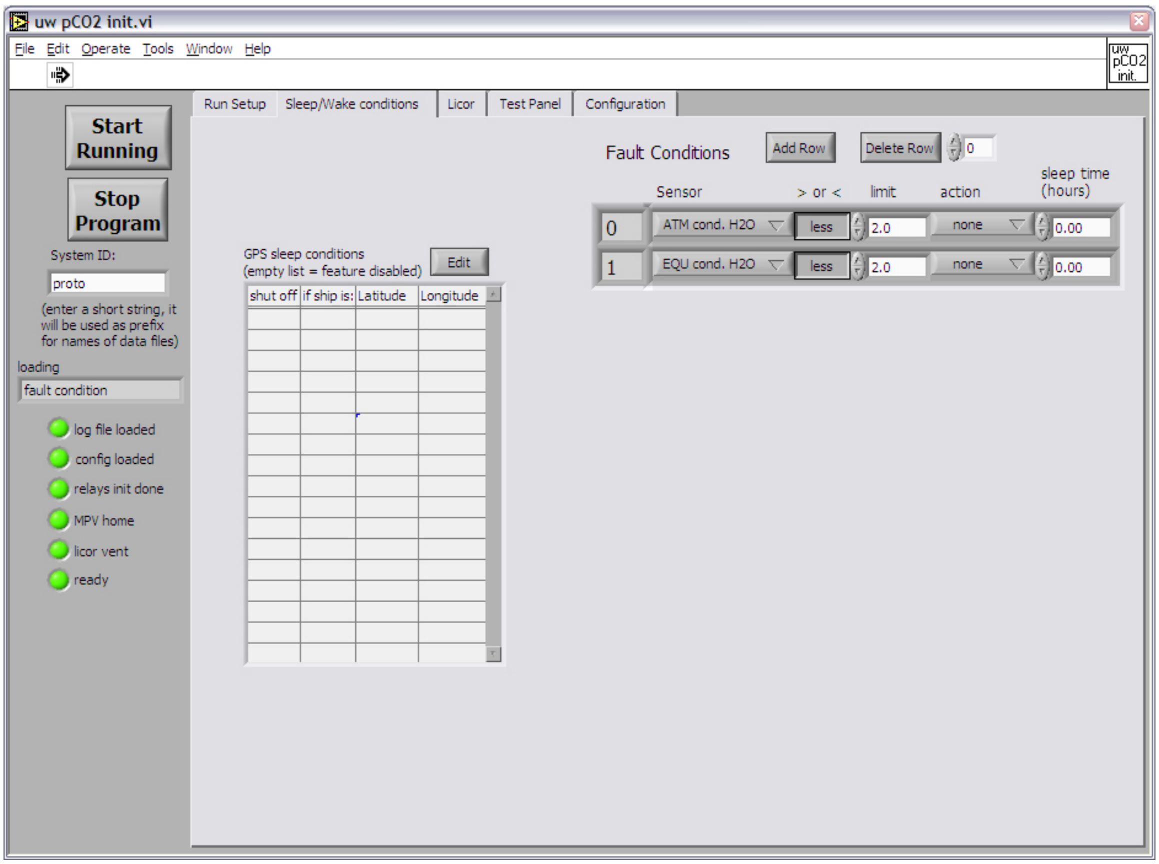


Figure 13."Sleep/Wake Conditions" Tab

GPS Sleep Conditions

Here you can designate positions where you want the system to go to sleep and wake up. “Sleep” means that it will turn off all the pumps and the condenser, stop taking measurements and stay in that mode until the ship leaves the zone defined in the table.

Press the “edit” button to add or remove GPS sleep conditions. A window will appear (Figure 14) that allows you to add or remove conditions.

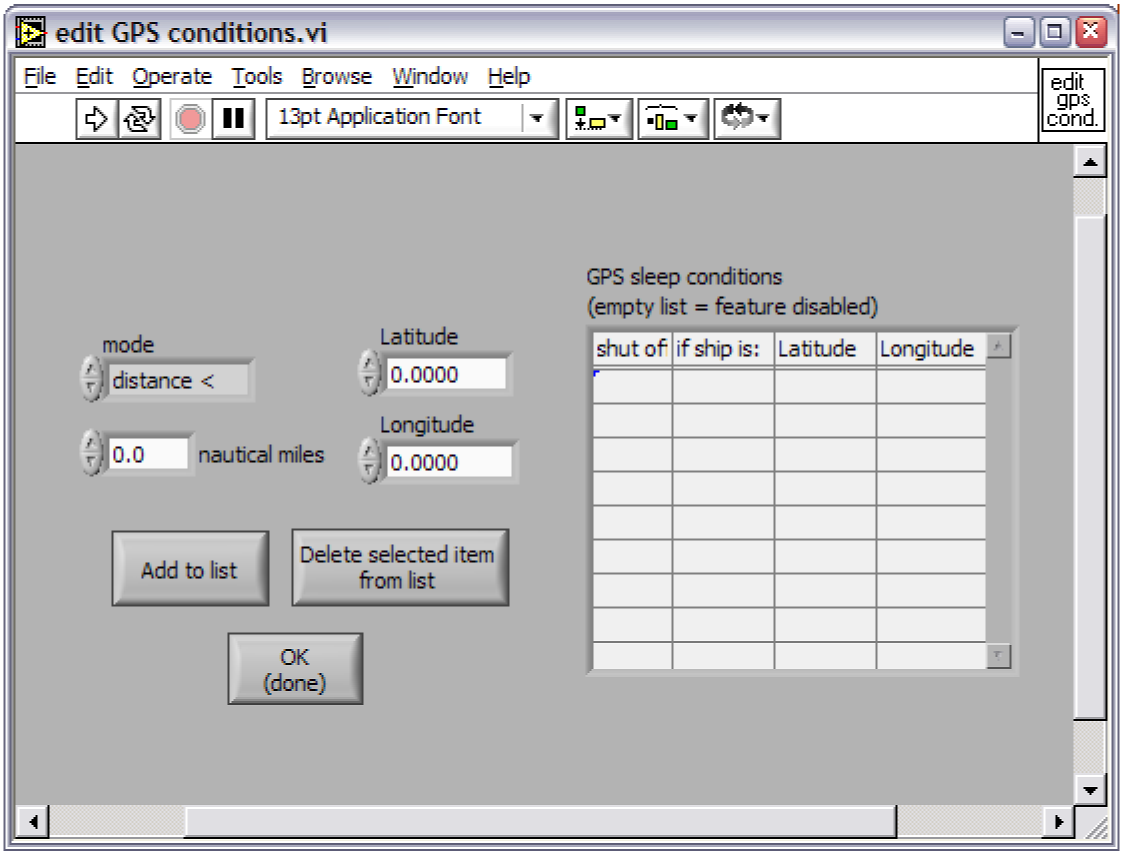


Figure 14. Edit GPS Sleep Conditions

To remove a condition from the list, click and drag the mouse on the line you want to remove so that one or more of the cells on that line (and only that line) are outlined in blue – then press the delete button.
When adding conditions there are two basic modes

- "distance <" means that the system will go to sleep if the ship's position is less that the specified distance from the coordinates.
- "SE of", "SW of", "NE of" and "NW of"… let you define quadrants of the world map as "sleep zones".

Fault Conditions

Also on this page (Figure 13) is the list of "fault conditions". Fault conditions are user defined limits in the values of readings from system sensors and actions that should be taken if the limits are exceeded. For example, shut down if the reading from the water sensor at the top of the EQU or ATM condenser tube indicates that there is water there.

NOTES:

- Specifying "no action" for a fault condition will generate a warning message in the daily fault/error file with no further action.
- The "sleep time" is only applicable if the action is "go to sleep".
- Entering a sleep time of zero or less will cause the system to go to sleep only until the condition that caused it remains true. If the sleep time is greater than zero the

system will go to sleep for that many hours and then wake up (if the sleep condition is still true, it will go back to sleep after one run).

3.3.3. LICOR

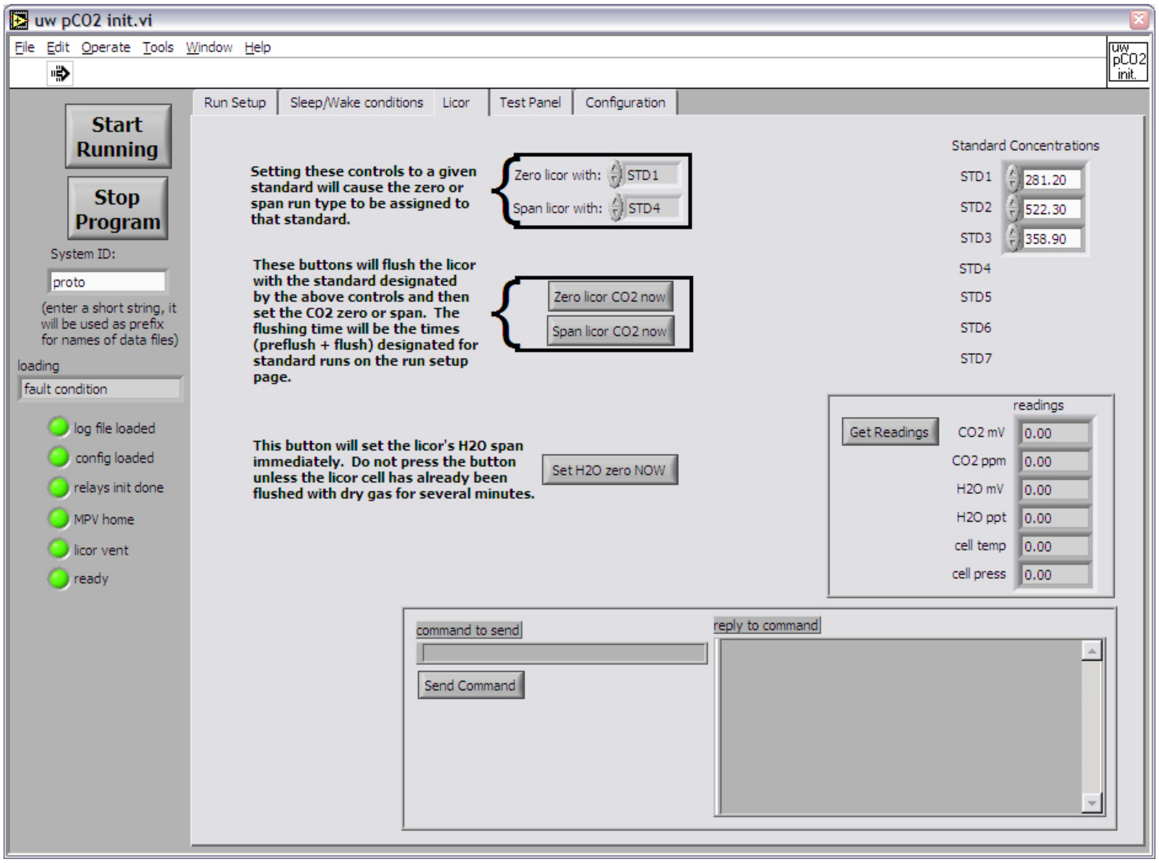


Figure 15. "LICOR" Tab

Standard Concentrations:

Here is a space to enter the concentration for each gas standard that is connected to the multi-position valve. Only those standard numbers that are listed in the multi-position valve setup control (on the Configuration page) are shown. If one of the standards is designated as a span gas and the SPAN run type is used, then the concentration entered here is sent to the LICOR with the span command.

Zero & Span Port Assignments Option:

The controls labeled “Zero Licor with:” and “Span Licor with:” are used to assign standards to the ZERO and SPAN run types and also to the “zero Licor now” and “span Licor now” buttons. If a standard is selected for the zero gas, the concentration entered for that standard must be zero. If a standard is designated as the span gas, it should always be the highest standard that is used for calibration.

Zero & Span Now Buttons Option:

The Licor is flushed with zero or span gas for the time designated in the “Run Setup” page (preflush time + reg flush time) and the zero or span command is sent to the Licor. To set the zero or span manually with the potentiometers on the Licor you could use the “set flow” utility on the test panel page to flush it with the appropriate gas.
- The “set H2O zero NOW” button does not perform any flushing before setting the H2O zero – the Licor should be flushed for several minutes with dry gas before pressing this button.

Note that zero and span settings done through software are lost if the Licor is powered down.

Licor testing Tools:

The get readings button will do just that – get one set of readings from the Licor and display the values.
The controls at the bottom of the page can be used to send any command to the Licor and view the response from the instrument (see Licor manual for commands and syntax).

3.3.4. Test

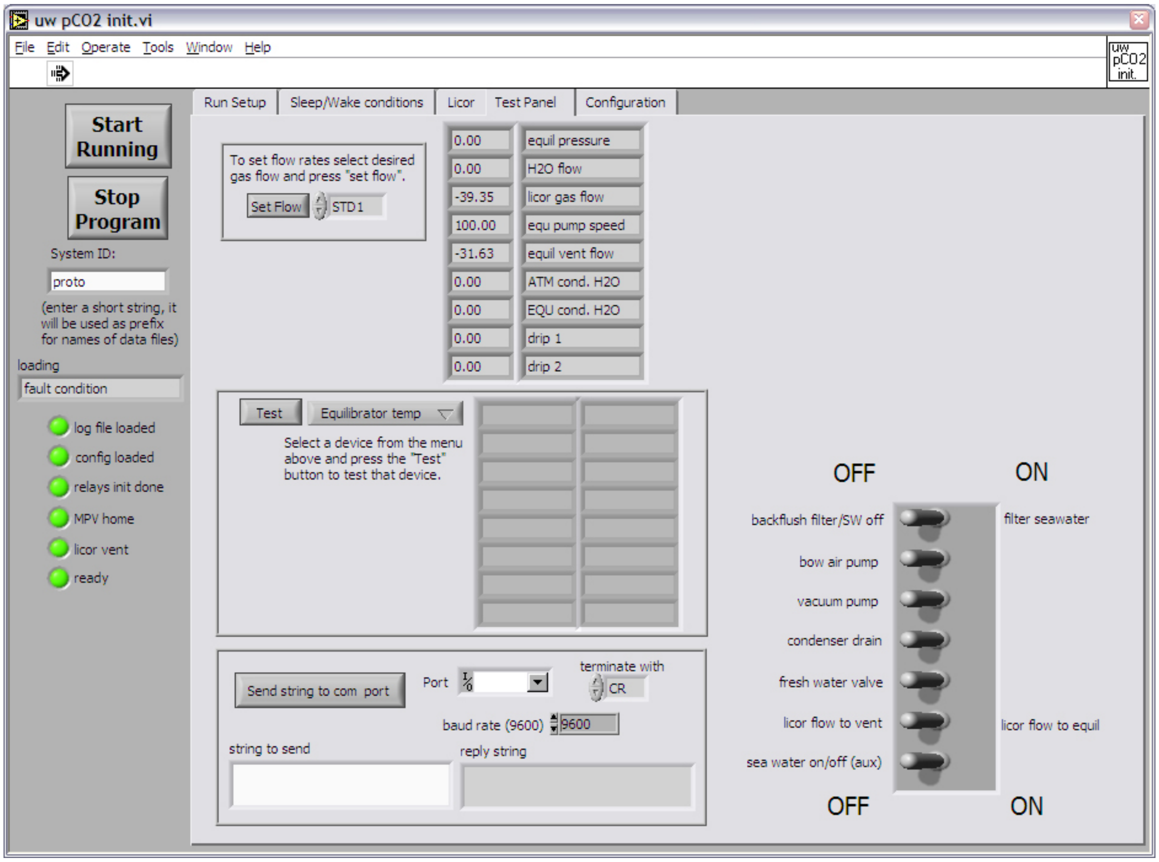


Figure 16. "Test" Tab

Toggle Switches Array

The array of toggle switches controls the various pumps and valves. If you switch more than one toggle switch in a two second interval the second change may not be registered by the program

"Backflush filter/SW" controls the EVSCO 3-Way valve and will turn on the flow of seawater.

"Bow air pump" and "Vacuum pump" control the corresponding pumps

"Condenser Drain" activates the peristaltic pumps below the condenser

"Fresh Water Valve" controls the 3-Way solenoid potentially connected to the fresh water line which can be used to backflush the filter.

"LICOR flow to vent" controls the 3-Way solenoid in the dry box which directs the outlet of the LICOR to either the outside air (vent) or the equilibrator.

"sea water on\off (aux)" controls a spare relay which can be connected to an external water valve (optional) in order to shut down the seawater input to the system in case of emergency.

Sensor Indicators Array

These indicators show the current readings from a variety of sensors and are updated about every two seconds.

Device Test

This section contains controls for testing other sensors and optional equipment (GPS, deck barometer, equilibrator temperature, O_2 optode, TSG and fluorometer). Select the sensor from the menu and press the "Test" button.

Serial Communications Utility

At the bottom of the page is a utility for sending and receiving commands from serial devices. This can be used for things like setting the number of positions in the Valco valve actuator or configuring the data acquisition modules.

Set Flow

This utility allows the user to set the flow of the analytical gases of the system. Simply select the gas type to adjust from the menu and press the "set flow" button.
The program will set the valves and pumps as needed to measure the flow and display a window (Figure 17) that shows a strip chart of CO_2 or H_2O readings from the LICOR (you can select mV or ppm).
The gas flow will be displayed in the control next to the "Stop" button. Pressing the "Stop" button will bring the user back to the "Test" panel. A reading is added to the chart every 1.5 seconds and the current value is displayed in the indicator top center. The Y scale of the plot can be set to a specified span, centered on the current reading, with the "set Y scale" and "Y scale span" controls.
The "Set Pump Speed" button and the box associated with it allow the user to control the headspace pump speed. This control accepts values between 0 and 255, where 0 represents the minimum speed (~7% duty cycle, which means that the pump is not stopped at 0) and 255 is the maximum (100% duty cycle). Setting the pump speed by clicking the button will also set the value for the "Initial Pump Speed" on the "Run Setup" tab (see 3.3.1 Run Setup).

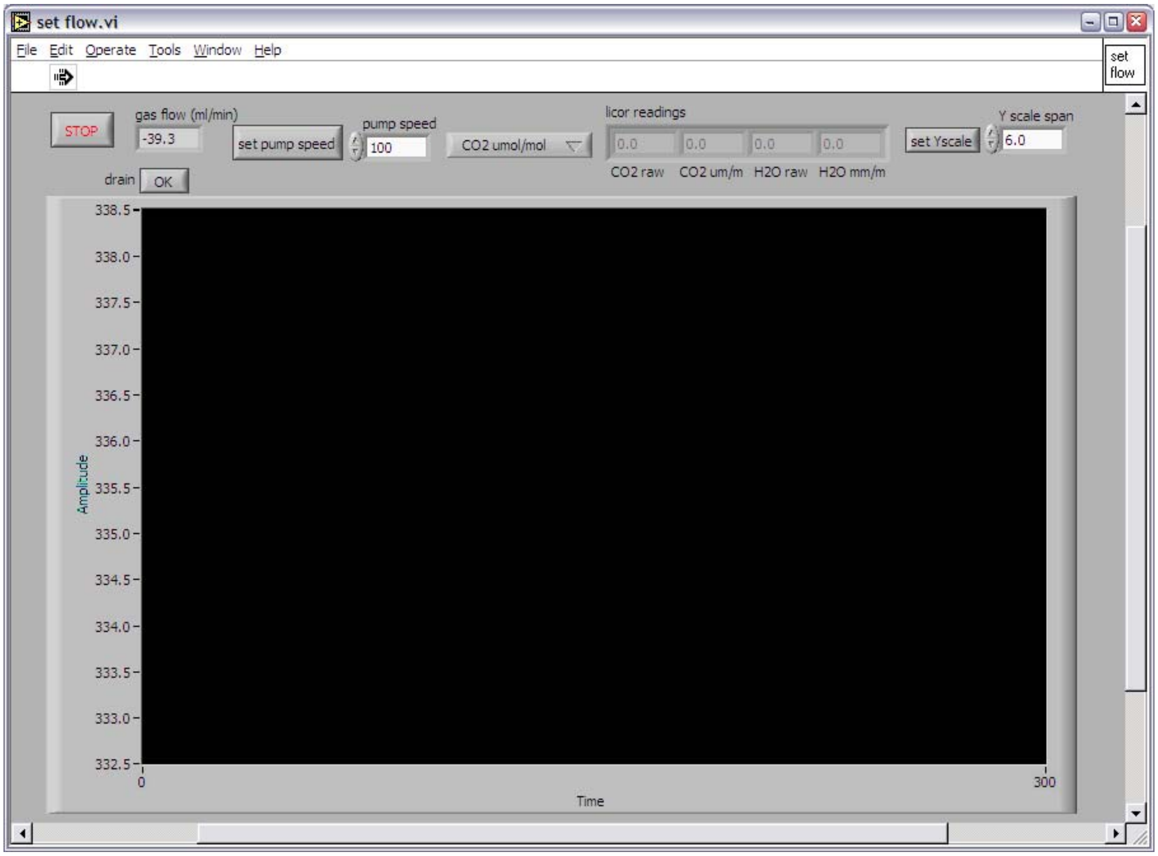


Figure 17."Set Flow" window

This utility is very useful, not only in setting the gas flows, but also in monitoring the LICOR response to various events such as:

- Gas switching to determine how long the system takes to flush the LICOR sample cell
- Leaks. An unstable signal is generally a good sign for it.

3.3.5. Configuration

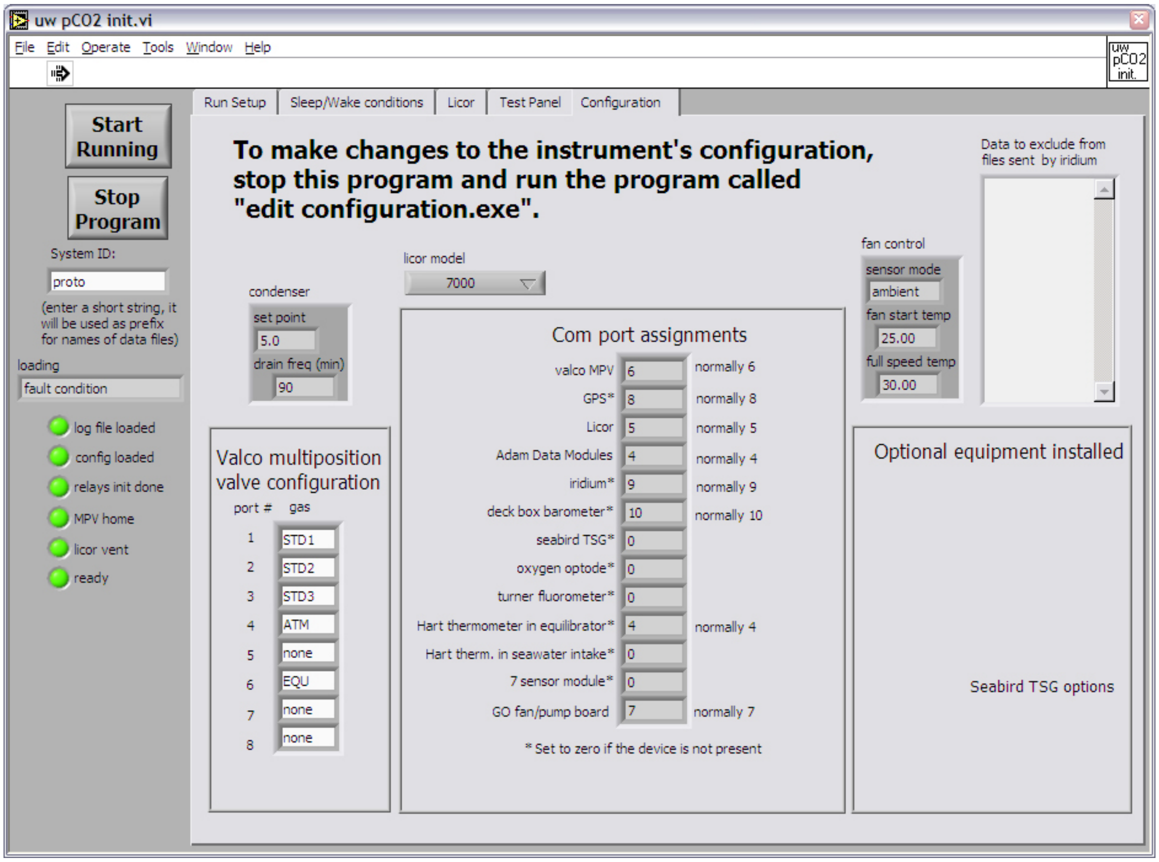


Figure 18. "Configuration" Tab

This tab is only for information purposes and cannot be changed with this software in order to avoid involuntary changes. Parameters shown here relate to the permanent physical configuration of the instrument and should seldom need changing. A separate program (“*Edit Configuration.exe*”) is used instead (see 3.2.1 for an explanation of these parameters).

3.4. Main Program

3.4.1. Events Description

Here is a list of events that occur after the “Start Running” button is pressed (or the autostart timer runs out):

- “Run Setup” table is checked for problems. If any are found, the program stays in loop.
- EQU pump speed setting sent to GO Board again (in case it was changed by user)
- Condenser set point sent to GO Board again
- All relays are reset

- ATM pump turned on
- 3-way solenoid set to vent position

- Condenser is drained for 20 s
- Vacuum pump is turned on
- PC clock is set to GPS time if a good fix is available
- EVSCO valve is set to the “seawater on” position; seawater starts flowing through the equilibrator
- Spare seawater on/off relay is turned on
- VALCO valve positioned for the first gas type to be measured
- Measure Sequence is started:
  - Sample Gas is circulated for *preflush,* then *regular flush* time
  - Gas flow meter, EQU Pressure are read
  - Flow is stopped for “*Stop flow´* time, either by stepping the VALCO by one position for standard and ATM gases or by stopping the Headspace pump for the EQU gas
  - LICOR and auxiliary parameters (temperature, pressure, position…) are read and recorded
  - Flow is resumed for next sample measurement

System Response to Outside Events:

- While system is flushed with sample gas, the sensors are monitored and read every 10 seconds.
- “Stop” button pressed: after confirmation from the user, the system will finish the current measurement, then put the system to sleep and terminate the program.
- Water detected: if any of the drip sensors’ readings drop below the set value, the system will immediately display an error message on the screen, record the error in the error file as well as the data file and perform the action specified in the setup (see the Fault Conditions in section 3.3.2).

3.4.2. Data Display

The data can be displayed either in a graph or in a table. The two forms are accessible by clicking on the appropriate tab (Plot or Table) in the top left area of the screen.

Below (Figure 19) is a screen shot of the “Plot” tab. The right side of the screen displays the readings from the different sensors of the system. These readings are updated every 10 seconds.

Every measurement is plotted on the graph as soon as it is made. Two parameters can be displayed at the same time, the default ones being “CO_2 um/m” and “equil temp”.

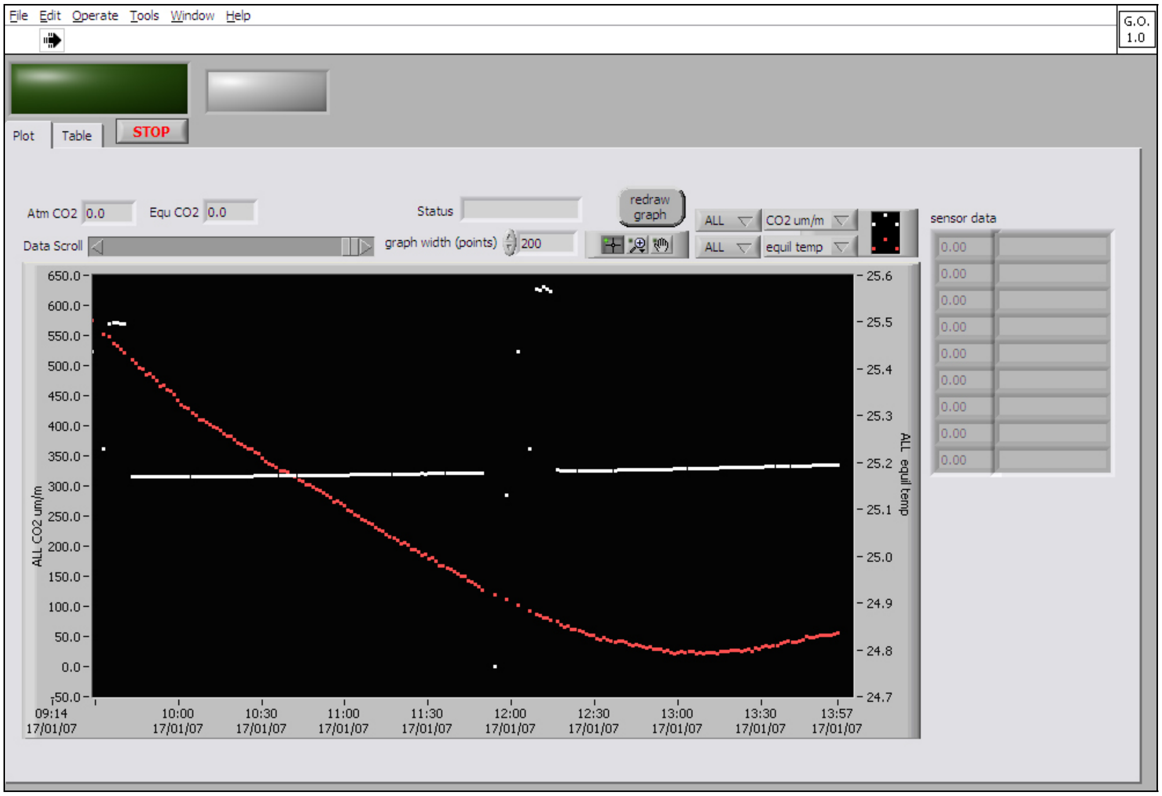


Figure 19. Graph Data Display - Main Program

Graph Options:

- Parameter to plot.

  equil temp, xCO_2 fit, CO_2 raw, CO_2 um/m, H_2O raw, H_2O mm/m, cell temp, cell press

- Sample Type.

  ALL, any STDx, ATM, EQU or any UNKx

- Plot Attributes 

  By clicking on the button shown above, the user can changes plot attributes such as point color, line width…etc…

- Graph Width

  The user can select how many points to show on the graph (default = 200). Points off the graph can be displayed by moving the slide control "data scroll"

Also displayed are the last ATM CO_2 and EQU CO_2 values recorded, along with the current status (what it is measuring) of the system.

Figure 20 shows the Table display

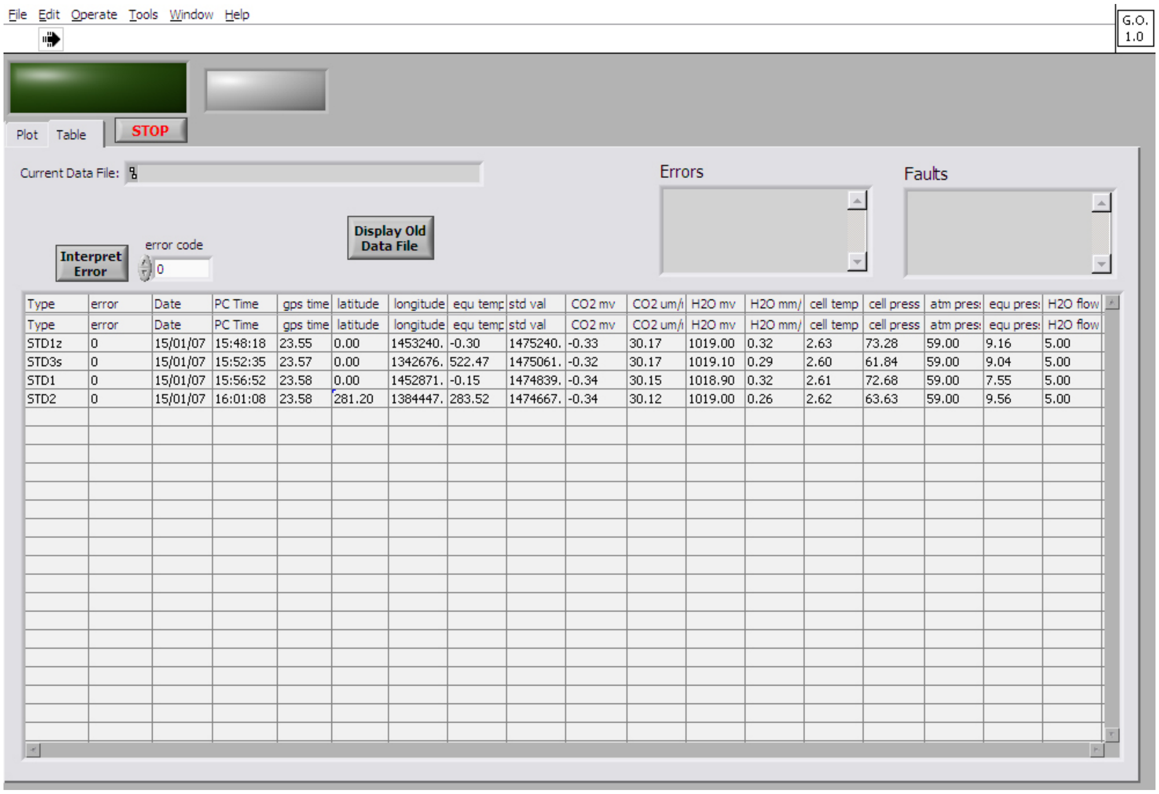


Figure 20. Table Data Display - Main Program

3.5. Data Files

Data files are created either when the system analysis starts or at the beginning of each day, just past midnight according to the computer's clock.

Data File

The naming convention for the data files is the following:

*sysID_ddd_hhmm***dat.txt**

where

sysID is the system ID string as entered in the initialization panel of the main program (see 3.3.1).

ddd is the day number of the year when the file was created

hhmm is the time of the file creation in the 24-hour format (i.e 1904 for 7:04 pm)

Error File

Along with the data file is created an error file containing a summary of the errors that occurred during the time period covered by the data file. Its naming convention is similar to that of the data file (see above) with the exception of the extension:

*sysID_ddd_hhmm***err.txt**

Compressed Binary File

When it is time for the system to send the data via Iridium modem, as determined by the user, the software compresses the two data and error files which name was stored in memory into a single ".dat" file in binary format. For naming convention and how to decompress this file, see 3.7.6.

3.6. Error Codes

1	…….	relay module driver took more than one iteration
2	…….	relay module driver failed to send command
4	…….	relay module driver solenoid check failed
8	…….	GO board driver did not get RD - cmd not sent
16	…….	valco valve did not go to correct position
32	…….	valco driver took more than one iteration
64	…….	GO board command failed (no reply)
128	…….	Hart driver took more than one iteration
256	…….	No response from Hart after 3 attempts
512	…….	serial I/O error reading licor
1024	…….	serial I/O error reading GPS
2048	…….	bad GPS fix
4096	…….	A/D module took more than one iteration
8192	…….	A/D module failed after 3 attempts
16384	…….	GO board driver took more than one iteration.
32768	…….	Technman failed to turn on (no reply)

The error code generated when several errors occur at the same time will be the sum of the individual error codes. The error code can be interpreted by the main software, on the "Table" tab. Simply enter the error code in the box provided and click the "Interpret Error" button.
NOTE: error codes 1, 32, 128, 4096 and 16384 (Event X took more than one iteration) are used for diagnostic purposes. They occur periodically but do not affect the proper functioning of the system since the communication with the hardware in question did not fail. Users should disregard these error codes.

3.7. Iridium Communication Program

3.7.1. Overview

The Iridium communication software consists of two separate programs ("*Underway_Co2_011.exe*" and "*Irid_Land_03.exe*") which are kindly provided, as is, by the Pacific Marine Environmental Laboratory (PMEL) in Seattle, WA. The code is open source and can be obtained by request to General Oceanics, Inc.

The Iridium modem interface for the underway pCO_2 system ("*Underway_Co2_011.exe*") is a driver that strictly focuses on sending or receiving data through the satellite system. It uses a file based system to pass information in both directions; data from the system to shore; commands from shore to the system. In both cases, the iridium driver is an application that interfaces the main pCO_2 application to the Iridium satellite system.

To do this, the driver creates two subdirectories in the pathway where the executable is installed, ~path/inbox/ and ~path/outbox/. Inside each of these is a .log file that contains information about the files that have been sent to shore (for the outbox) or received (for the inbox). Every second, the iridium interface checks the modem to see if there is an incoming call. If so, it receives the data, creates a new file in the inbox, and makes an entry in the .log file there. If there is no incoming call, it checks to see if there is a file with a .dat extension in the outbox. If so, it attempts to send that file to shore, deletes the file from the outbox after the phone session ends, and creates an entry in the .log file detailing the success for failure of the attempt.

Whenever the underway system wants to send data to shore, the data is made into a file with the .dat extension and placed into the outbox. The maximum baud rate through the satellites is 2400 baud, so even though the upper limit of file size is 1 megabyte, it is better to keep file sizes down into the 10s of kbyte sizes if possible to improve the probability of successful transmission.

Similarly, whenever the pCO_2 system sees a file in the inbox, it knows that the shore side has sent it some information.

The protocol used is a customized protocol base loosely on xmodem. Because of substantial time lags inherent in a satellite base system, sending and acknowledging a small packet at a time causes significant delays. A custom transmission protocol was designed in which the calling platform establishes contact with the receiving station and identifies itself. After this com link is established, the file is divided into blocks and sent in its entirety to shore, with appropriate block header information and checksums. After the receiving side determines it has received all the data, it checks the blocks' checksums and determines if any blocks need to be resent. If so it requests all the resend blocks at once from the sending side. This can happen up to twice per call. Then, if the call is still not successful, up to two recalls are scheduled totaling 3 calls with two retries per call, or 9 attempts to send the file per session. Every call has an entry in the log file with success or failure information.

3.7.2. SIM Card

The Iridium modem needs a SIM card located inside the modem in order to work. It needs to be purchased by the user. PMEL purchases from Stratos since experience here has proven them to be the most reliable (http://www.stratosglobal.com)

When purchasing, specify that the SIM card will be used for data transmission, not for phone calls, and ask to have the PIN number deactivated. If you receive your SIM card with the PIN number activated, you'll need access to an Iridium phone in order to deactivate it, or get instructions on how to deactivate the PIN using Hyperterm.
To install, punch out the SIM card (you'll get what looks like a credit card, and the SIM card is the small portion that can be punched out). Follow the instructions in the technical document from NAL Research "SIM_Install.pdf" to install the SIM card.

3.7.3. Program Configuration

Refer to section 3.1.2 to install the program files. The program refers to the "config.txt" file for setup parameters. An example of such a file is shown below:

```
// Configuration file for the Underway CO2 system
//
//
// USA prefix 001
//
//
//
//
//  Of the following parameters, the directory is the
//  optional entry.  IF left blank, the directory
//  will default to the directory where the .exe file
//  has been installed.  This file must also be in
// that same directory.
// All other entries will cause the .exce file to abort
// If they are not found in here.

Directory = c:\iridium
Com Port = 9
Prefix = 001
Phone Number = 1115554444
Project = pCO2
Platform = skogafoss
```

Figure 21. Example of "Config.txt" file for the Ship-Based Iridium Communications

The “config.txt” file needs to be edited with the correct COM port number and the phone number of the modem you wish to call. (i.e. the phone number of the modem in the land-side computer).
The prefix is a 3-digit number representing the country code for the modem in the land-side computer (e.g. 001 for USA, 033 for France). The Platform and Project fields are not used in this application but can be used to identify the “Config.txt” file.

NOTE:

- The program should be installed in the Startup folder, as mentioned in 3.1.2.
- The time at which the main program copies the latest data to the “outbox” folder is determined by the user in the main program (see 3.3.1).
- If communication fails three times, the Iridium modem will give up and delete the file from the outbox folder…the file will not be transmitted
- Proper functioning of the program can be tested by dropping a small text file (with a “.dat” extension) into the “outbox” folder when the Iridium program is running. Below is a screen shot of the program after a successful transmission.

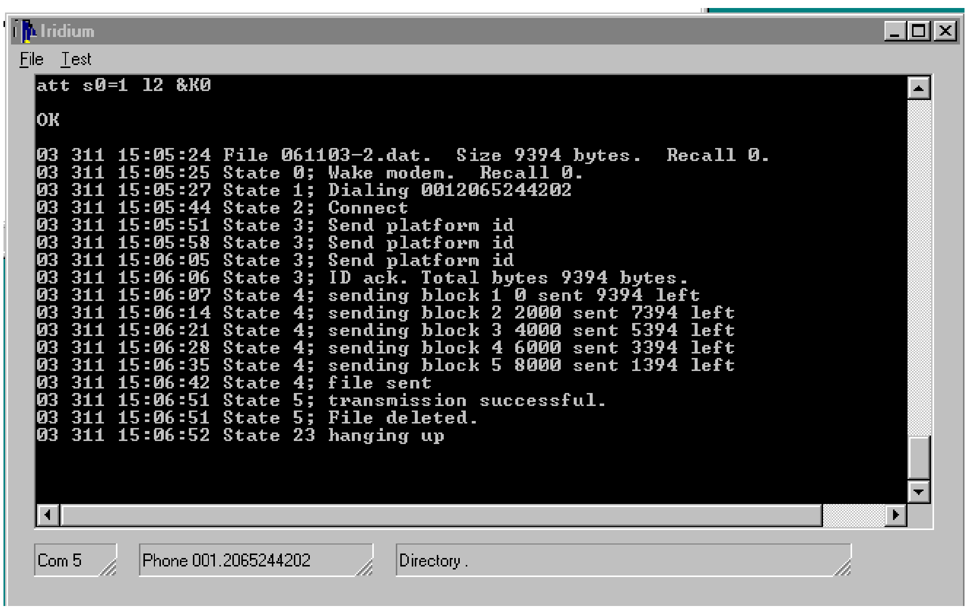


Figure 22. Successful Transmission of Data by the Iridium Program on the pCO2 System Computer.

3.7.4. A Partial Guide to Troubleshooting Iridium at Sea Transmissions

Error State1: Time Out [failure to connect to the modem]

- Is the modem powered?
- Has the power to the modem been cycled recently?
- Is the communication cable connected?

(if running software separate from CO_2 instrument, use null modem between DB9 on modem and PC COM port)

Error State 2: No Carrier [failure to connect with satellite]

- Is the SIM card in the modem, and does it have minutes?
- Is the coax cable connected and are the terminal connectors good?
- Is the antenna connected and does it have clear view of most of the sky?

Error State 2: Time Out [failure to connect with land-side software]

- Is the land-side program running and has that software been recently restarted?

3.7.5. Land-side setup

In order to receive data transmitted by the system, three things are needed:

- a computer with a modem
- an analog phone line
- the program "Irid_Land_03.exe"

The "Iridium_Land" folder contains the executable, a sample "config.txt" file and two "inbox" and "outbox" folders. It also contains the program to decompress the received files (iridium sorter.exe) and the zlib.dll necessary for that exe file to run. The user can copy this folder to a location of his choice in the receiving computer.
The "config.txt" file needs to be edited to match the user' setup.

- the "Rx Com Port =" line needs to reflect the COM port of the modem.
- the "Tx Com Port =" line also needs to reflect an active COM port on the computer, though it won't be used. (This line and all others pertain to a buoy-based system, not to this application. The program will, however, search for two active COM ports, so both need to be specified).

Below is an example of a "config.txt" file for the land-based Iridium communications

```
// Configuration file for the Underway CO2 system
//
//
// If calling buoy to land using a commercial card use USA prefix 001
// If calling modem to modem (ie ship to buoy) use prefix 00
//
//
//
//
//
//
//
//
//
//
//  Of the following parameters, the directory is the
//  optional entry.  IF left blank, the directory
//  will default to the directory where the .exe file
//  has been installed.  This file must also be in
// that same directory.
// Allother entries will cause the .exce file to abort
// If they are not found in here.

Directory = c:\Iridium_Land
Rx Com Port = 3
Tx Com Port = 1
Prefix = 00
Phone Number = 111222235
Project = pCO2
Platform = skogafoss
```

Figure 23.. Example of "Config.txt" file for the Land-Based Iridium Communications

To start receiving calls/data on the land-side computer, start up the executable "Irid_Land_03.exe". The user will be prompted for the inbox and outbox directories. Simply clicking "OK" will create the directories in the directory which contains the executable. Below is a screen shot of the program after a successful transmission.

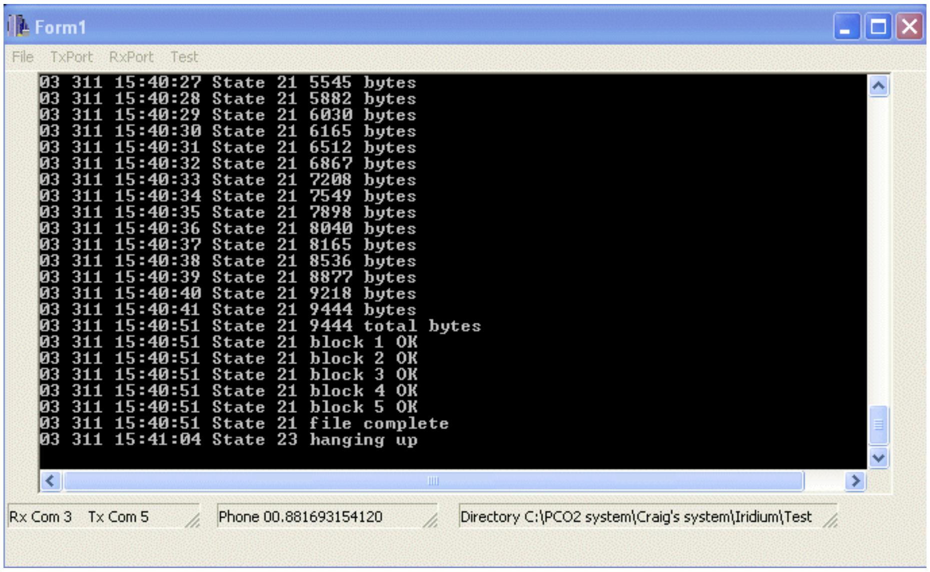


Figure 24.Successful Transmission of Data by the Iridium Program on Land-Based Computer.

3.7.6. Decompression of Transmitted files

Each day, the pCO_2 system generates a data file (*dat.txt) and an error file (*err.txt) (see 3.5). These two files are combined and compressed into a binary format to save transmission time. To read the transmitted files, they need to be decompressed. The program “Iridium Sorter.exe” is provided to that effect.

The naming convention for the transmitted files is

yy_ddd_hhmm.**dat**

where

yy is the last 2 digit of the year in which the transmission was done
ddd is the day number of the year in which the transmission was done
hhmm is the time of the transmission in the 24-hour format (ex. 1904 for 7:04 pm)

How it works

- The transmitted file contains information on the system ID, and the original data file name which refers to the time and date at which the data file was created on the system.
- The program will monitor the “inbox” folder on the receiving computer and, at a time determined by the user, will decompress the received “.dat” file, re-generate the data and error files and save them into a directory chosen by the user.
- The name of the decompressed files will be the same as the original data file generated by the system (see 3.5) and they will be saved in the chosen directory.
- In that directory, the program will create three sub-folders:
  - “compressed files” folder: The original received files are stored here with their original names

▪ “duplicate files” folder: If files present in the selected directory have the same name as the decompressed files, they will be saved in this folder instead. The corresponding error files will be saved in the “duplicate files” sub-folder in the “error files” folder (see below).
▪ “error files” folder: the decompressed error files are saved here. A “duplicate files” sub-folder is also created here, in case files with the same name are decompressed twice (see above)

Setting up the program

Run the “*LVRunTimeEng.exe”* program located on the system CD under the “1_LVruntime” folder to install the Labview Runtime engine on the computer

The “*iridium sorter.exe*” program can be run from the Iridium_Land folder copied to the C:\ drive or from another folder but it needs to have the “config.txt” and “zlib.dll” files in the same folder.

Start the “*iridium sorter.exe*” program.

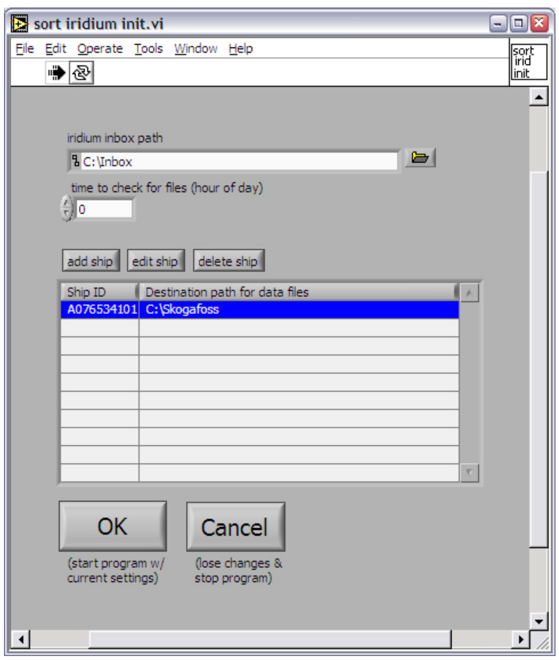


Figure 25. Iridium Sorter Main Window

- Select the iridium inbox path by clicking on the folder icon.

  Open the desired directory and click on “Select Cur Dir”

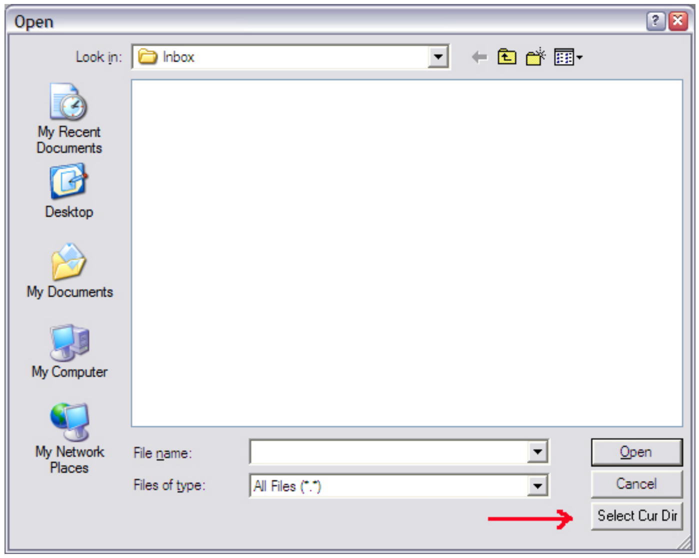


Figure 26. Selecting a Directory for "Iridium Sorter.exe"

- Select the time of day at which to monitor the inbox folder
- Create a list of ships where pCO2 systems are installed

Add, edit or delete ship information. When adding or editing information, enter the system ID as entered in the pCO$_2$ program running the system in question and select a destination folder for the decompressed files.

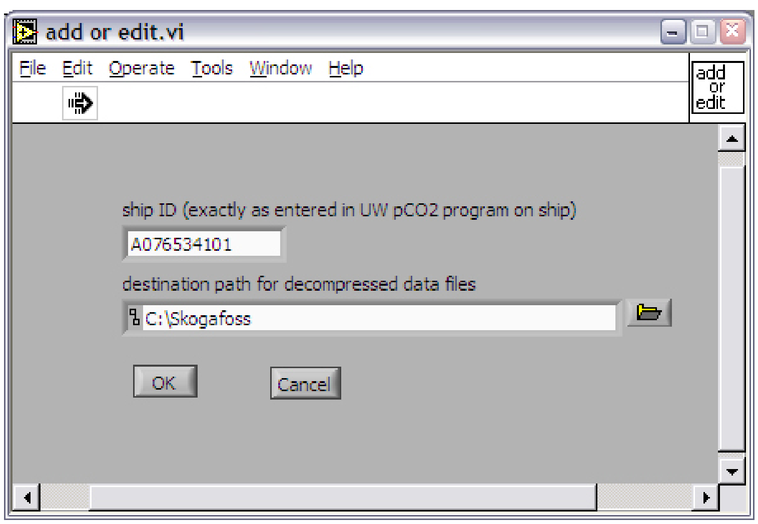


Figure 27. Ship Information in "Iridium Sorter.exe"

NOTE:
If the system ID (or ship ID) does not correspond to what is in the file, the program will create a new folder called "unknown ship" with the sub-folders as described earlier.

Chapter 4. SYSTEM SETUP

4.1. Mounting

Mounting dimensions for all three boxes are given in Appendix J. Both Dry and Wet boxes should be mounted vertically. The Deck box is weather proof. However, the barometer inlet is not as it needs to be opened to the atmosphere. Caution should be applied to protect that inlet from the elements.

General considerations when mounting the system:

Mount the Dry and Wet box as close as possible from each other in order to minimize the volume of gas in the tubing connecting the two.

Electrical cables should not be kinked as it might break the wires inside.

The seawater is drained out of the equilibrators by gravity. This is fine for a laboratory setup but, on a ship, the seawater needs to be disposed of.

When mounting on a bench top of a laboratory, the system needs to be raised to allow room for the different connections at the bottom of the boxes. Appendix K gives the dimensions of two supports that can be built for that purpose.

4.2. Connections

Figure 28 is a diagram showing all the connections to be made. They are described in the text below and more information can be found in Appendix J. It is recommended to use either copper or Stainless Steel 316 tubing for all gas connections, if possible. If not, Nylon can be used as a replacement.
All gases connections use a ⅛" Swagelok nut except for the ATM gas which uses a ¼" Swagelok nut. Stainless Steel fittings should be tightened just **¼ TURN** after finger tight. The nylon fittings should just be tightened **FINGER TIGHT**.

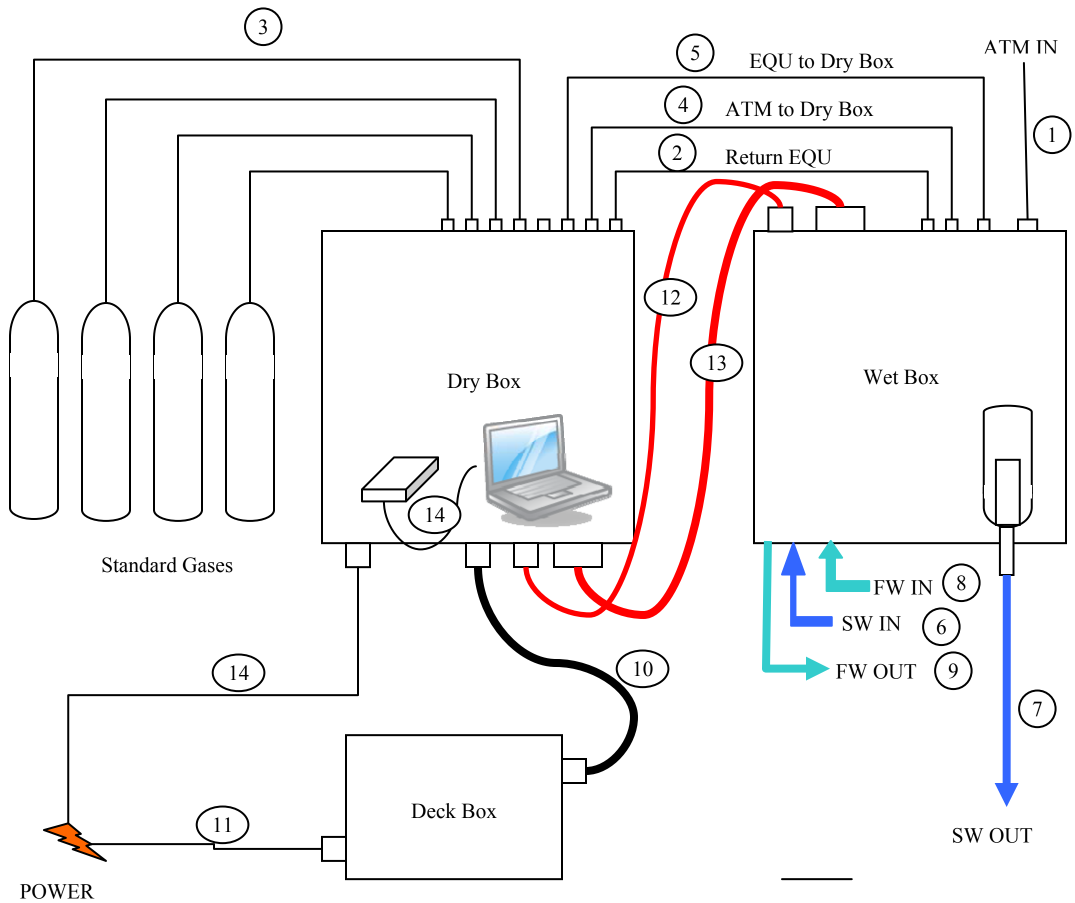


Figure 28. System Connections Diagram

4.2.1. Gases

Wet Box

- Connect the atmospheric air line to the "ATM IN". (1)
- The "vent" outlet of the dry box connects to the "Equilibrator Return" inlet of the wet box(2)

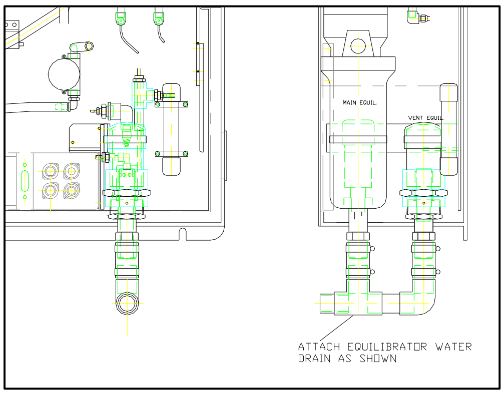
Dry Box

- Connect the standard gases to any of the 8-ports of the VALCO valve(3). It is recommended to connect the gases in the order they will be used so as to reduce the wear and tear on the VALCO valve due to unnecessary back and forth rotations of the head.

- The "EQU TO DRY BOX" outlet on the wet box connects to one of the 8-ports of the VALCO valve on the dry box.(4)
- The "ATM TO DRY BOX" outlet on the wet box connects to one of the 8-ports of the VALCO valve on the dry box.(5)

4.2.2. Water

All water connectors are 3/8" barbed connectors except the seawater drain which is a 3/4" barbed connector. The figure below shows how the drain should be installed.



- The seawater connects to the middle barbed connector at the bottom of the wet box.(6)
- The seawater outlet is situated just below the two equilibrators.(7)
- The fresh water connects to the back barbed connector which then connects to the solenoid inside the box.(8)
- The fresh water outlet is the front barbed connector(9)

4.2.3. Electrical

- The Deck box connects via an Ethernet cable to the 14-pin connector at the bottom of the dry box.(10)
- The Deck box also needs to be connected to the power via its power cord.(11)
- The Dry box connects to the Wet box by 2 red cables: a small 9-connector cable (12) which transmits the signals between the two boxes and a bigger 19-connector cable (13) which brings power to the Wet box. Each connects from its own bulkhead connector at the bottom of the Dry box to a similar bulkhead connector at the top of the Wet box.

- The Dry box also needs to be connected to the power using its power cord. (14)
- The computer connects to the DIGI Ethernet to Serial converter by an Ethernet cable. (15)

Maximum Cables Lengths

Dry Box – Deck Box	250 ft (76m)
GPS - Deck Box	60 ft (18 m)
Iridium Antenna	100 ft (30 m)

Note: The Iridium Antennae cable should NOT be spliced. Even when 100ft is needed, the cable should be just one length.

Once all the electrical connections are made and the Dry and Deck boxes are plugged in, the system can be powered up by TURNING ON THE POWER STRIP inside the Dry box. The computer can now be started. If configured properly, the "UW $p\mathrm{CO_2}$.exe" program should start automatically. Click "View Setup Screen" when prompted.

4.3. Flow rates

Setting the flow rates is done from the "Set Flow" routine in the "Test Panel" tab of the main program. In order to conserve standard gases but still flush the system adequately, the following flow rates are recommended:

Standard Gases ~60 ml/min

Set the pressure of the gas to ~ 9 psi and regulate the flow using the appropriate needle valves connected to the VALCO valve.

Atmospheric Air ~80-100 ml/min

In most installation, the ATM air line is very long. To ensure that what is measured is the current outside air, the line is flushed as much as possible and most of the air is vented right after the pump. What is not vented goes through the condenser and then to the ballast. A clamp on the pump vent allows to regulate how much air goes to the ballast. Most of the ballast air is also vented through a bottom opening which is also regulated by a clamp. The rest of the ballast air is used as the counter flow for the Nafion dryers by the vacuum pump and as the ATM gas being measured by the system.

The ATM gas flow going through the LICOR is therefore dependent upon how much gas is vented at the pump and at the ballast, how much is pumped through the Nafion dryers, and the needle valve at the VALCO valve.

While in the "Set Flow" routine of the program (the vacuum pump should be running), with the needle valve closed, adjust the two clamps so as to get approximately ~100-200 ml/min flow out of the ballast (a flow meter connected to the vent of the ballast is necessary). Once set, the clamps should not need re-adjusting.

After the ballast vent flow is adjusted, use the needle valve to regulate the flow through the LICOR.

Equilibrator Air ~80-100 ml/min

The equilibrator flow rate can be adjusted by the speed of the Headspace pump and the appropriate needle valve connected to the VALCO valve.
The Headspace pump speed is adjusted programmatically during runtime in order to keep it between the high and low limits entered in the “Run Setup” tab of the main program (see 3.3.1 Run Setup). It is therefore recommended to select a value around 100 as the initial speed to allow the program to adjust it up or down.

The flow can then be further adjusted using the needle valve.

4.4. Leak Tests

Before running the system, it is recommended to check that the system is leak proof. Leak checking is usually performed by exhaling around specific parts of the system while running the “Set Flow” routine from the “Test Panel” tab of the program and observing the recorded LICOR signal. It is recommended to blow in a piece of tubing in order to better pinpoint the source of a potential leak.

Standard Gas Lines

First , ensure that the gas lines are air tight when pressurized. Set the VALCO valve to a closed position (even number position). Open the regulators for each individual tank, set the outlet pressure to ~9 psi and close the second stage of the regulator. The pressure should stay constant.

In the “Test Panel” tab of the main program, select a standard and click the “Set Flow” button. When the values have stabilized, exhale around various parts of the system. Parts susceptible to leaks are:

- The VALCO valve connections
- The LICOR

Observe the response of the LICOR on the graph. If a leak is present, the recorded signal will go up.

Atmospheric Air Line

In the “Test Panel” tab of the main program, select “ATM” and click the “Set Flow” button. When the values have stabilized, exhale around various parts of the system. Parts susceptible to leaks are:

- The right side and bottom of the condenser
- The Acro-disk filters
- The Nafion dryers
- The VALCO valve connections
- The LICOR

Observe the response of the LICOR on the graph. If a leak is present, the recorded signal will go up.

Equilibrator Air Line

In the "Test Panel" tab of the main program, select "EQU" and click the "Set Flow" button. When the values have stabilized, exhale around various parts of the system. Parts susceptible to leaks are:

- The top of the equilibrator
- The right side and bottom of the condenser
- The Acro-disk filters
- The Nafion dryers
- The VALCO valve connections
- The LICOR

Observe the response of the LICOR on the graph. If a leak is present, the recorded signal will go up.

4.5. Recommended Run Settings

- In the "Edit Configuration.exe" program

  - Condenser set point: 5 °C
  - Condenser drain frequency: 60 to 90 minutes
  - Fan start temperature: 25 °C
  - Fan full speed temperature: 30 °C

- In the "Run Setup" tab of the main program

  - Equilibrator flow high limit: 100 ml/min
  - Equilibrator flow low limit: 70 ml/min
  -
  - Preflush times (for all types): 180 seconds
  - Reg flush times (for all types): 60 seconds
  - Stop flow time : 10 seconds

- Sequence Setup

0	ZERO	1
1	SPAN	1

2	STD1	3
3	STD2	3
4	STD3	3
5	STD4	3
6	ATM	5
7	EQU	100
8	LOOP2	4
9	FILTER	1
10	STD1	3
11	STD2	3
12	STD3	3
13	STD4	3
14	END	

Timings for this sequence:

Zero/Span - Filter	every 10.0 hours
Standards	every 2.5 hours
ATM	every 2.5 hours
EQU	runs for 2.5 hours

The last set of standards (steps 10 to 13) will make sure that every ZERO and SPAN procedure is bracketed by sets of standards and is necessary in order to interpolate the standards properly.

The analysis is now ready to start (see 3.4 Main Program).

Appendix A. FAQs about Installation

A.1 What type of tubing for atmospheric air? Where to position intake?

The air inlet line should have a diameter of at least 3/8 inch and should be inert and resistant to diffusion. Larger diameter tubing presents less resistance to air being pulled through the entire inlet but presents a larger volume that needs to be flushed to ensure good sampling. The preferred tubing material is either stainless steel or a composite system (i.e. Dekoran type 1300).

The positioning and the type of inlet are important for the quality of the atmospheric data and for the ease of continuous sampling. The inlet should be located so as to minimize the possibility of local contamination from combustion sources. The largest contamination source is the ship's stack. The inlet should be as far forward of the stack and as far off the water surface as feasible. Higher locations of the inlet reduces the chance that sea spray or water will be sucked into the air tubing. An inverted tubing inlet inside a rain guard is a common arrangement. General Oceanics has a kit available for that purpose (see Appendix C).

A.2 What kind of water intake pump?

The pCO_2 instrument runs best when the seawater source can deliver 4 L/min against a back pressure of 10 psi. The instrument might run acceptably well with 20% less flow and pressure; however, temporal and/or spatial resolution is lost.

If the ship's system cannot deliver a high enough flow and pressure, then a booster pump should be used. The pump should be designed for continuous use with performance characteristics that at least meet the stated flow and pressure requirements. Centrifugal pumps are a suitable choice so long as the pump does not have to prime itself (see Appendix D).

A.3 What kind of waste water pump, if any?

The analyzed water drains from the equilibrator by gravity. It is convenient if the water can drain directly outside the ship. If not, some arrangement for temporarily collecting the water and then pushing it overboard needs to be arranged. The exact characteristics of the installation environment will determine the best solution to this engineering problem. Consultation with an engineer could be helpful or necessary.

Questions and answers that will affect the engineering solution include:

- How much space, located where, is available for the temporary collection tank?

- Where does the waste water get pushed, against what back pressure?
- Is the ship's water suitable for the use of an "eductor" (also called "jet" or "aspirator") pump. This would allow the continuous evacuation of the waste water and therefore, a smaller collection tank.
- If an eductor pump is not an option, a pump needs to be used. This pump should not run continuously but be turned on when the collection tank is full and off when it is empty. The options are numerous.

A.4 Additional information regarding SIM card.

There are numerous vendors of SIM Cards for Iridium communications. The plans are as numerous as personal phone service. Some of the service providers are:
Stratos, http://www.stratosglobal.com/products/page-products_iridium.cfm
NALResearch, http://www.nalresearch.com/Airtime.html
RemoteSatellite, http://www.remotesatellite.com/prepaid_satellite_iridium_recharge.php

A.5 Standard gas regulator specifications

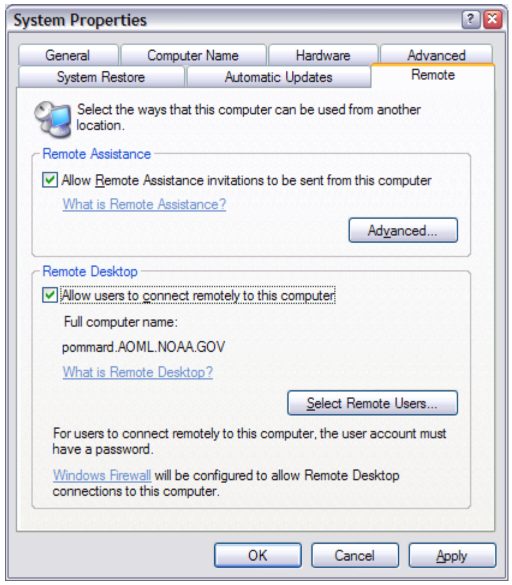
The standard gases should be delivered to the dry box at a constant pressure close to the 4-9 psi range. A **two-stage** pressure regulator with a second stage of 0-15 psi is a good choice. A **compact** regulator has advantages, and a **high purity** regulator is worth the expense. The regulator must have a fitting that matches the gas cylinder fitting (in the U.S. typically a CGA 590 or 580). Vendors of suitable regulators include Scott Specialty Gases (e.g. model 14, 51-14B-CGA) and Air Products (e.g. series 300, R302).

A.6 Can the system be accessed and monitored in real time?

If the computer is connected to the internet or a LAN and has an IP address, it is possible for a user to access and control the computer remotely. Included with Windows XP (and possibly Vista) is a utility called "Remote Desktop Communication", usually located in "Start→All Programs→Accessories→Communications", which allows to do just that.

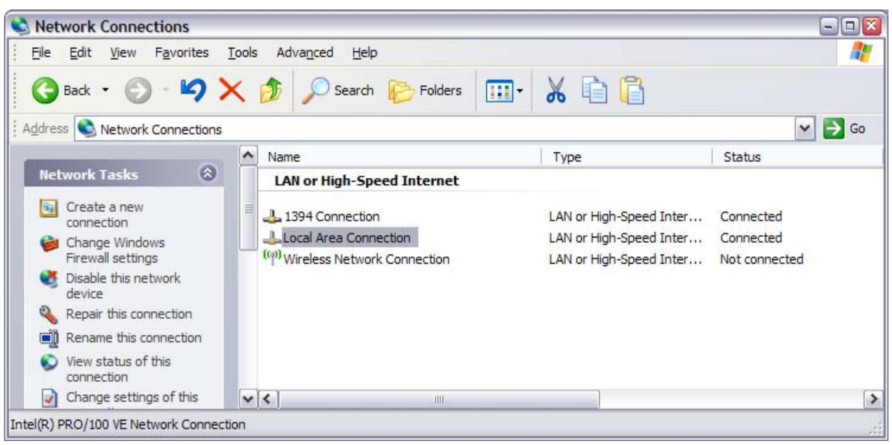
1. First, the system's computer needs to be setup properly.

In "Windows Explorer", right-click on "My computer" and select "Properties".
Click on the "Remote" tab
Under "Remote Desktop", select "Allow users to connect remotely to this computer". Notice that the user account used to log in needs to have a password.



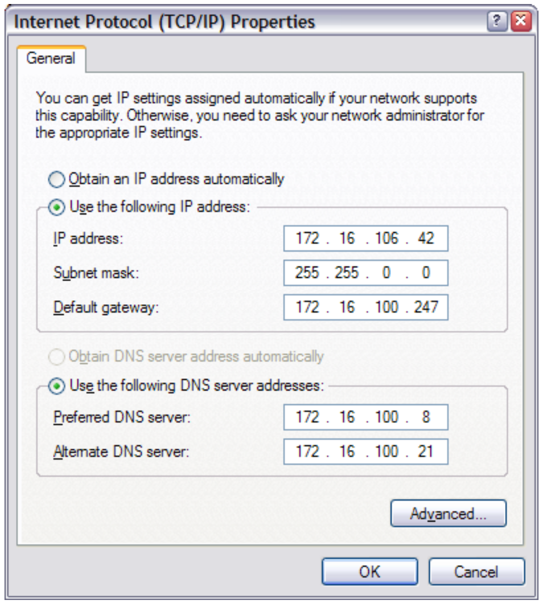
2. Get the computer's IP address:

In "Control Panel", select "Network and Internet Connections", then "Network Connections".

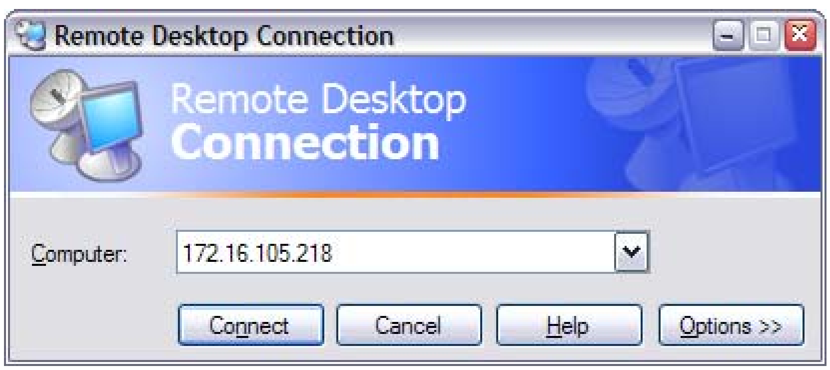


Double click on "Local Area Connection" then select "Properties".

Under the "General Tab" , select "Internet Protocol (TCP/IP)" then "Properties". The IP address will be displayed as below.



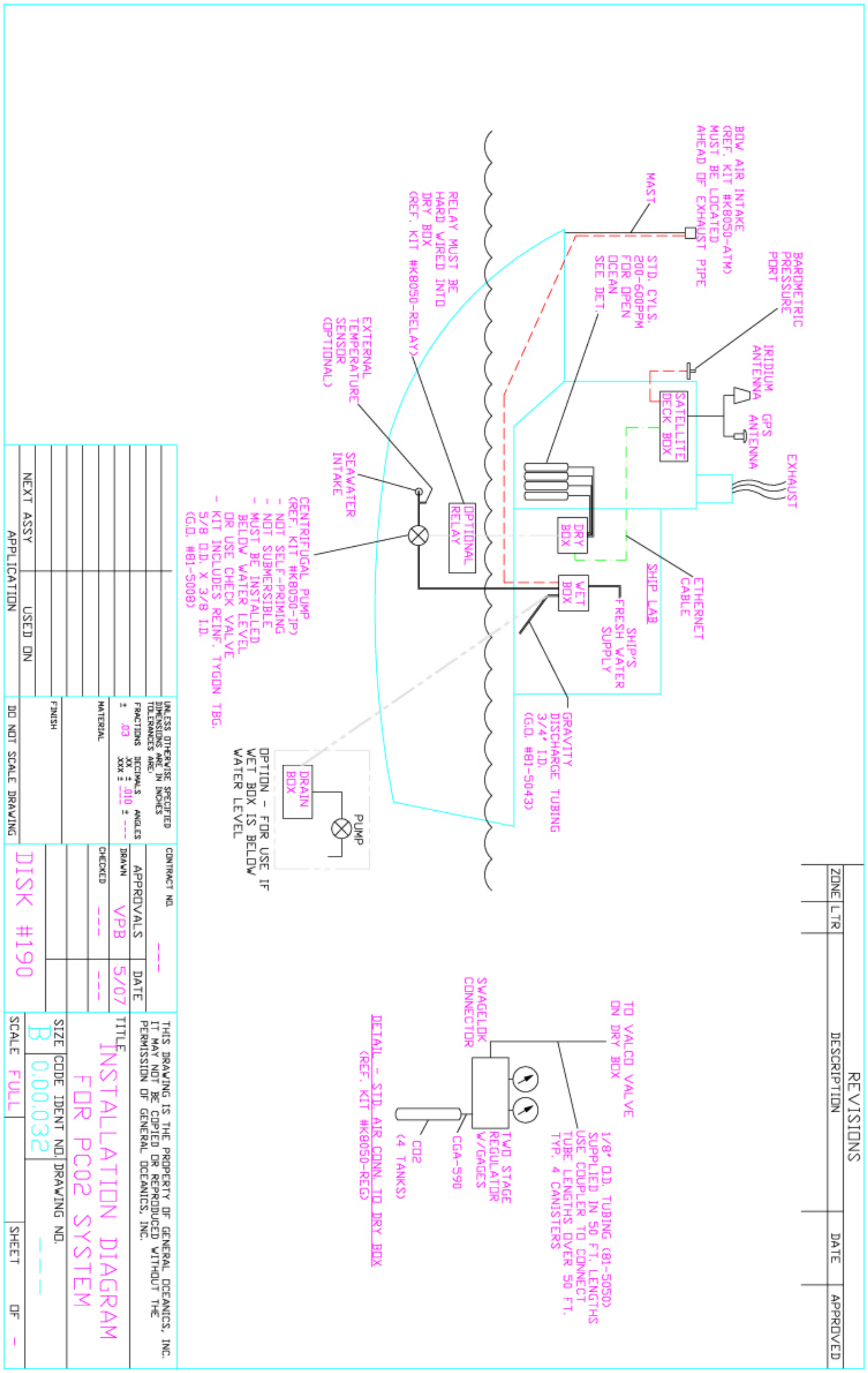
3. Start "Remote Desktop Communications", enter the IP address of the computer and then "connect".



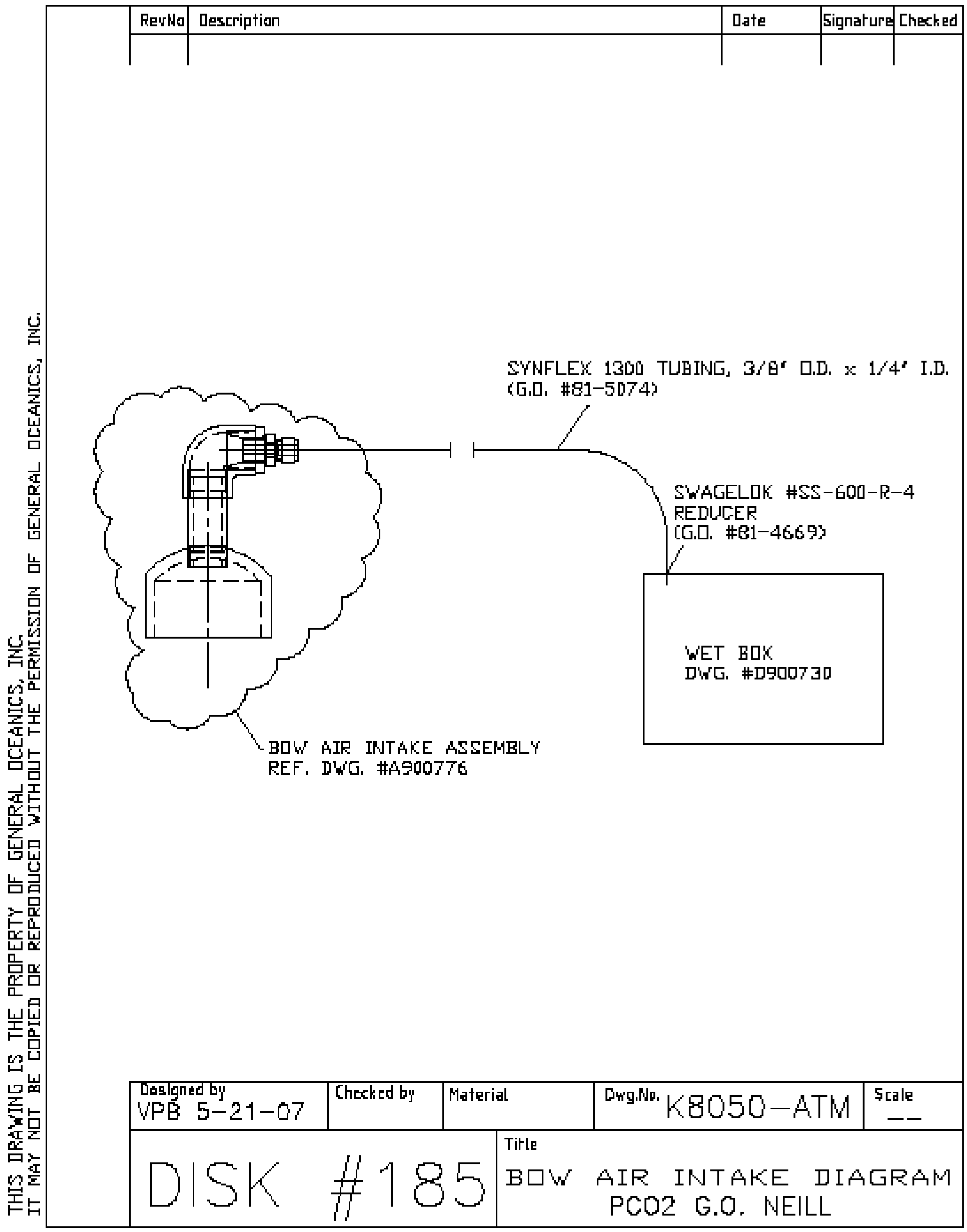
Enter the user name and password in the next window and you are done. You will be logged in the system's computer.

Note: Only one user at a time is allowed.

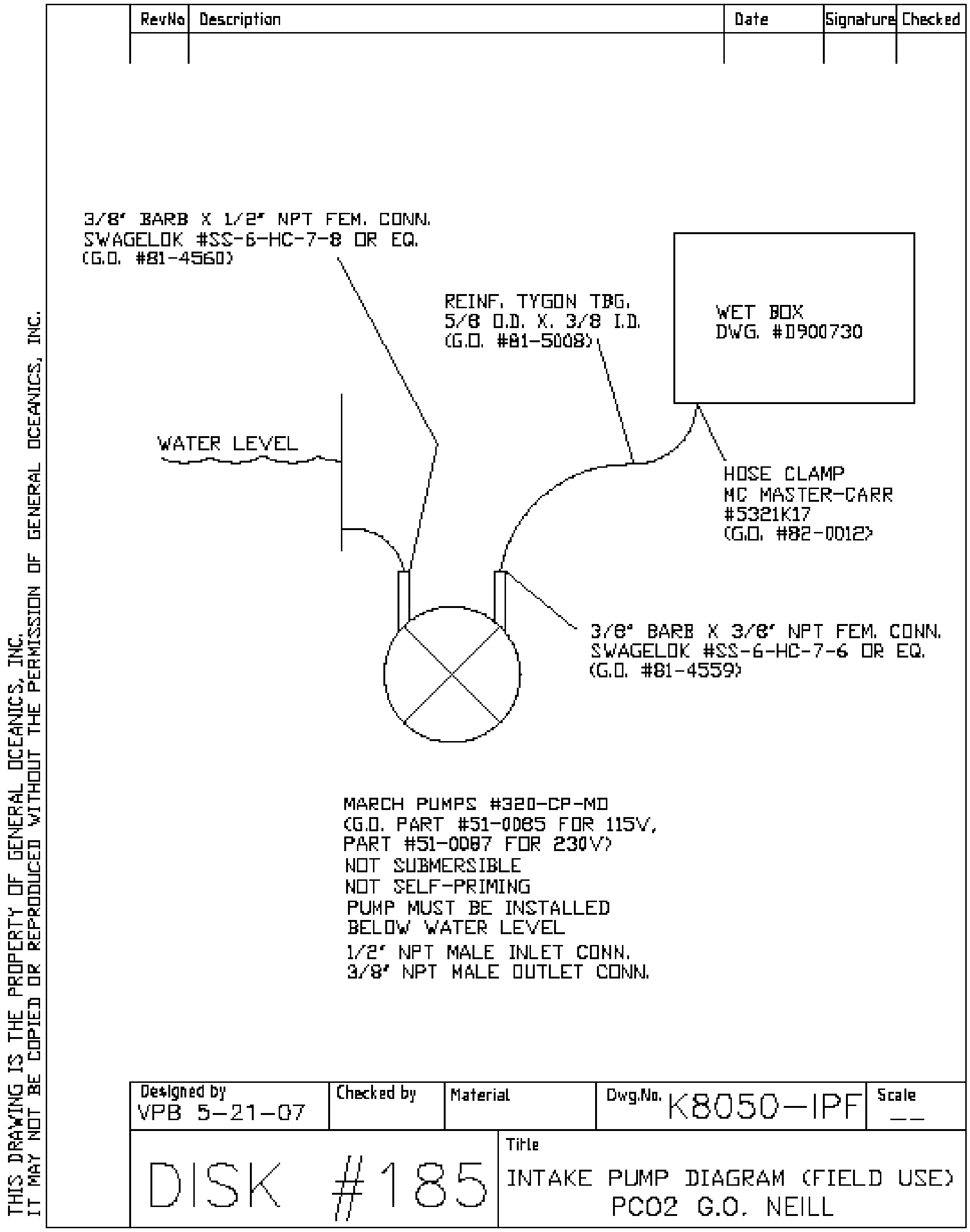
Appendix B. Installation Diagram



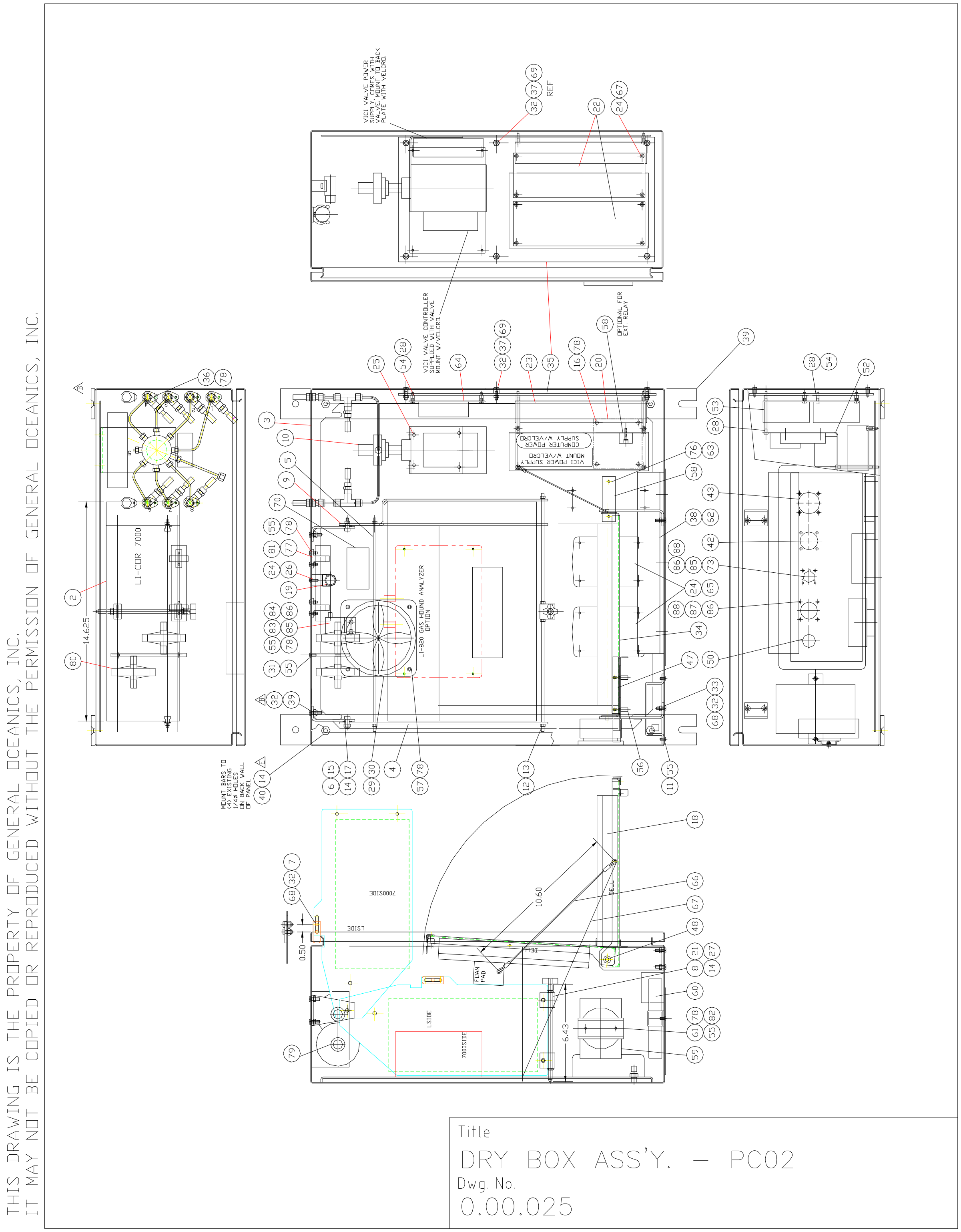
Appendix C. Atmospheric Air Intake Assembly



Appendix D. Seawater Intake Pump



Appendix E. Dry Box Assembly Diagram



ITEM	QTY.	WAE NUMBER	DESCRIPTION	MAT'L.	SIZE/MFR. NUMBER
1		D900731	DRY BOX ASSEMBLY		
2	REF		CO2 GAS ANALYZER		LI-COR 7000 (ALT. 6262)
	BY	CUSTOMER,	OR BY G.O. AS ALTERNATIVE		LICOR 7000 SHOWN
3	1	D390215	DRY BOX MOD.	S/S	
4	1	B340131	L.SIDE PIVOT SUPPORT	S/S	
5	1	A311211	TIE ROD, LICOR SUPP.	S/S	
6	2	B340132	MTG. BKT., PIVOT		
7	2	A340140	LATCH, LICOR MTG. BKT	S/S	
8	2	A300825	LOCK BLOCK, LICOR MTG.	PVC	
9	1	C340142	R.SIDE PIVOT SUPPORT	ALUM	
10	1	D900739	ROTARY VALVE ASS'Y		
11	1	B340153	MTG. BKT, ETHERNET	ALUM	
12	12	48-0510H	NO.10-24NC LOCK NUT	S/S	
13	2	A311211	TIE ROD, LICOR SUPP.	S/S	
14	23	48-0513	1/4-20NC HEX LOCKNUT	S/S	
15	2	48-0157	1/4-20NC X 5/8 SHCS	S/S	
16	4	48-0073	NO.6-32 X 3/8 FHMS	S/S	
17	2	48-0411F	1/4 FLAT WASHER	S/S	
18	1	3003	COMPUTER, LAPTOP		
19	1	8000-008A	3 WAY SOLENOID VALVE		
20	1	8000-113	INTAKE VENT	PL	
21	1	A300827	SCREW, LICOR LOCK	S/S	
22	2	60-0343	POWER SUPPLY, 12V	-	
23	1	60-0344	POWER SUPPLY, 24V	-	
24	8	48-0075A	NO.6-32 X 1/2 PHMS	S/S	
25	4	48-0130A	NO.10-32NF X 3/8 PHMS	S/S	
26	1	A300806	VALVE MTG. BLOCK	PVC	
27	1	62-0505	4 ARM KNOB,1/4-20 THD	NYL	
28	16	48-0071A	NO.6-32NC X 1/4 PHMS	S/S	
29	1	81-4586	GENERIC 5'' FAN	--	
30	1	81-4584	FAN GUARD	S/S	
31	1	B300830	HOLD. BKT, FILTERS	ALUM	
32	12	48-0510L	NO.10-32NF LOCK NUT	S/S	
33	2	B340138	COMPUTER BRACKET	S/S	
34	1	B340139	COMPUTER CRADLE	S/S	

Title
DRY BOX B.O.M. SHEET 1 — PC02
Dwg. No.
0.00.028

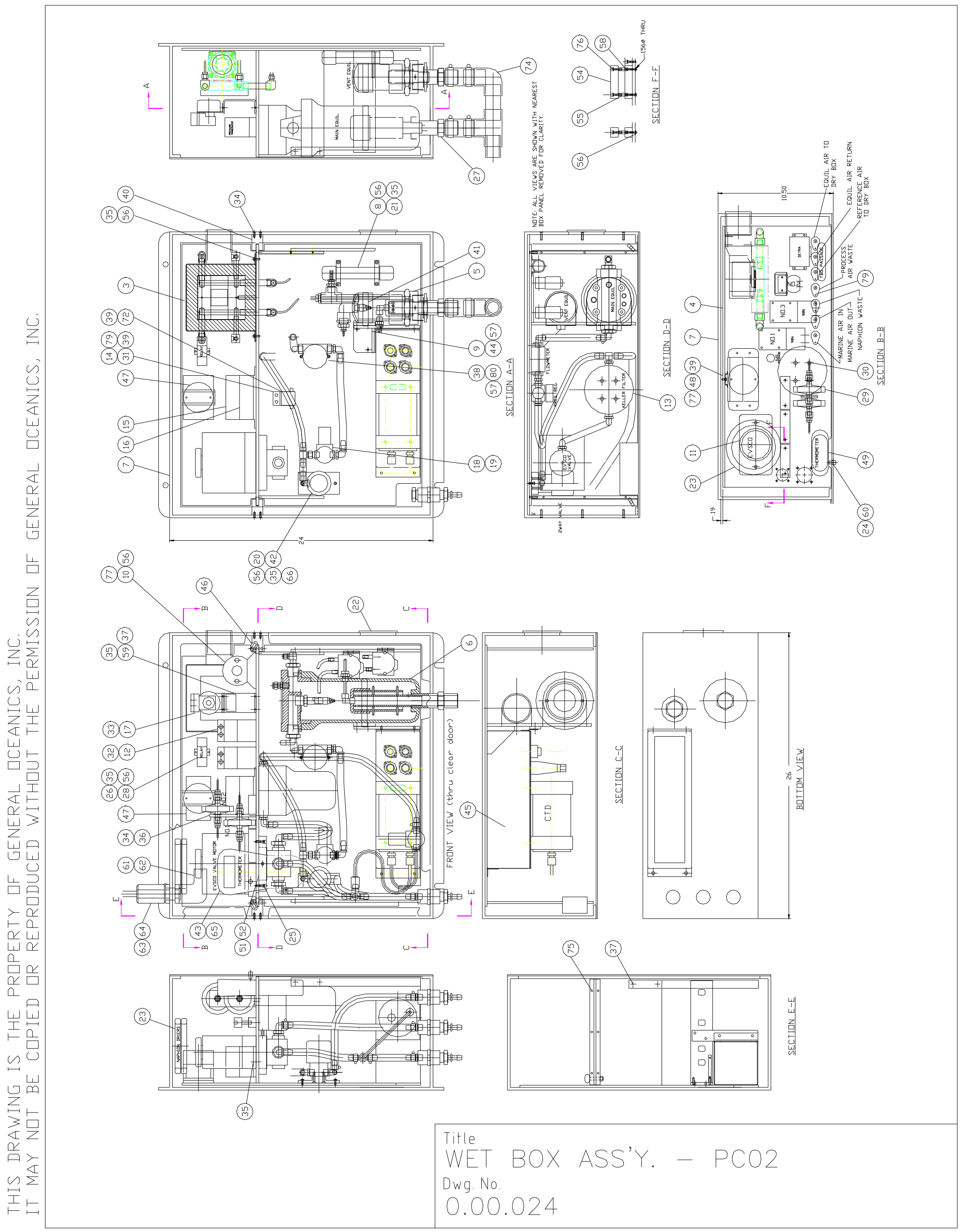
ITEM	QTY.	WAE NUMBER	DESCRIPTION	MAT'L.	SIZE/MFR. NUMBER
35	1	B300807	SIDE MTG. PLATE	ALUM	
36	11	48-0073A	NO.6-32NC X 3/8 PHMS	S/S	
37	6	48-0809	NO.10 X .25 LG SPACER	NYL	
38	1	60-0350	6 OUTLET POWER STRIP		
39	2	B300858	DRY BOX MTG. BAR	ALUM	
40	4	48-0161	FLAT HD. MACH. SCREW	SS	
41		23102CHR5	GASKET, SELF ADHES.	NEOP.	
42	1	50-0151	CONNECTOR		
43	1	50-0152	CONNECTOR		
44	TBD	48-0410F	NO.10 FLAT WASHER	S/S	
47	1	A340134	LATCH, COMPUTER	S/S	
48	2	48-0411FN	FLAT WASHER	NYL	
49	1	57-0111	MTG. BKT.		
50	1	50-0635	CONNECTOR, CORD		
51	1	48-0561	CONDUIT LOCKNUT		
52	1	B340141	SHIELD, POWER SUPPLY	ALUM	
53	4	44-0001	STANDOFF, 2LG, MXF	STL	
54	16	44-0002	STANDOFF, 3/8LG, MXF	STL	
55	16	48-0076	NO.6-32NC X 5/16 PHMS	S/S	
56	2	48-0075T	NO.6-32 THUMB SCREW	S/S	
57	4	48-0082A	NO.6-32NC X 1.50 PHMS	S/S	
58	1	65-0199	TERMINAL BLOCK		
59	1	55-0155	ETHERNET SWITCH		
60	1	51-0154	PORT SERVER TS4 MEI		
61	1	A300822	DIN RAIL	STL	
62	1	A300851	MTG. BAR, POW. STRIP	PVC	
63	6	48-0406ES	NO.6 STAR LOCKWASHER	S/S	
64	1	A910411	PC BOARD, GEN. CTRL.		
65	2	51-0156	FUSE BLOCK		
66	1	A030275	LANYARD, COMP. CRADLE	L.S.	
67	1	A030276	LANYARD, COMP. CRADLE	R.S.	
68	12	48-0132A	NO.10-32NF X 1/2 PHMS	S/S	

Title
DRY BOX B.O.M. SHEET 2 - PC02
Dwg. No.
0.00.029

ITEM	QTY.	WAE NUMBER	DESCRIPTION	MAT'L.	SIZE/MFR. NUMBER
69	10	48-0120	NO.10-32NF X 3/4 PHMS	S/S	
70	1	A910409	PC BOARD, VALVE		
73	1	50-0136	FEED THROUGH		
76	4	48-0076A	NO.6-32NC X 5/8 PHMS	S/S	
77	2	42-0093	CLIP, SPRING ACTION	PLAST	
78	21	48-0508H	NO.6-32 REG HEX NUT	S/S	
79	2	81-4806	3/8 GROMMET	SBR	
80	2	51-0080A	VENT FILTER, 1/8NPT		ACRO50 4400 20 MICRON
81	1		SCRUBBER		
82	4	48-0406	NO.6 FLAT WASHER	S/S	
83	1	51-0068	MASS AIR FLOWMETER		
84	1	A311199	MTG.BKT,AIR FLOWMETER	ALUM	
85	6	48-0048A	NO.4-40NC X 1/4 PHMS	S/S	
86	18	48-0404ES	NO.4 STAR LOCK WASHER	S/S	
87	12	48-0050D	NO.4-40NC X 3/8 PHMS	S/S	
88	16	2300440001	NO.4-40NC HEX NUT	S/S	
89	REF	D020410	POWER WIRING		
90	REF	D020411	CONTROL/ACQ. WIRING		
91	1	B910395	CABLE ASS'Y CN1 (WET TO DRY BOX)		
92	1	B910396	CABLE ASS'Y. CN2 (WET TO DRY BOX)		
93	1	A910398	DOOR THERMOMETER ASS'Y.		
94	1	A910403	30" ETHERNET CABLE ASS'Y.		
95	1	A910404	12" ETHERNET CABLE ASS'Y.		
96	1	A910405	30" RJ45/SR232 CABLE ASS'Y.		
97	1	A910406	30" RJ45/3 PIN MOLEX ASS'Y.		
98	1	A910412	EXTERNAL ETHERNET HARNESS ASS'Y.		
99	1	A910413	CN1 PIGTAIL ASS'Y.		
100	1	A910414	CN2 PIGTAIL ASS'Y.		
101	1	A910415	AC HARNESS ASS'Y. FOR POWER SUPPLIES		
102	1	A910416	DC HARNESS ASS'Y. FOR POWER SUPPLIES		

Title
DRY BOX B.O.M. SHEET 3 - PC02
Dwg No
0.00.030

Appendix F. Wet Box Assembly Diagram



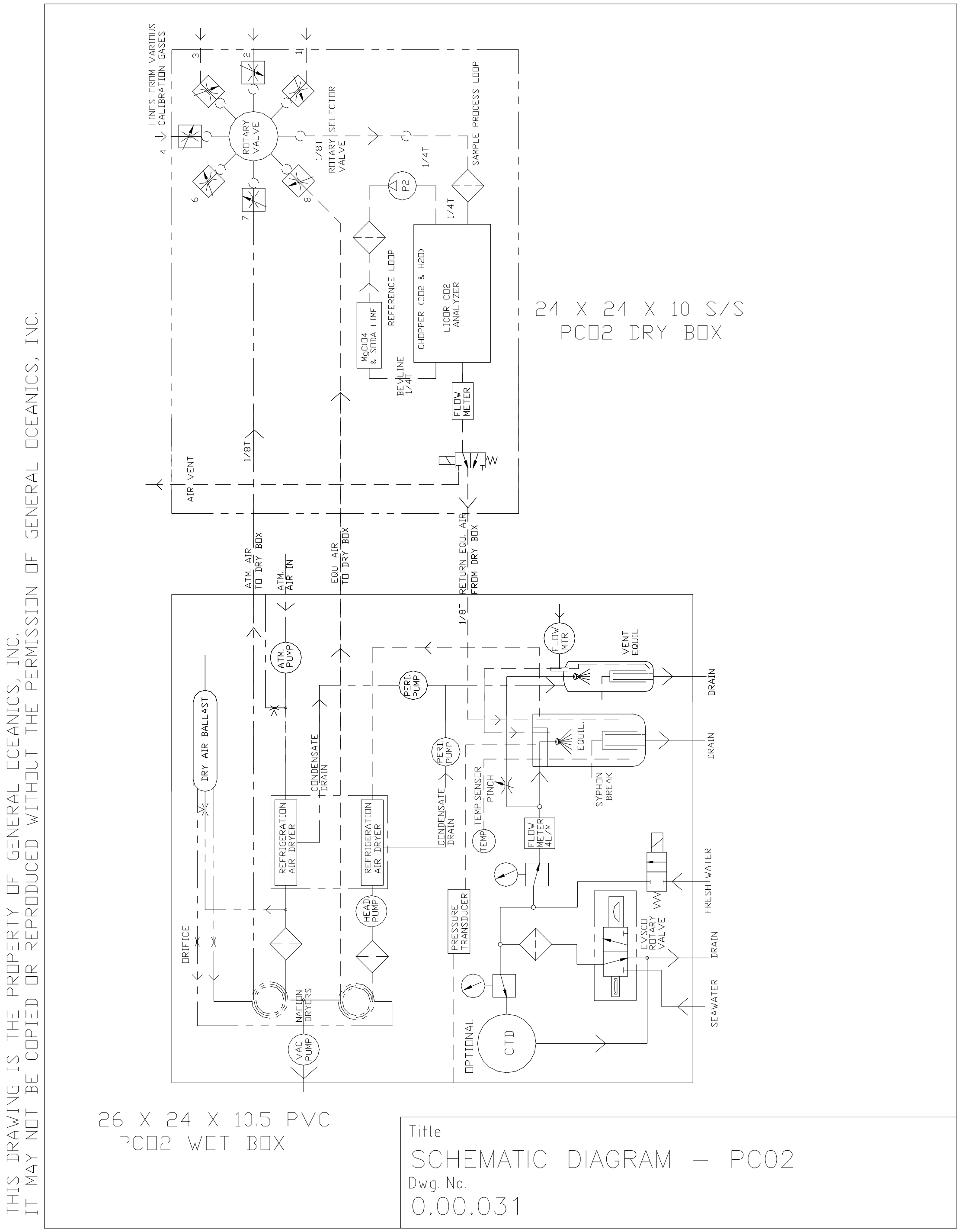
ITEM	QTY.	WAE NUMBER	DESCRIPTION	MAT'L.	SIZE/MFR. NUMBER
1	-	D900730	ASS'Y, WET BOX	-	PCO2 SYSTEM
2	1	D030273	PIPING ASS'Y/SCHEMATIC	-	
3	1	D900734	CHILLER ASS'Y	-	---
4	1	D900743	MOUNTING STRUCTURE	ALUM	
5	1	C900733	EQUILIBRATOR, VENT	-	SUB-ASS'Y
6	1	C900732	EQUILIBRATOR, MAIN	-	SUB-ASS'Y
7	1	D900749	CASE MOD CEM'NT ASS'Y	PVC	
8	1	B900740	DRY AIR BALLAST	PVC	SUB-ASS'Y
9	1	B900736	MTG. BKT. EQUILIBRATOR	ALUM.	SUB-ASS'Y
10	1	21-0536	PRESSURE TRANSDUCER	-	
11	1	51-0100	ROTARY VALVE, EVSCO	-	
12	2	51-0102	VACUUM PUMP	-	
13	1	51-0104	WATER FILTER,PRE-EQUIL.	-	
14	1	51-0068	MASS AIR FLOW METER	-	
15	1	51-0101B	A/D MODULE		
16	1	51-0101C	RS-422/485 TO RS-232 CONV.		
17	1	51-0103	MICRO VACUUM PUMP	-	
18	1	51-0105	WATER PRESSURE REG.	PLAST	
19	1	51-0106	PRES. GAGE, REAR MT.	-	
20	1	51-0082	2WAY N.C. SOL. VALVE	-	
21	2	81-4486	CONDUIT CLAMP, 3/4 P	PLAST	
22	1	81-4588	FAN GUARD 3.5''	-	
23	2	81-5019	NAPHION DRYER TBG.		
24	1	B390227	COVER MOD. FOR HART RESET		
25	2	48-0133C	NO.10-32NF X 5/8 SHCS	S/S	---
26	1	51-0110	RELAY, DPDT, 24V, 10A		---
27	2	B311189	NIPPLE, DRAIN	PVC	
28	1	51-0110S	BASE, RELAY		
29	2	51-0080A	VENT FILTER, 1/8MNPT	-	ACRO50 4400 .20 MICR VWR28143-955
30	4	48-0133K	NO10-32NF X 5/8 FHMS	S/S	
31	1	A311199	MTG.BKT,AIR FLOWMETER	ALUM	
32	8	48-0008	METRIC MACH. SCR	S/S	
33	2	48-0001	METRIC MACH. SCR	S/S	
34	4	48-0075B	NO.6-32NC X .50 FHMS	S/S	
35	14	48-0075A	NO.6-32NC X 1/2 PHMS	S/S	
36	1	B300788	FILTER HOLDING BKT.	ALUM	
37	1	A910410	PC BOARD, VAC. PUMP		
38	1	0504SN2	WATER FLOW SENSOR	-	
39	10	48-0050A	NO.6-32NC X 5/16 PHMS	S/S	
40	2	B300797	SLIDE TRACK	PVC	
41	2	82-0002	HOSE CLAMP, #72	S/S	

Title
WET BOX B.O.M. SHEET 1 — PC02
Dwg. No.
0.00.026

ITEM	QTY.	WAE NUMBER	DESCRIPTION	MAT'L.	SIZE/MFR. NUMBER
42	1	B300795	MTG. PAD, 2WAY VALVE	PVC	
43	1	51-0107	THERMOMETER		
44	2	504106	NO.8-32NC X 1/2 PHMS	S/S	
45	OPT	C900746	CTD OPTION ASS'Y		
46	2	30-0014D	QUICK RELEASE PIN	STL	
47	1	51-0101D	RELAY OUTPUT MOD.		
48	1	A300819	DIN RAIL	STL	
49	1	A910392	RS232 CABLE/THERMO.		
50	24	48-1219	CABLE TIES		
51	1	B300808	CLAMP RING, EVSCO	PVC	
52	1	48-0091G	1/4-20NC SOC SET SCR	S/S	
53	2	48-0509H	NO.8-32NC LOCK NUT	S/S	
54	4	65-0199	TERMINAL BLOCK		
55	2	44-0026	STANDOFF, FXF,NO.6-32	ALUM	
56	22	48-0406ES	NO.6 STAR LOCKWASHER	S/S	
57	4	48-0408IS	NO.8 STAR LOCKWASHER	S/S	
58	2	503940	NO.6-32 X 1 LG PHMS	S/S	
59	1	B340154	STAND, EQUILIB. PUMP	ALUM	
60	1	81-4646	PLUG, COVER HOLE	RUBR	
61	1	A910393	CABLE ASS'Y		
62	1	A910394	CABLE ASS'Y		
63	1	50-0151	CONNECTOR		
64	1	50-0152	CONNECTOR		
65	1	A910401	ASS'Y, POWER PIGTAIL		
66	2	48-0136B	NO.10-32 X 1 LG FHMS	S/S	
67	3	58-3415	150K OHM RESISTOR		
68	1	62-1010	SPIRAL TUBING	PLAST	
69	20	212221375	CABLE CLAMPS		
70	9	65-0053	CRIMP PIN		
71					
72	4	48-0404L	NO.4 LOCK WASHER	S/S	
73					
74	1	B920330	DRAIN PIPE CEMENTMENT	PVC	
75	12	48-0092B	NO.8-32NC X 3/4 FHMS	S/S	
76	6	48-0077A	NO.6-32NC X 3/4 SHMS	S/S	
77	2	48-0406	NO.6 FLAT WASHER	S/S	
78	REF	D020408	WET BOX POWER WIRING		
79	9	48-0073A	NO.6-32NC X 3/8 PHMS	S/S	
80	2	48-0090	NO.8-32NC X 3/4 PHMS	S/S	
81	REF	D020409	CONTROL/ACQ. WIRING		

Title
WET BOX B.O.M. SHEET 2 — PC02
Dwg. No.
0.00.027

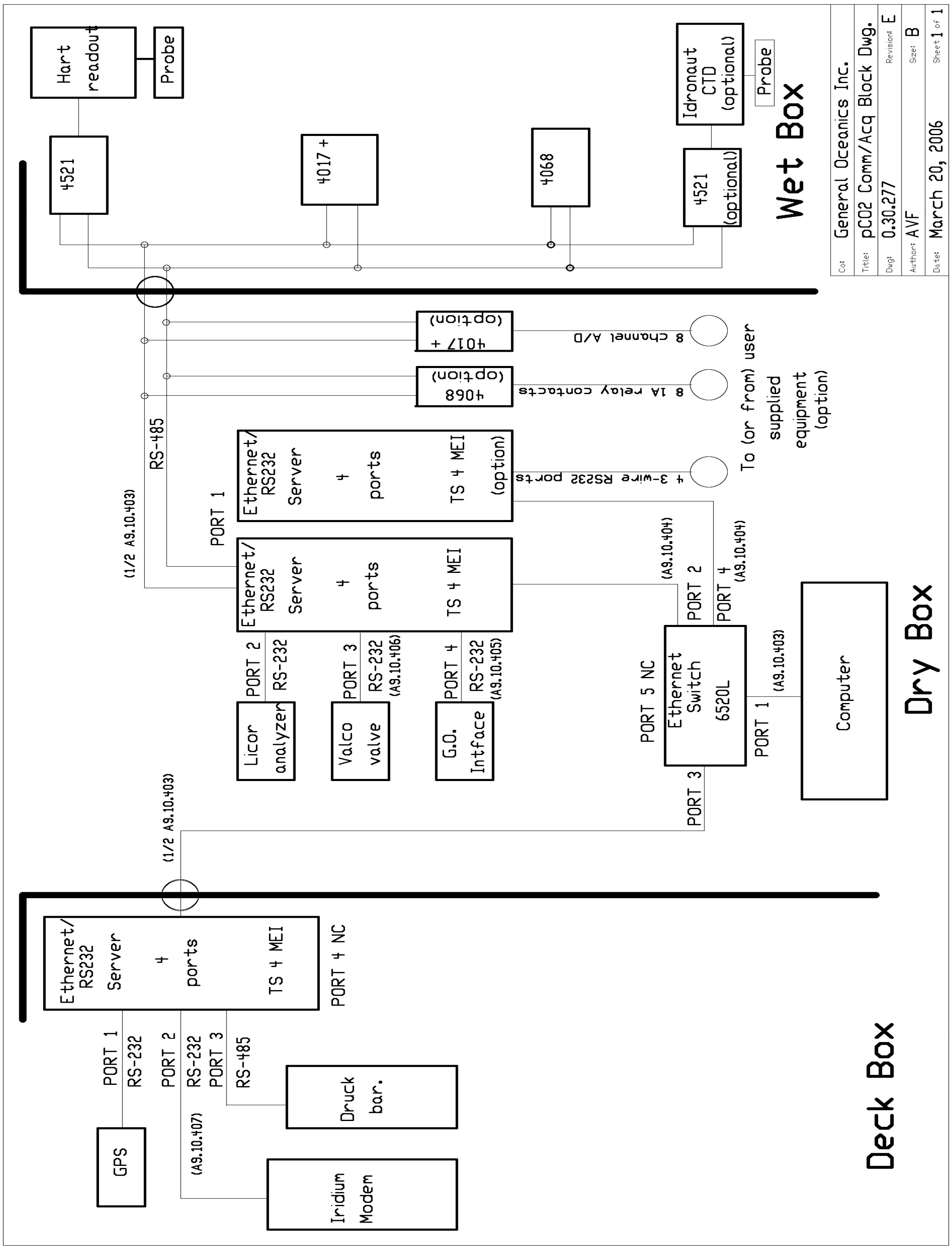
Appendix G. Gas and Water Flow Diagram



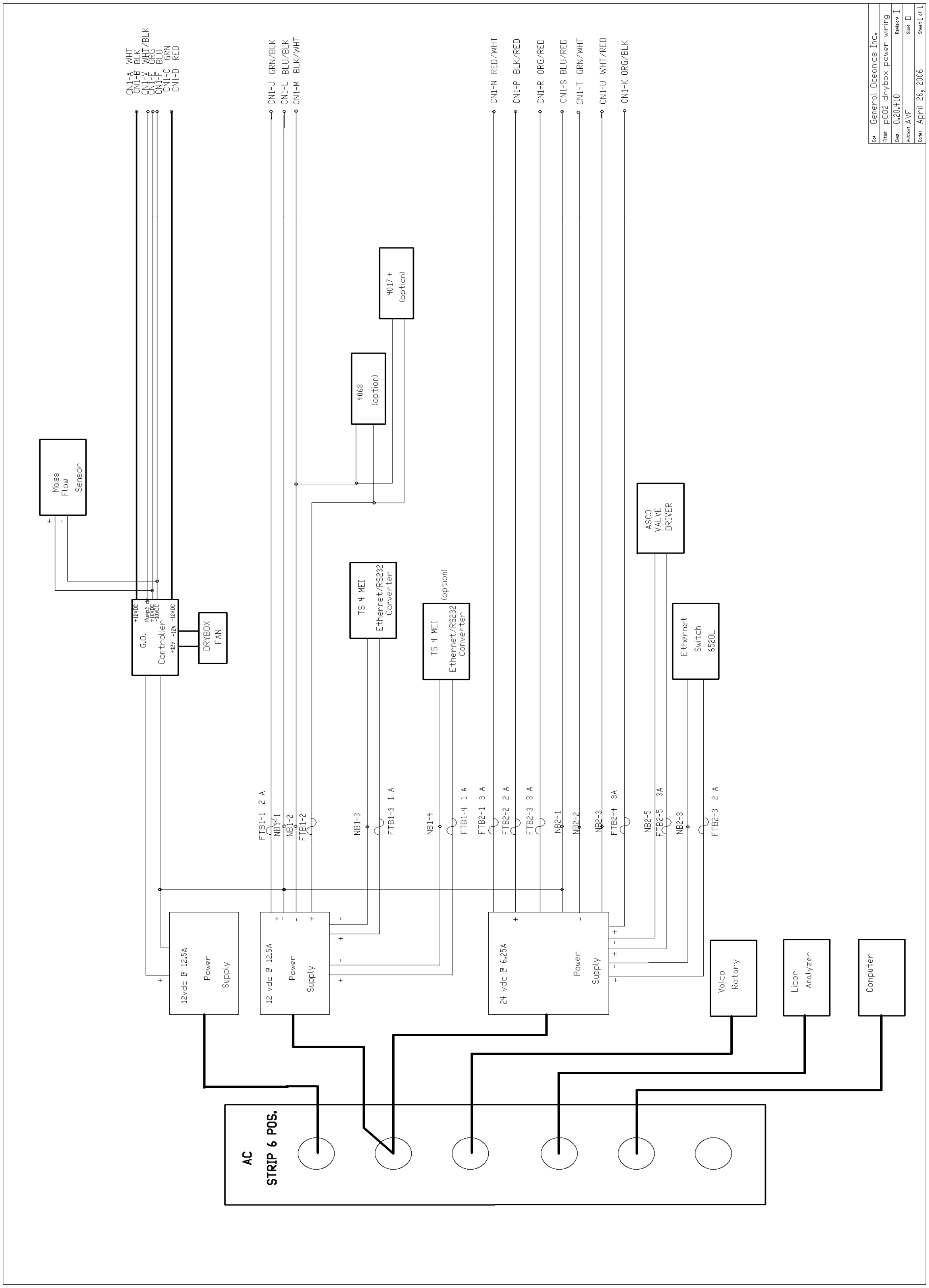
Appendix H. Electrical Diagrams

These diagrams might not be readable when printed. They are best view from a computer.

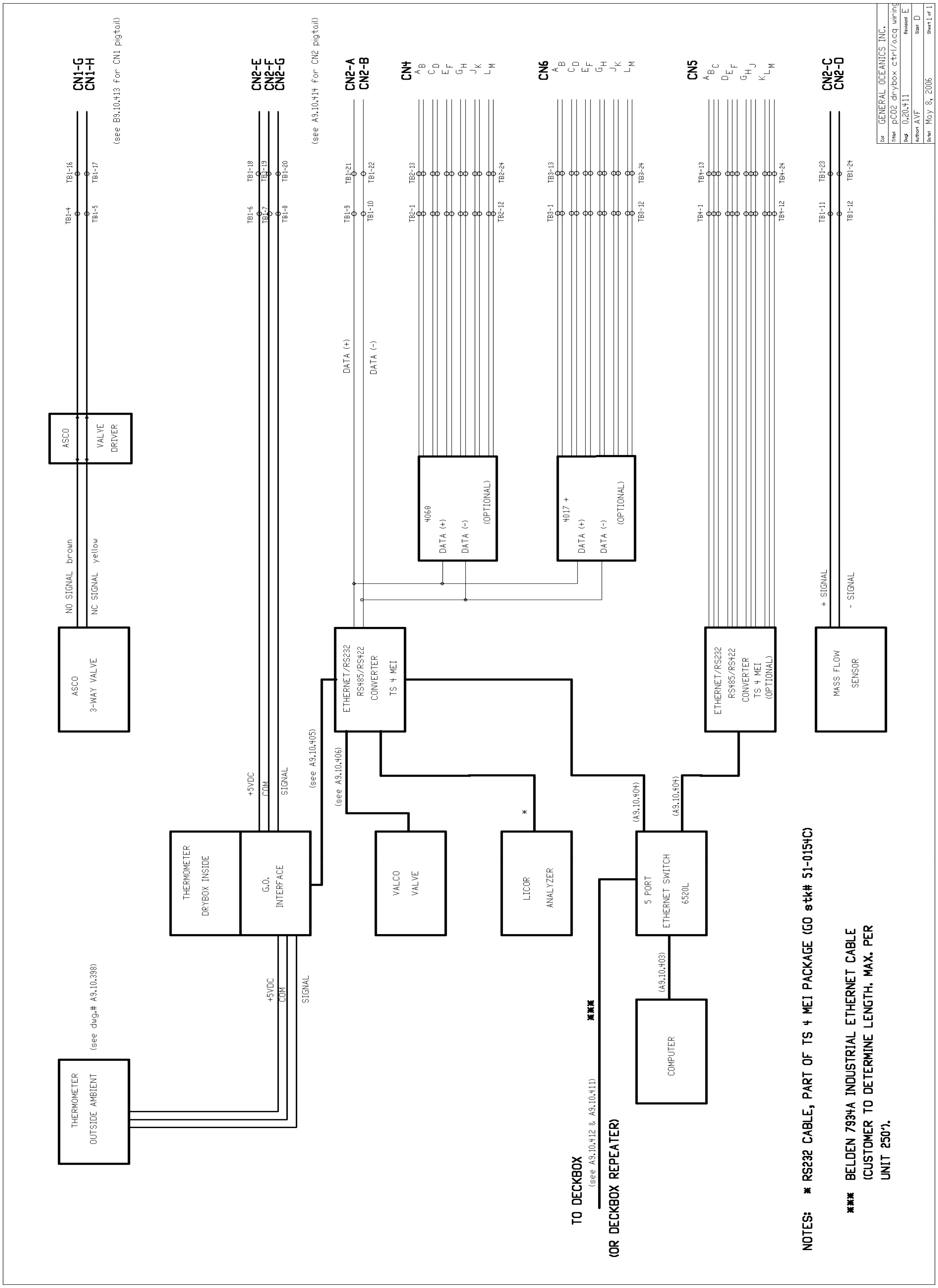
H.1 General Acquisition Block Diagram



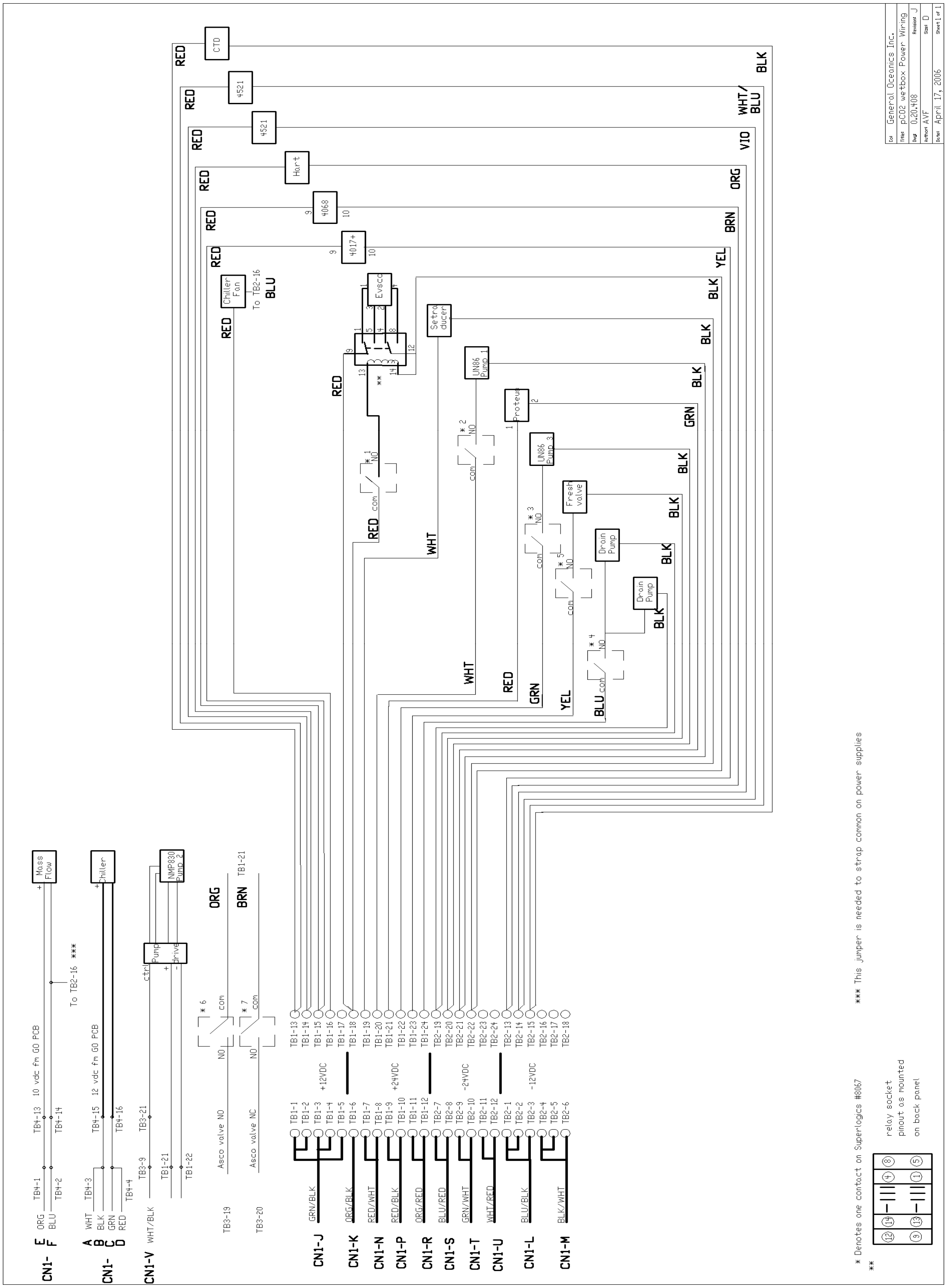
H.2 Dry Box Power Wiring



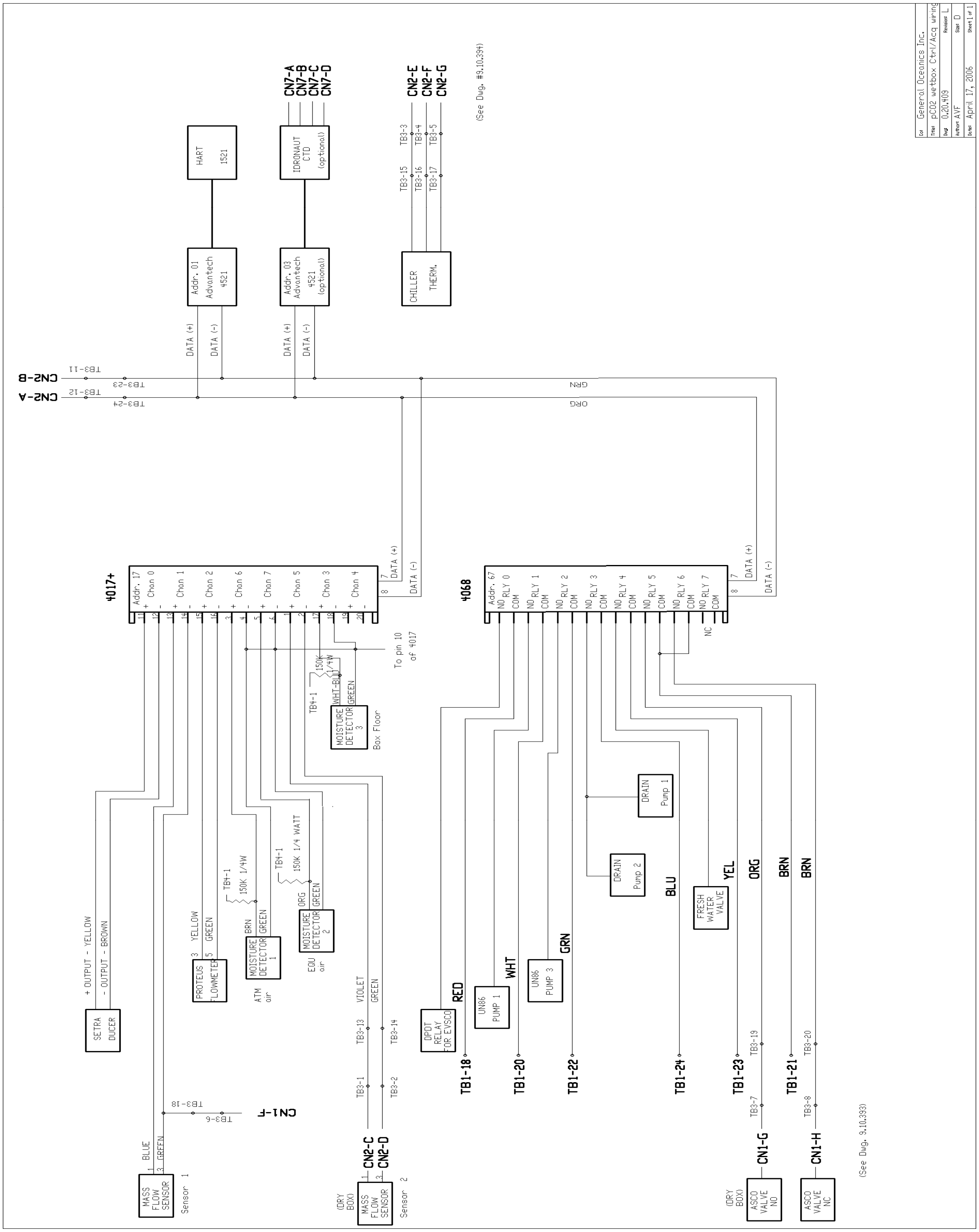
H.3 Dry Box Data Control Wiring



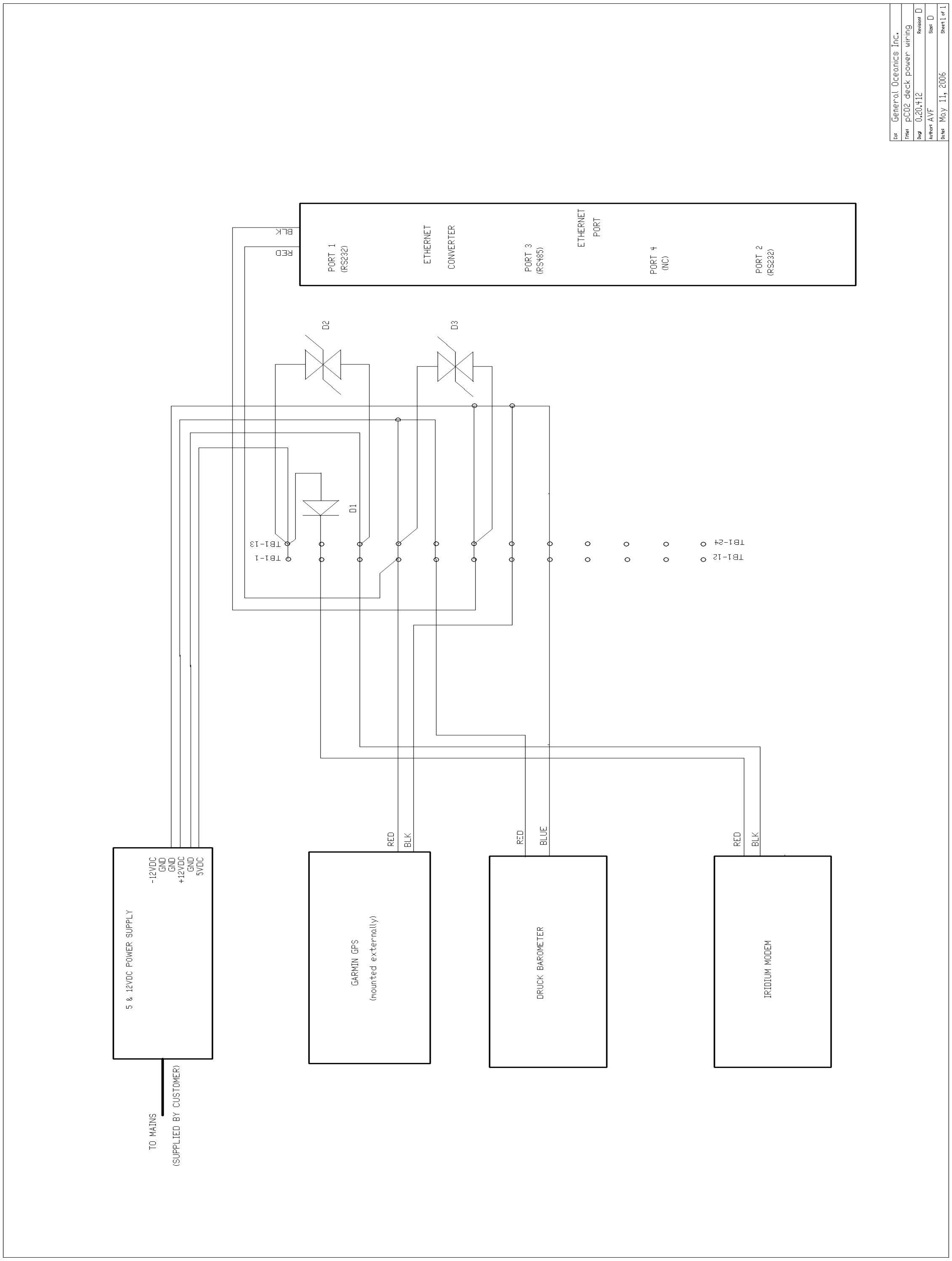
H.4 Wet Box Power Wiring



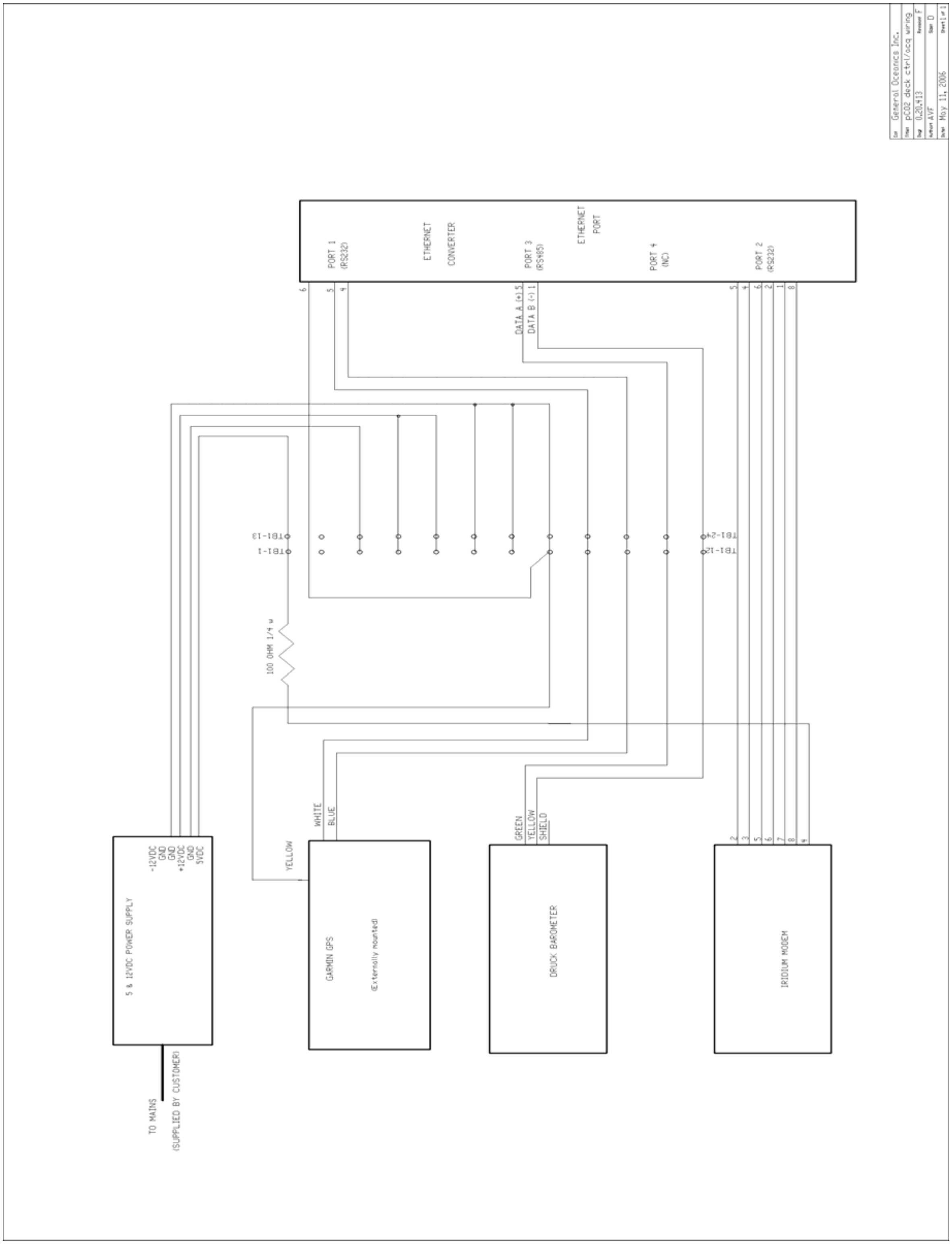
H.5 Wet Box Data Control Wiring



H.6 Deck Box Power Wiring

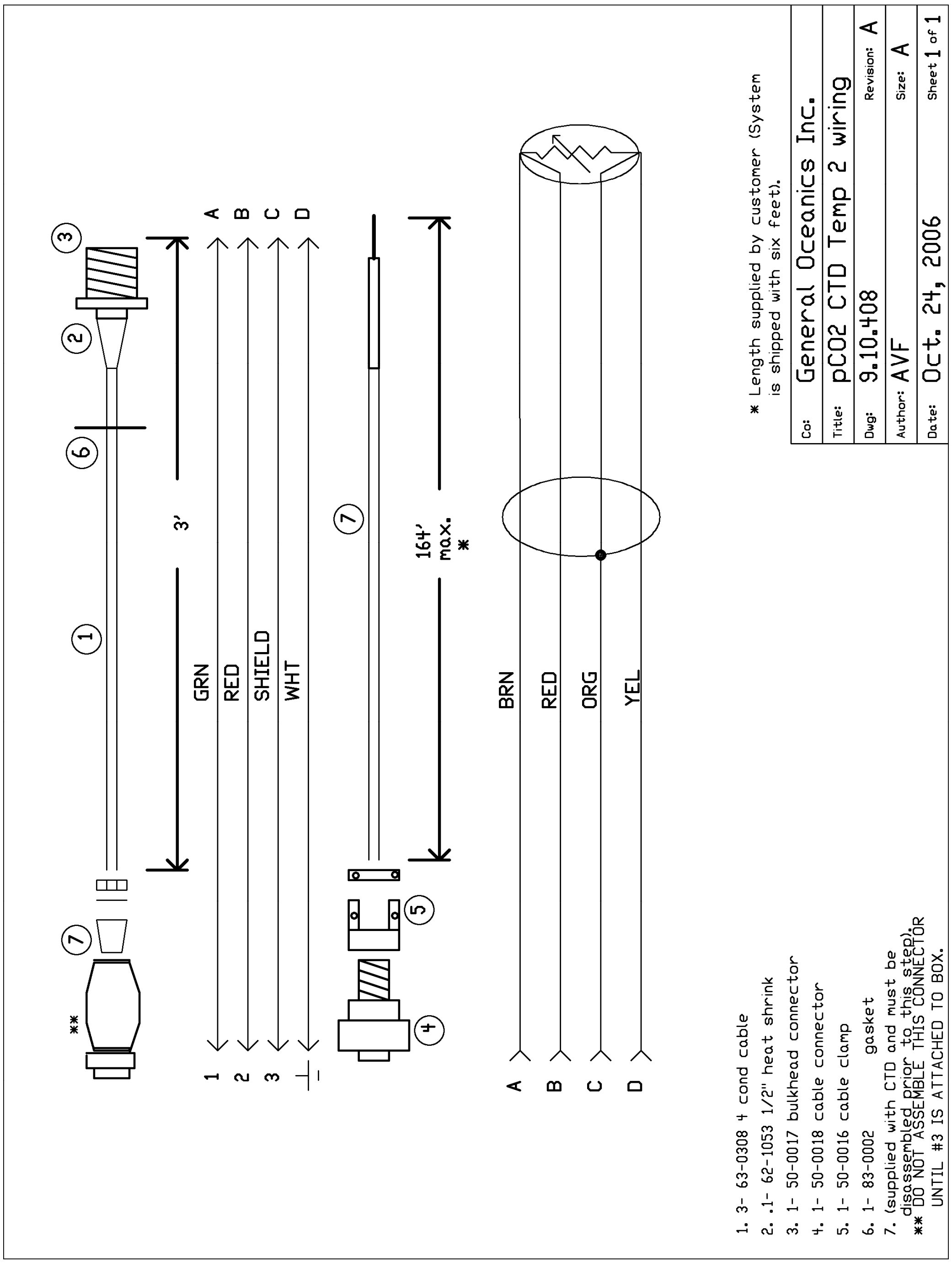


H.7 Deck Box Data Control Wiring



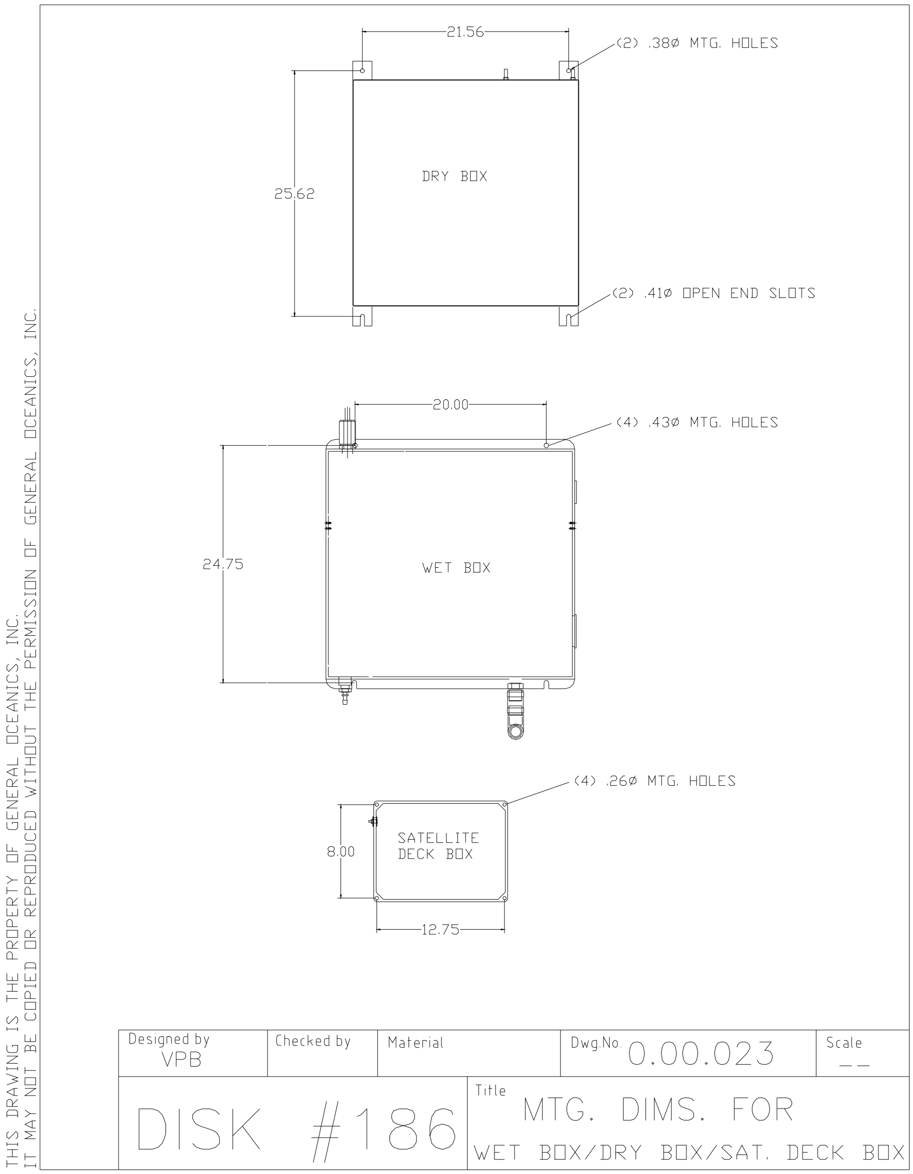
Appendix I. Temperature Probe to Module I8050-7 (optional) Cable Wiring

General Oceanics provides this cable with a standard length of 6 feet when the optional 7-parameter sensor CTD module (model I8050-7) is ordered. This diagram is provided should the user wish to splice it in order to increase its length.

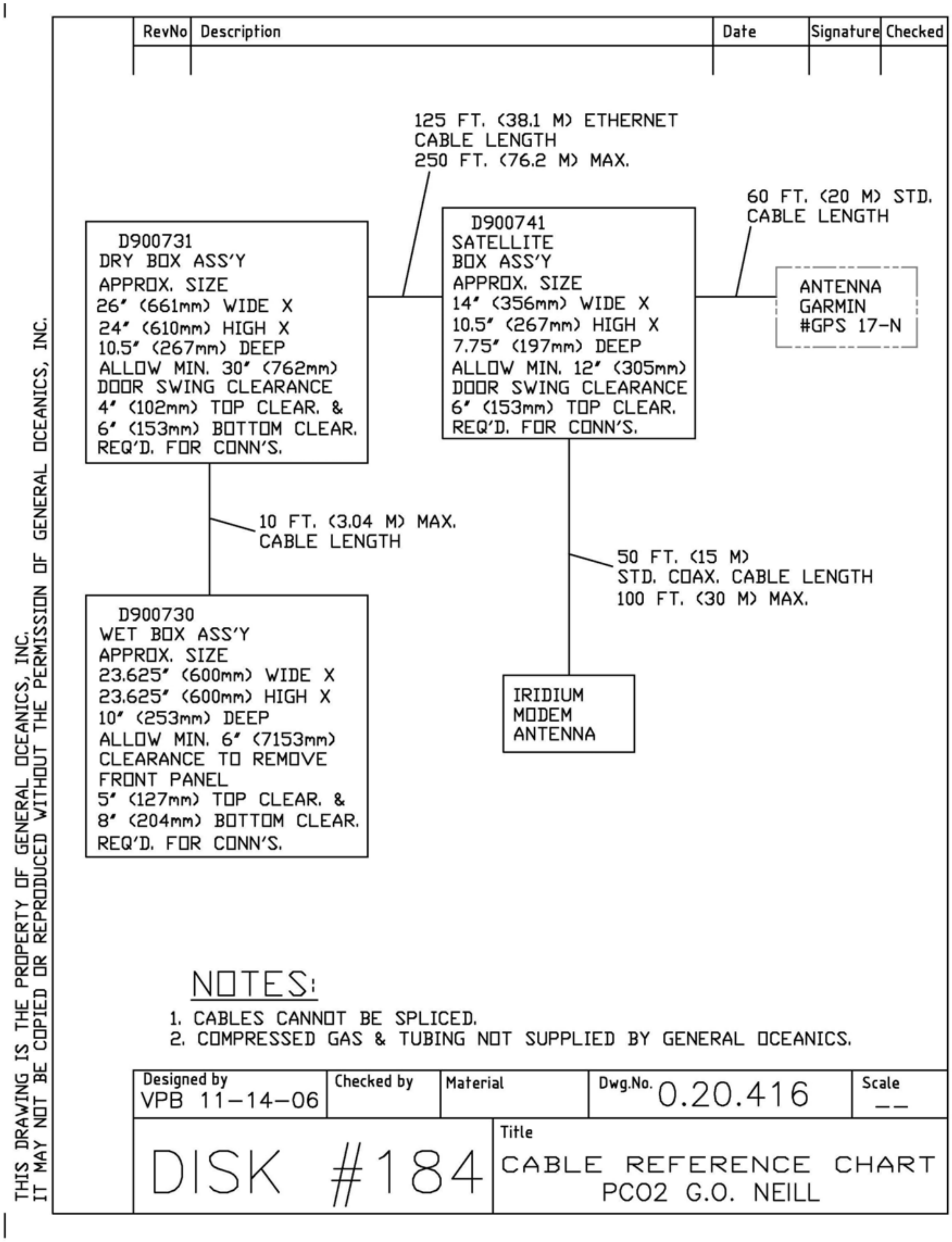


Appendix J. Mounting Dimensions

J.1 Box Dimensions



J.2 Box Connections



Appendix K. Bench Top Supports