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# CGS-240

## Manual

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## 1 INTRODUCTION

The RH Systems CGS-240 Humidity Generator is a system capable of continuous, high-accuracy humidity generation over a wide range of humidity, temperature, and flow rates. The CGS-240 design is an RHS hybrid two-pressure two-temperature system based on the fundamental two-pressure principle originally developed by NIST. The basis of this principle and its original development are discussed below.

### 1.1 BACKGROUND OF HUMIDITY GENERATION

In 1948 at the U.S. National Bureau of Standards (now the National Institute of Standards and Technology), E.R. Weaver and R. Riley developed a “pressure method” for the generation and control of humidity. Their method, termed the *two-pressure principle*, was derived from measurements of temperature and pressure rather than requiring measurements of water vapor.

Using their technique, air or some other gas was saturated with water vapor at high pressure and then expanded to a lower pressure. When saturation and expansion were performed under constant-temperature conditions, the resulting relative humidity of the gas was simply the ratio of the lower pressure to the higher pressure (or at least very nearly).

Their equipment was designed for low rates of gas flow and was used under ambient temperature conditions. Their saturator was a small cylinder containing water and filled with fragments of pumice or stream-washed gravel through which the gas could be bubbled under pressure. This device was developed primarily for the calibration of electrically conductive hygroscopic films used in the measurement of water vapor in gases.

In 1951, also at the National Bureau of Standards, the two-pressure principle was the foundation on which A. Wexler and R.D. Daniels developed a new “pressure–humidity apparatus” with higher air-flow capability. Another significant improvement was the incorporation of temperature control. Developed primarily for hygrometer research and calibration, it was capable of producing atmospheres of known relative humidity from 10 %RH to 98 %RH over a fairly wide temperature range  $-40^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$ .

Wexler also designed and constructed a low-humidity generator based on a method termed the *two-temperature principle*. With the two-temperature principle, a stream of air or other gas is saturated with water vapor at a given temperature; then its temperature is raised to a specified higher value.

### 1.2 SCOPE

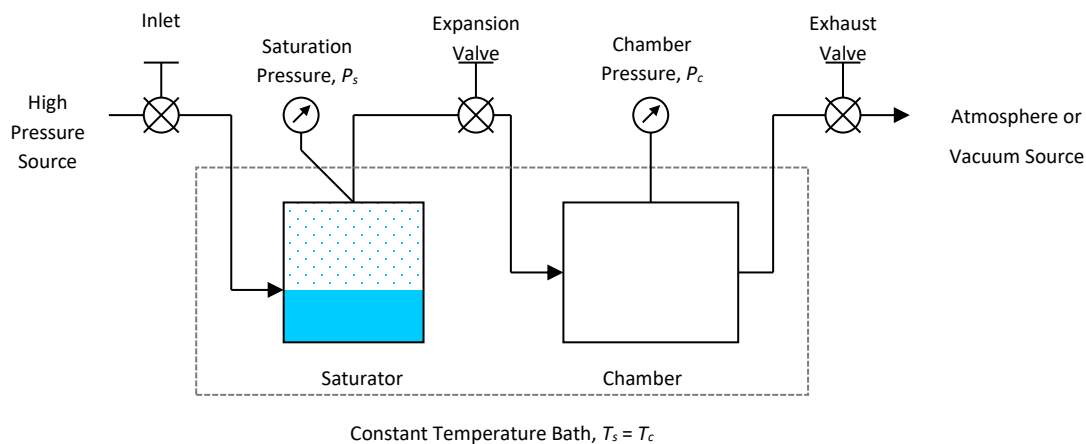
The CGS-240 Humidity Generator is a portable, self-contained system which produces stable atmospheres of known humidity and temperature using the two-temperature, two-pressure saturated vapor stream principle. Its capability and intended purpose is to provide accurate humidity and temperature for the calibration of humidity sensors, hygrothermographs, chilled mirror hygrometers, and other environmental measuring devices.



## 2 THEORY OF OPERATION

### 2.1 TWO-PRESSURE PRINCIPLE

In an ideal two-pressure system, a stream of gas at an elevated pressure is saturated with respect to the liquid or solid phase of water and then expanded isothermally to a lower pressure. Measurements of the pressure and temperature of the gas stream, both at saturation and after expansion, are all that is required to determine the resulting humidity content of the expanded gas stream. The two-pressure system is shown in Figure 1.



**Figure 1**—Simplified schematic diagram of the two-pressure principle where  $T_s$  is saturator temperature,  $T_c$  is chamber temperature, and  $T_s = T_c$ .

A two-pressure generator is commonly used in the generation of a range of relative humidity values at fixed temperatures. The saturator and chamber share a common fluid bath temperature and are, ideally, in thermal equilibrium with each other. In this case, where saturator temperature,  $T_s$ , and chamber temperature,  $T_c$ , are of nearly the same value, the generated relative humidity may be approximated by the ratio of the measured saturated gas-stream pressure (saturator pressure) to the measured chamber pressure by using the simplified expression

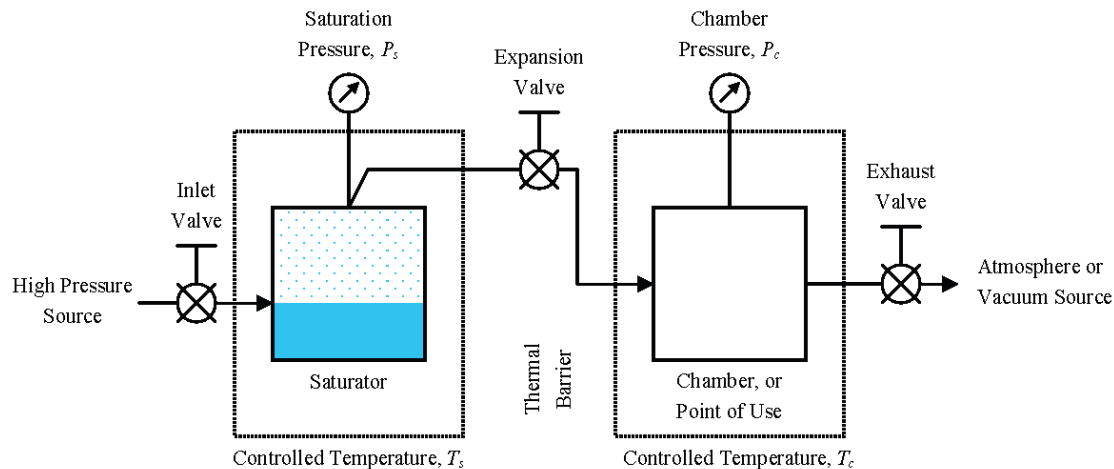
$$RH = \frac{P_c}{P_s} \cdot 100$$

where  $P_c$  is the absolute chamber pressure  
 $P_s$  is the absolute saturation pressure.

Please note that the above expression ignores the use of enhancement factors which account for non-ideal properties of the air / water-vapor mixture, and is therefore only an approximation. More exacting equations which include enhancement factors are used internally within the system.

## 2.2 COMBINED TWO-PRESSURE AND TWO-TEMPERATURE PRINCIPLE

The two-pressure principle described above can be combined with a two-temperature principle to form a combined Two-Pressure, Two-Temperature system which exploits the benefits of both architectures. In addition to measurement of saturation and chamber pressures (as in the case of a two-pressure system), a combined two-pressure two-temperature system also relies on measurement of saturation and chamber temperatures to fully determine the resulting humidity. A combined two-pressure two-temperature system is shown in elemental schematic form in Figure 2—*Simplified schematic diagram of the two-pressure, two-temperature principle where  $T_s \neq T_c$  and  $P_s \neq P_c$ .*



**Figure 2**—Simplified schematic diagram of the two-pressure, two-temperature principle where  $T_s \neq T_c$  and  $P_s \neq P_c$ .

Here, the temperature of saturation,  $T_s$ , and temperature of the chamber,  $T_c$ , may be controlled independently of each other if desired. By allowing the saturator and chamber to operate at different temperatures from each other, a wider variety of humidity values may be generated with reduced requirements on the height of saturation pressure required. Regardless of whether the saturator and chamber are operated at the same temperature, or at temperatures different from each other, all humidity calculations rely on the two pressures ( $P_s$  and  $P_c$ ) and on the two temperatures ( $T_s$  and  $T_c$ ).

## 2.3 COMMON DEFINING EQUATIONS

The following equations of R. Hardy for saturation vapor pressure, enhancement factor, and temperature (from saturation vapor pressure) are common and fundamental to most of the humidity calculations presented here.

### 2.3.1 SATURATION VAPOR PRESSURE OVER WATER

Saturation vapor pressure over *water* at a given ITS-90 temperature in the range  $-100\text{ }^{\circ}\text{C}$  to  $+100\text{ }^{\circ}\text{C}$  is defined by the formula

$$e = \exp \left( \sum_{i=0}^6 g_i T^{i-2} + g_7 \ln T \right) \quad (1)$$

where  $e$  is the saturation vapor pressure (in Pascals) over liquid water in the pure phase

$T$  is the temperature in Kelvin

and

$$\begin{aligned} g_0 &= -2.8365744 \cdot 10^3 \\ g_1 &= -6.028076559 \cdot 10^3 \\ g_2 &= 1.954263612 \cdot 10^1 \\ g_3 &= -2.737830188 \cdot 10^{-2} \\ g_4 &= 1.6261698 \cdot 10^{-5} \\ g_5 &= 7.0229056 \cdot 10^{-10} \\ g_6 &= -1.8680009 \cdot 10^{-13} \\ g_7 &= 2.7150305 \end{aligned}$$


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### 2.3.2 SATURATION VAPOR PRESSURE OVER ICE

Saturation vapor pressure over *ice* at a given ITS-90 temperature in the range  $-100\text{ °C}$  to  $0.01\text{ °C}$  is defined by the formula

$$e = \exp \left( \sum_{i=0}^4 k_i T^{i-1} + k_5 \ln T \right) \quad (2)$$

where  $e$  is the saturation vapor pressure (in Pascals) over ice in the pure phase

$T$  is the temperature in Kelvin

and

$$\begin{aligned} k_0 &= -5.8666426 \cdot 10^3 \\ k_1 &= 2.232870244 \cdot 10^1 \\ k_2 &= 1.39387003 \cdot 10^{-2} \\ k_3 &= -3.4262402 \cdot 10^{-5} \\ k_4 &= 2.7040955 \cdot 10^{-8} \\ k_5 &= 6.7063522 \cdot 10^{-1} \end{aligned}$$


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### 2.3.3 ENHANCEMENT FACTOR

The “effective” saturation vapor pressure over water or ice in the presence of other gases differs from the ideal saturation vapor pressures given in Equations 1 and 2. The effective saturation vapor pressure is related to the ideal by

$$e' = e \cdot f \quad (3)$$

where  $e'$  is the “effective” saturation vapor pressure

$e$  is the ideal saturation vapor pressure (as given in Equation 1 or 2)

and  $f$  is the enhancement factor

The enhancement factor, for an air and water-vapor mixture, is determined at a given temperature and pressure from the formula

$$f = \exp \left[ \alpha \left( 1 - \frac{e}{P} \right) + \beta \left( \frac{P}{e} - 1 \right) \right] \quad (4)$$

$$\text{with } \alpha = \sum_{i=0}^3 a_i T^i \quad (5)$$

$$\text{and } \beta = \exp \left( \sum_{i=0}^3 b_i T^i \right) \quad (6)$$

where  $P$  is the total pressure in the same units as  $e$

$T$  is temperature in Kelvin

and  $a_i, b_i$  depend on temperature range and are given as

for water:

223.15 K to 273.15 K (−50 °C to 0 °C)

$$a_0 = -5.5898101 \cdot 10^{-2}$$

$$a_1 = 6.7140389 \cdot 10^{-4}$$

$$a_2 = -2.7492721 \cdot 10^{-6}$$

$$a_3 = 3.8268958 \cdot 10^{-9}$$

$$b_0 = -8.1985393 \cdot 10^1$$

$$b_1 = 5.8230823 \cdot 10^{-1}$$

$$b_2 = -1.6340527 \cdot 10^{-3}$$

$$b_3 = 1.6725084 \cdot 10^{-6}$$

273.15 K to 373.15 K (0 °C to 100 °C)

$$a_0 = -1.6302041 \cdot 10^{-1}$$

$$a_1 = 1.8071570 \cdot 10^{-3}$$

$$a_2 = -6.7703064 \cdot 10^{-6}$$

$$a_3 = 8.5813609 \cdot 10^{-9}$$

$$b_0 = -5.9890467 \cdot 10^1$$

$$b_1 = 3.4378043 \cdot 10^{-1}$$

$$b_2 = -7.7326396 \cdot 10^{-4}$$

$$b_3 = 6.3405286 \cdot 10^{-7}$$

for ice:

173.15 to 223.15 K (−100 °C to −50 °C)

$$a_0 = -7.4712663 \cdot 10^{-2}$$

$$a_1 = 9.5972907 \cdot 10^{-4}$$

223.15 to 273.15 K (−50 °C to 0 °C)

$$a_0 = -7.1044201 \cdot 10^{-2}$$

$$a_1 = 8.6786223 \cdot 10^{-4}$$

$$a_2 = -4.1935419 \cdot 10^{-6}$$

$$a_3 = 6.2038841 \cdot 10^{-9}$$

$$b_0 = -1.0385289 \cdot 10^2$$

$$b_1 = 8.5753626 \cdot 10^{-1}$$

$$b_2 = -2.8578612 \cdot 10^{-3}$$

$$b_3 = 3.5499292 \cdot 10^{-6}$$

$$a_2 = -3.5912529 \cdot 10^{-6}$$

$$a_3 = 5.0194210 \cdot 10^{-9}$$

$$b_0 = -8.2308868 \cdot 10^1$$

$$b_1 = 5.6519110 \cdot 10^{-1}$$

$$b_2 = -1.5304505 \cdot 10^{-3}$$

$$b_3 = 1.5395086 \cdot 10^{-6}$$

#### 2.3.4 TEMPERATURE FROM SATURATION VAPOR PRESSURE

Equations 1 and 2 are easily solved for saturation vapor pressure over water or ice for a given saturation temperature. However, if vapor pressure is known and temperature is the unknown desired quantity, the solution immediately becomes complicated and must be solved by iteration. For ease of computation, the following inverse equation is provided. This equation is generally used to find the dew point or frost point temperature when the vapor pressure of a gas has been determined. When vapor pressure is known, use the water coefficients to obtain the dew point and use the ice coefficients to obtain the frost point.

$$T = \frac{\sum_{i=0}^3 c_i (\ln e)^i}{\sum_{i=0}^3 d_i (\ln e)^i} \quad (7)$$

where  $T$  is the temperature in kelvin

and  $e$  is the saturation vapor pressure in pascals

with coefficients

for water:

$$c_0 = 2.0798233 \cdot 10^2$$

$$c_1 = -2.0156028 \cdot 10^1$$

$$c_2 = 4.6778925 \cdot 10^{-1}$$

$$c_3 = -9.2288067 \cdot 10^{-6}$$

$$d_0 = 1$$

$$d_1 = -1.3319669 \cdot 10^{-1}$$

$$d_2 = 5.6577518 \cdot 10^{-3}$$

$$d_3 = -7.5172865 \cdot 10^{-5}$$

for ice:

$$c_0 = 2.1257969 \cdot 10^2$$

$$c_1 = -1.0264612 \cdot 10^1$$

$$c_2 = 1.4354796 \cdot 10^{-1}$$

$$c_3 = 0$$

$$d_0 = 1$$

$$d_1 = -8.2871619 \cdot 10^{-2}$$

$$d_2 = 2.3540411 \cdot 10^{-3}$$

$$d_3 = -2.4363951 \cdot 10^{-5}$$

## 2.4 HUMIDITY EQUATIONS

The following equations are used in the CGS-240 to calculate various humidity parameters. These equations are not approximations, but rather account for the temperature differences between the saturator and chamber, and the non-ideal behavior of water vapor when admixed with air or other gases.

### 2.4.1 RELATIVE HUMIDITY

Percent relative humidity is the ratio of the amount of water vapor in a gas to the maximum amount possible at the same temperature and pressure. For two-pressure, two-temperature systems, it is defined by the equation

$$RH = \frac{P_c}{P_s} \cdot \frac{e'_s}{e'_c} \cdot 100 \quad (8)$$

which then expands to

$$RH = \frac{P_c}{P_s} \cdot \frac{f_s}{f_c} \cdot \frac{e_s}{e_c} \cdot 100 \quad (9)$$

where  $P_c$  is the absolute chamber pressure

$P_s$  is the absolute saturation pressure

$f_c$  is the enhancement factor at chamber temperature and pressure

$f_s$  is the enhancement factor at saturator temperature and pressure

$e_c$  is the saturation vapor pressure at chamber temperature

and  $e_s$  is the saturation vapor pressure at saturator temperature.

### 2.4.2 DEW POINT TEMPERATURE

Dew point temperature is the temperature to which a gas must be cooled to initiate condensing water vapor in the form of dew (note that dew point temperature can exist above or below 0°C). Dew point temperature is obtained with the following iterative steps.

- Make an educated guess at the dew or frost point enhancement factor  $f_d$ . Setting  $f_d = 1$  is a suitable first guess.
- Next, compute the dew or frost point vapor pressure of the gas with the formula

$$e_d = e_s \cdot \frac{f_s}{f_d} \cdot \frac{P_c}{P_s} \quad (10)$$

- Use the dew or frost point vapor pressure  $e_d$  determined in the previous step, along with Equation 7 for water, to compute  $T$ . Call this value the dew point temperature  $T_d$ .

- d. Use the dew point temperature  $T_d$ , chamber pressure  $P_c$ , and Equation 4 for water to compute the dew or frost point enhancement factor  $f_d$ .
- e. Converge to the proper dew point temperature  $T_d$  by repeating steps b through d several times, as necessary.

### 2.4.3 FROST POINT TEMPERATURE

Frost point temperature is the temperature to which a gas must be cooled to begin condensing water vapor in the form of frost or ice. Frost point exists only at temperatures below freezing. Frost point is obtained with the following iterative steps.

- a. Make an educated guess at the dew or frost point enhancement factor  $f_d$ . Setting  $f_d = 1$  is a suitable first guess.
- b. Next, compute the dew or frost point vapor pressure of the gas with the formula
 
$$e_d = e_s \cdot \frac{f_s}{f_d} \cdot \frac{P_c}{P_s} \quad (10)$$
- c. Use the dew or frost point vapor pressure  $e_d$  determined in the previous step, along with Equation 7 for ice, to compute  $T$ . Call this value the frost point temperature  $T_f$ .
- d. Use the frost point temperature  $T_f$ , chamber pressure  $P_c$ , and Equation 4 for ice to compute the dew or frost point enhancement factor  $f_d$ .
- e. Converge to the proper frost point temperature  $T_f$  by repeating steps b through d several times, as necessary.

### 2.4.4 VAPOR CONCENTRATION, PPMV

Vapor-concentration, traditionally referred to as parts per million by volume (ppmv), is a ratio relating the number of moles of water vapor to the number of moles of the remaining constituents in the gas (the dry gas component). Once established by the following formula, the vapor concentration is insensitive to further changes in pressure or temperature, provided there is no subsequent condensation.

$$\text{vapor concentration} = \frac{f_s \cdot e_s}{P_s - f_s \cdot e_s} \cdot 10^6 \text{ } \mu\text{mol/mol} \quad (11)$$

### 2.4.5 HUMIDITY RATIO

Humidity ratio  $w$  is defined as the mass of water vapor to the mass of the dry gas; it is computed with the formula

$$w = \frac{M_w \cdot f_s \cdot e_s}{M_g (P_s - f_s \cdot e_s)} \text{ g/g} \quad (12)$$

where  $M_w$  is the molecular weight of water vapor, 18.02

$M_g$  is the molecular weight of the carrier gas (28.9645 for air).

Humidity ratio may also be computed and expressed in grams per kilogram and micrograms per gram. When expressed in micrograms per gram, humidity ratio is traditionally referred to in parts per million by weight (ppmw).

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#### 2.4.6 ABSOLUTE HUMIDITY

Absolute humidity  $d_v$  is defined as the mass of water vapor to the unit volume of humidified gas and is computed with the formula

$$d_v = \frac{M_w}{R \cdot T_c} \cdot \frac{f_s \cdot e_s \cdot P_c}{P_s} \text{ g/m}^3 \quad (13)$$

where  $R$  is the molar gas constant 8.31472

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#### 2.4.7 SPECIFIC HUMIDITY

Specific humidity  $q$  is defined as the mass of the water vapor to the total mass of the gas mixture and is computed with the formula

$$q = \frac{M_w \cdot f_s \cdot e_s}{M_g (P_s - f_s \cdot e_s) + M_w \cdot f_s \cdot e_s} \text{ g/g} \quad (14)$$



## 3 INSTALLATION

### 3.1 FACILITY REQUIREMENTS

#### 3.1.1 POWER

The generator requires 200-240 VAC, single phase, 20A, 50/60 Hz. The system is supplied with a custom Y-style power cord. One connector feeds the humidity generator via the upper cabinet receptacle; the other connector feeds the air compressor via the lower cabinet receptacle.

The power cord is generally fitted with a NEMA 6-20 plug, however other plugs are available upon request.

#### 3.1.2 COMPRESSED GAS SUPPLY

The system requires oil-free compressed air or nitrogen to operate and is supplied with an internal air compressor that resides in the lower cabinet. The pressurized air is connected through an air hose to the upper cabinet of the humidity generator.

The system may operate from this supplied air source, or from a user supplied external pressurized gas source. The recommended pressure is approximately 90 psi but a supply pressure range from 60 psi to 150 psi is suitable. It should be capable of providing a flow rate of approximately 20 liters per minute more. When utilizing your own pressurized gas supply, it should meet the following minimum requirements:

- Clean** A general purpose 10 micron in-line air filter is generally sufficient to limit particle size.
- Dry** A pressure dew point of 20 °C or lower is recommended. Liquid water should not be present in the air supply line if possible as this could overload the capacity of the humidity generator's internal air drier system.
- Oil-free** Oil within the air supply stream is one of the most harmful contaminants to a humidity generator as it tends to coat the internal surfaces of the saturator, preventing it from producing the correct humidity. While there are coalescing filters (for liquid oil removal), and activated charcoal filters (for vaporous oil removal), these oil removal practices are not recommended as oil could still find its way through the filters and into the system. It is best to start with an oil-free compressor. An oil-free compressor eliminates the need for oil filtration / removal.

#### 3.1.3 DISTILLED WATER

This system requires a source of distilled water for operation. The amount required depends on several factors, including the humidity being generated, the temperature of that generation and the flow rate. For initial operation, about 5 gallons of distilled water will be required. Additional distilled water will be required depending on usage which is based on generated humidity, temperature, and flow rate. Generating high temperature, high humidity, and high flow rate utilize the most water, while lower temperature, lower humidity, and lower flow rate utilize the least. Plan on typical usage of about 1 gallon (4 liters) of distilled water per week.

### 3.1.4 FLOOR SPACE

The system dimensions are 52 inches wide, 30 inches deep, 54 ½ inches high (1.3 m x 0.76 m x 1.4 m). For service access and swing of the doors, the system should have 2 feet (0.6 m) of free space in the rear and on each side, and approximately 2 feet (0.6 m) of space in the front.

The system is on casters and may be rolled into tight areas for use and rolled out for service. To secure the system in place, the caster locks may be engaged, preventing the casters from rolling.

## 3.2 UTILITY CONNECTIONS

### 3.2.1 AC POWER CONNECTION

The system connects to AC power via the supplied 200-240V AC Y-style power cable. Plug the two connectors into the system at the rear panel (one into the upper cabinet receptacle and one into the lower cabinet receptacle) then plug the other end into your 200-240VAC power source.

Turning on the upper cabinet rear panel power switch applies power to the upper cabinet only which houses the humidity generator.

The lower cabinet rear panel power switch applies power to the lower cabinet only which houses the air compressor system.



Figure 3.1

### 3.2.2 GAS SUPPLY CONNECTION WHEN UTILIZING SUPPLIED AIR COMPRESSOR

The lower cabinet houses the supplied air compressor. As shipped, a pneumatic connection is already made between the lower and upper cabinets to supply the compressed air from the lower cabinet to the humidity generator housed in the upper cabinet. This connection is via the short blue tube located between the rear panel power switches.



Figure 3.2

Enable the air compressor operation by turning on the lower cabinet rear power switch.



Figure 3.3

Open the lower front cabinet doors and ensure the red knob on the top of the compressor pressure switch is in the ON position. The air compressor should begin running and continue until its maximum (cut-out) pressure is achieved. The current tank pressure is indicated on the tank mounted mechanical pressure gauge. The air compressor will cycle between its lower (cut-in) and upper (cut-out) factory pressure settings.



Figure 3.3 "ON"



Figure 3.4 "OFF"



Figure 3.4

Ensure the orange pneumatic valve is also in the OPEN position, with its arrow in-line with the hose connections and pointing away from the air compressor.



Figure 3.6 "OPEN"



Figure 3.5 "CLOSED"

Adjust the pressure regulator at the back of the unit to approximately 50-55 psi, see section 7.1.5.3.

### 3.2.3 GAS SUPPLY CONNECTION WHEN UTILIZING AN EXTERNAL PRESSURIZED AIR SOURCE

It is possible to operate the humidity generator from an external pressurized air source. Before connection, ensure the external pressurized air source is clean, dry, and oil-free as identified in section 3.1.2. A regulated pressure of approximately 60 to 150 psig is recommended.

Prior to connection of an external pressurized air source, ensure the internal air compressor that was supplied with the system is turned off (Figure 3.4) and the pneumatic valve is closed (Figure 3.7). If not using the supplied air compressor, the lower rear panel power switch may also be turned off.

Disconnect the short blue  $\frac{1}{4}$ " diameter pneumatic connection tube from the upper cabinet fitting. Do so by pressing upward on the end of the fitting where the tube inserts, while simultaneously pulling downward on the tube to remove it. Connect your external gas supply to this upper cabinet push-to-connect fitting using a standard  $\frac{1}{4}$ " outer diameter flexible hose (such as PTFE, PFA, PUR). Press the tube fully into the fitting to lock it into place.

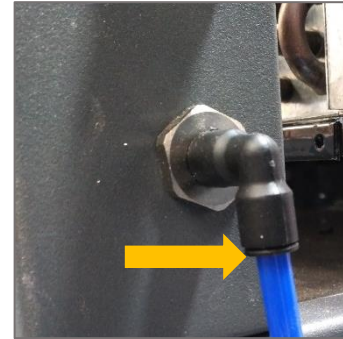


Figure 3.7 Pressurized Air Connection



Figure 3.8A Pressure Regulator

Turn on your external air source and power up the CGS-240 on the front panel below the monitor (the back panel power switch of the upper cabinet must also be on). Press and hold the red button on the left side of the air dryer assembly to activate the air inlet solenoid (pictured below). Then adjust the internal pressure regulator to a value of at least 5 psi lower than the lowest pressure expected from your external pressurized source. This allows the internal pressure regulator to operate normally and ensure stable pressure to the system. After regulator adjustment, you can let go of the red button and the pressure on the gauge will slowly drop to 0, which is normal.



Figure 3.9B Red Button on Air Dryer Solenoid

If the regulator was adjusted more than 20-30% of its previous pressure value, then it is recommended to adjust the air bleed to the fan motor housing, located on the back of the chamber.

To adjust the air bleed to the fan motor housing refer to section 7.1.5.3.

### 3.2.4 DISTILLED WATER CONNECTION

The system automatically siphons distilled water from its Distilled Water Reservoir located in the lower cabinet. A 1/8" diameter flexible tube is pre-installed into the tank to siphon water from the tank bottom. It passes through the tank's cover screw, through a fitting in the lower cabinet, connects through a fitting on the upper cabinet, connecting finally to the presaturator fill pump. As these tubes and connections are pre-installed at the factory, there are no other additional connections to make for distilled water.

### 3.2.5 SYSTEM DISCHARGE CONNECTION

There is a 1/2" pipe connection on the rear corner of the cabinet for discharge of air, water vapor, and condensate removed via the air drier.

If your pressurized air source is dry, and you generally operate the humidity generator at a temperature no warmer than 25 °C, you will likely never see any water coming from the discharge connection. However, if you utilize the internal air compressor, or operate the generator at chamber temperatures above 25 °C, condensation may occur at this discharge connection. The higher the chamber temperature and humidity, the more condensation will be present.

You may, if desired, connect a 1/2" NPT fitting and tube to direct this discharge away from the system to a small drip pan or a floor drain. A drip pan volume of 0.5 to 1 liter is generally sufficient.

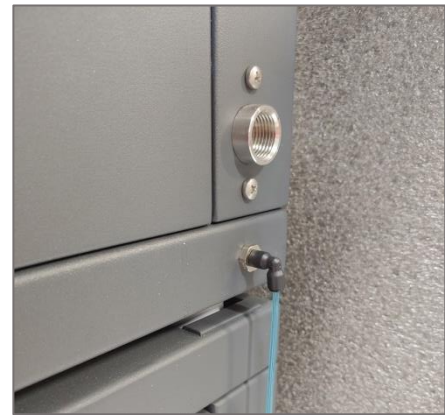


Figure 3.10 Discharge Connection

## 3.3 INITIAL PREPARATION

### 3.3.1 COMPUTER CONNECTION

The system is supplied with its own built-in computer and monitor on the right-side front panel door. Enable the computer, monitor, and internal control system by pressing the front panel power switch located below the monitor in the upper right cabinet panel. The switch should illuminate, the monitor should activate, and the operating system (Windows 10) should boot. Follow section 4.1 through 4.2.1 to launch the RHS Control program and connect to the CGS-240 Humidity Generator.

Interaction with the system is via touch screen or physical mouse/keyboard. To utilize the physical mouse/keyboard, plug them into the USB connectors located at the upper right rear of the system.

Additional connectors (HDMI and RS-232) are also available at the same location. The HDMI connector is for attachment of an additional external monitor if desired. The RS-232 connector allows connection of an external computer system if desired. An external computer system could be utilized to operate the generator in the event of needed firmware updates, secondary system monitoring, or alternate data collection. This connection may also



be utilized for system operation in the event of internal computer system failure. There is no need to connect to the HDMI or RS-232 connectors for operation of the humidity generator.

### 3.3.2 INITIAL FLUID FILL

When the system arrives, it will have shipped to you dry. Prior to operation, you'll need to fill the system with cooling fluid (a mix of propylene glycol and water used for temperature control of the system) and distilled water (used in the gas humidification process).

#### 3.3.2.1 FLUID LOOP INITIAL FILLING PROCEDURE

The system cooling/heating loop utilizes a fluid mixture of propylene glycol (PG) and water with a final PG concentration between 30% and 50%. The system will be supplied with 2 gallons of clear propylene glycol. You'll need to supply approximately 2.5 gallons of distilled water to mix with it. Total cooling loop system capacity is approximately 4 gallons (~16 liters).

- Remove the top and rear panels to gain access to the fill bottle. Do so by pressing the two black panel clips and pulling the panel straight outward (or upward on the top panel).
- Open the purge valve located at the top back center of the chamber. This valve helps to purge the system of trapped air while filling. The valve is open when the orange knob points upward, closed when the orange knob points to the side. (In the picture, the valve is closed.)



Figure 3.11 Water bottle and Vent valve

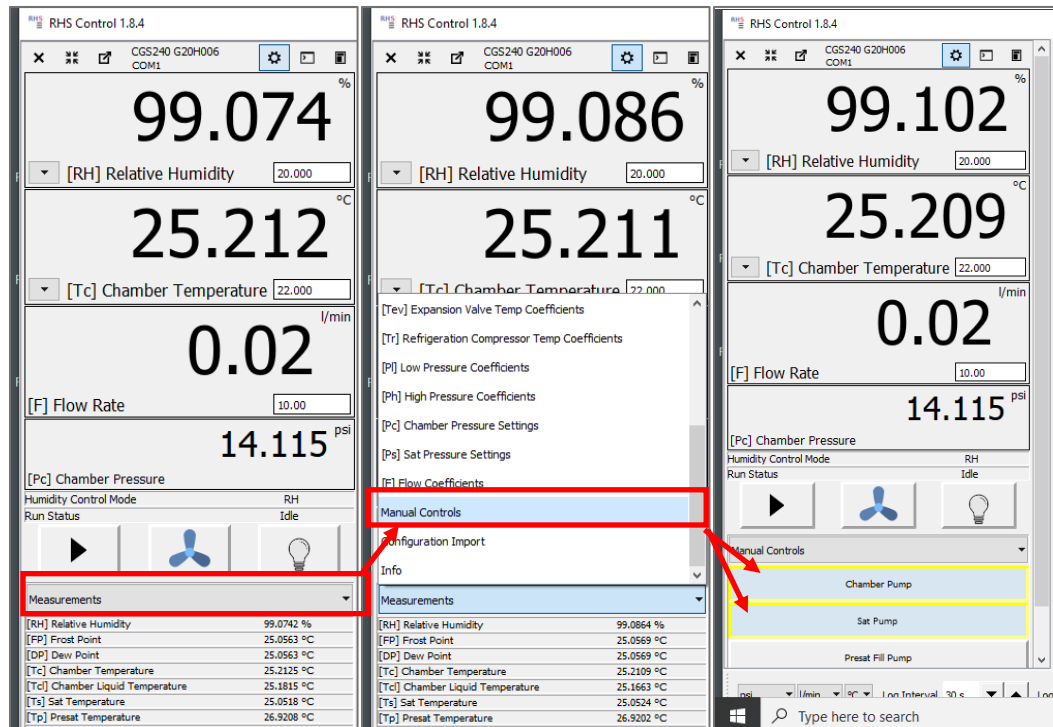
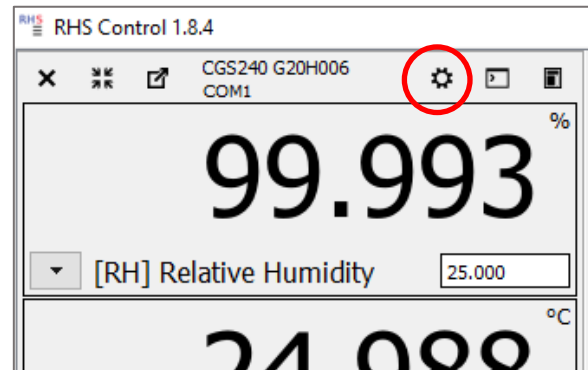
- Remove the black cap from the bottle's fill port located at the upper left rear corner.
- Using the supplied funnel, slowly pour in 1 gallon of water (do not overflow the fill port).
- Slowly add in 1.5 gallons of PG (do not overflow the fill port).



Figure 3.12 Fluid Fill Port

- Have about 2 gallons of distilled water readily available, and then start the Chamber Pump and Saturator Pump. To do this:

- Click the **Settings** icon at the top of the screen
- Using the newly displayed pull-down menu, select **Measurements > Manual Controls**.
- Click the **Chamber Pump** and **Saturator Pump** buttons to turn them on.



- Turning on the pumps causes the fluid to flow through the system. As the level in the fill port tank begins to drop, add water to maintain it within the tank's labeled center marks.
- Stop and Start the Chamber Pump and Saturator Pump a few times as necessary to clear the system of large, trapped air bubbles. The pumps take about a minute or so to ramp up to full speed each time they are restarted. Therefore, allow the pumps to run at least a minute between each Stop/Start sequence.

- After pumping for a few minutes, and the large air bubbles are cleared, close the purge valve located at the top rear center of the chamber.
- Ensure the tank level is between the labeled center marks by adding water or draining some fluid as necessary.
- Stop the Chamber and Saturator Pumps.
- Replace the fill port cap.
- After the first few hours of initial operation, check the fluid level again and adjust as needed to maintain it within the tank's labeled center marks.
- The initial fill results in a PG concentration between 30% and 50%.

---

#### 3.3.2.2 FILL THE DISTILLED WATER RESERVOIR

Distilled water goes in the 5-gallon (~20 liter) plastic reservoir located in the lower cabinet. Using DISTILLED WATER ONLY, fill this reservoir to at least half full (approximately 2.5 gallons) or more. This distilled water reservoir is used in maintaining the pre-saturator water level needed for the humidification process.

**Important:** Use DISTILLED WATER ONLY. Do not use DEIONIZED water, as it can be chemically aggressive to stainless steel and other materials used within the system causing system failure due to pitting, pinholes, and leaks.



Figure 3.13 Filling the Reservoir

---

#### 3.3.2.3 PRIME THE PRESAT FILL PUMP

Prior to initial operation, or if the Distilled Water Reservoir tank becomes empty, the preset pump requires priming.

- Ensure the Distilled Water Reservoir is at least half full.
- Fill the supplied syringe by drawing distilled water into it.

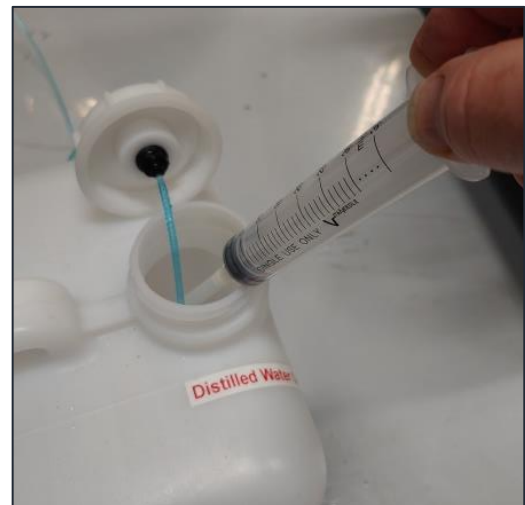


Figure 3.14 Filling the syringe



- With the tube pointing upward, squeeze the air from the tube and top of the syringe. You'll need at least 20 ml of water remaining to continue.
- Reach the end of the suction tube by pulling it out from the bottle.
- Press the syringe's hose over the end of the suction tube (don't worry about the stainless-steel nut near the end of the suction tube; it acts only as a weight to keep the tube below the water level during operation)
- Inject at least 20 ml of distilled water from the syringe through the suction tube. Water should reach the preset pump to wet and prime it. Any excess beyond the 20 ml minimum simply passes through the pump and ends up in the pre-saturator as expected.
- If the water will not go through, press the Presat Fill Pump button. This activates the pump for 10 seconds.
- Remove the syringe and allow the blue suction tube to drop to the bottom of the reservoir, below the water level.  
The end of the tube and the stainless-steel nut will rest on the bottom of the tank.
- Reinstall the reservoir cap and place the bottle within the lower cabinet, being careful not to kink or restrict the tube.

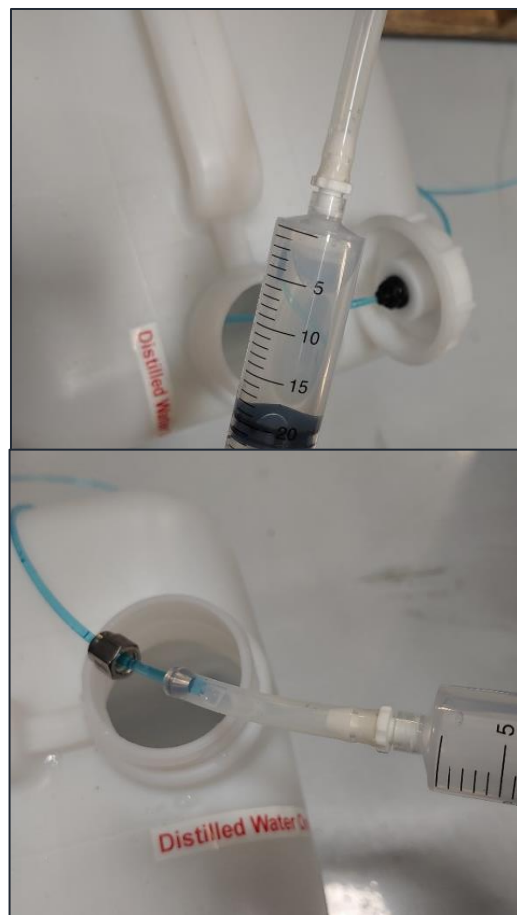


Figure 3.17 Prime the Presat Fill Pump

#### 3.3.2.4 INITIAL PRE-SATURATOR FILL

The presat fill pump will attempt to fill the presaturator automatically whenever the system is run (section 4.4.2). If the preset is dry, the initial presat fill operation may require up to 5 minutes of pumping time to reach the required level. The system may shut down during this initial filling operation with a presat filling error. This is normal and is intended as standard system protection. Simply run the generator again. It may take a few attempts to completely fill the pre-saturator the first time. Following this initial fill, the pre-saturator should automatically maintain its proper distilled water level, drawing from the reservoir as needed.

## 4 OPERATION

RHS Control is a PC program (available on Windows and Linux) which allows the user to operate the humidity generator system. Operation may be manual, through direct entry of desired setpoints, or automatically, through a series of preprogrammed, user selectable setpoints and times.

In addition to entering setpoints for control, the program offers visualization of resulting data in real-time both in numerical and graphical formats. It also allows for connection to other instruments such as those connected as Units Under Test, or UUT's, provided they have a serial data port. For those instruments with a serial data port, a customized protocol description in the form of a .json file is used to make the data connection. These .json files are text files utilizing our RHS Descriptor Language to define the instrument protocol, commands, and data presentation method. These instrument specific files may be created and/or modified by end users, or they may be obtained from RH Systems for particular instruments. While these descriptor files are available for RH Systems brand products, they can also be created for a wide variety of instruments and are not limited by brand and model. The main requirement is that the instrument be connected via a serial interface that can respond to command requests in a consistent manner.

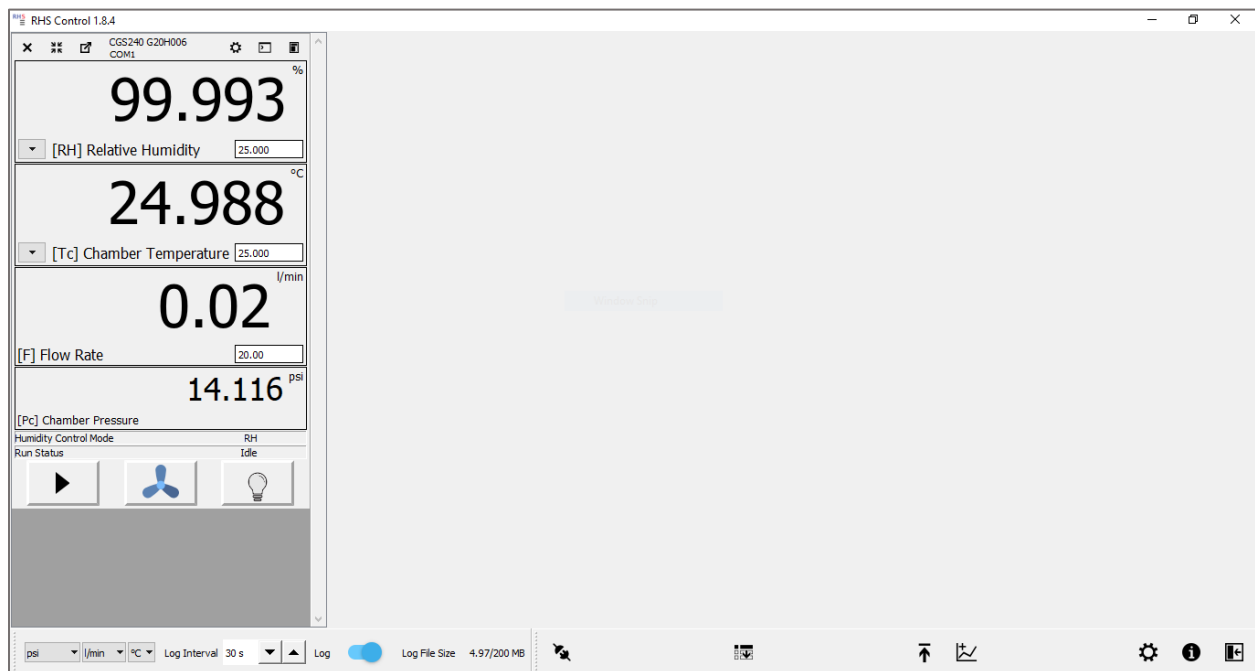


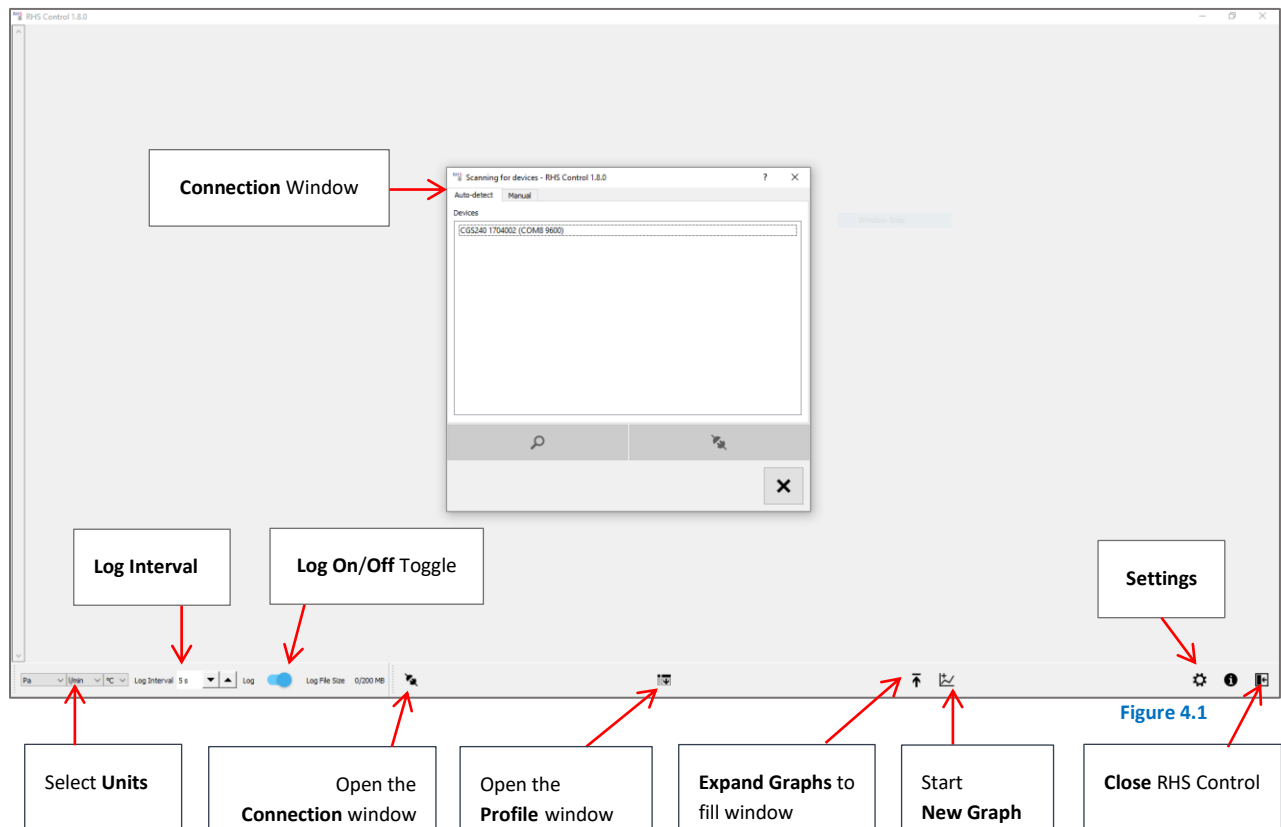
Figure 4.0

## 4.1 INTRODUCTION TO SOFTWARE

To launch RHS Control, simply click its desktop icon.



The main program loads and automatically presents the software splash screen followed by the Connection window. The splash screen indicates the software version number.



## 4.2 CONNECTION WINDOW

All instrument connections are initiated via the Connection window. When the program is first launched, this window appears automatically. However, it may be opened for use at any time simply by pressing the Connection button on the main RHS Control screen.

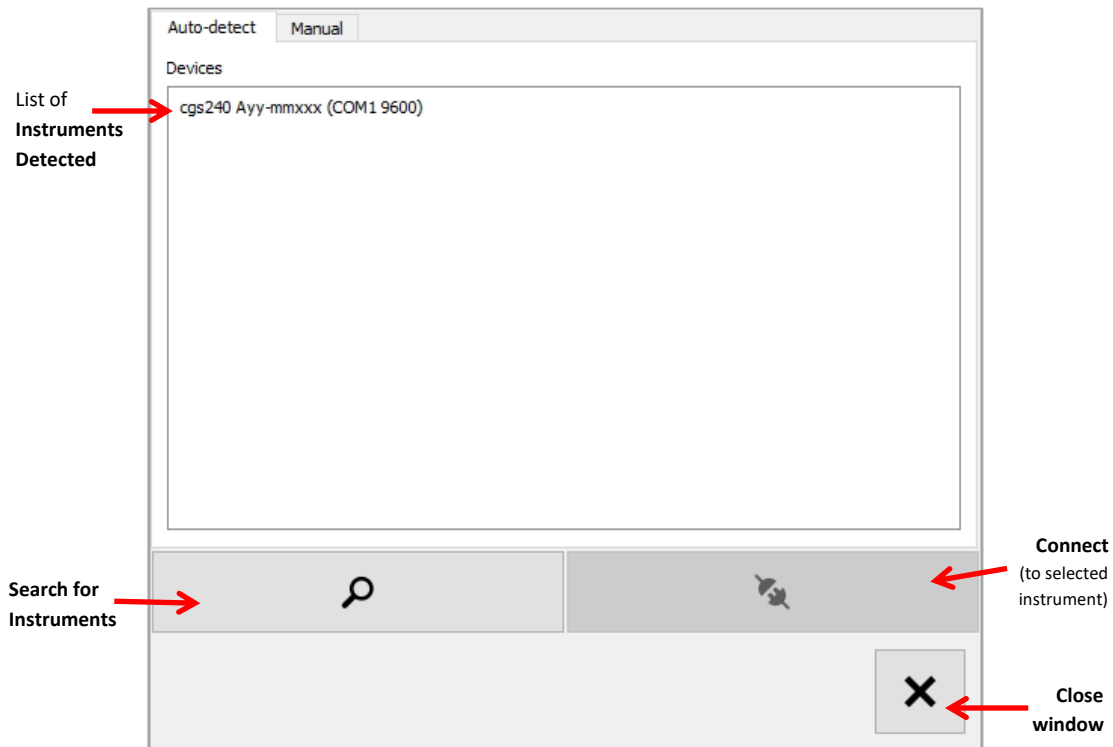


Figure 4.2

### 4.2.1 CONNECT THE CGS-240

When the Connection window opens, it initiates an automatic search for attached instruments.

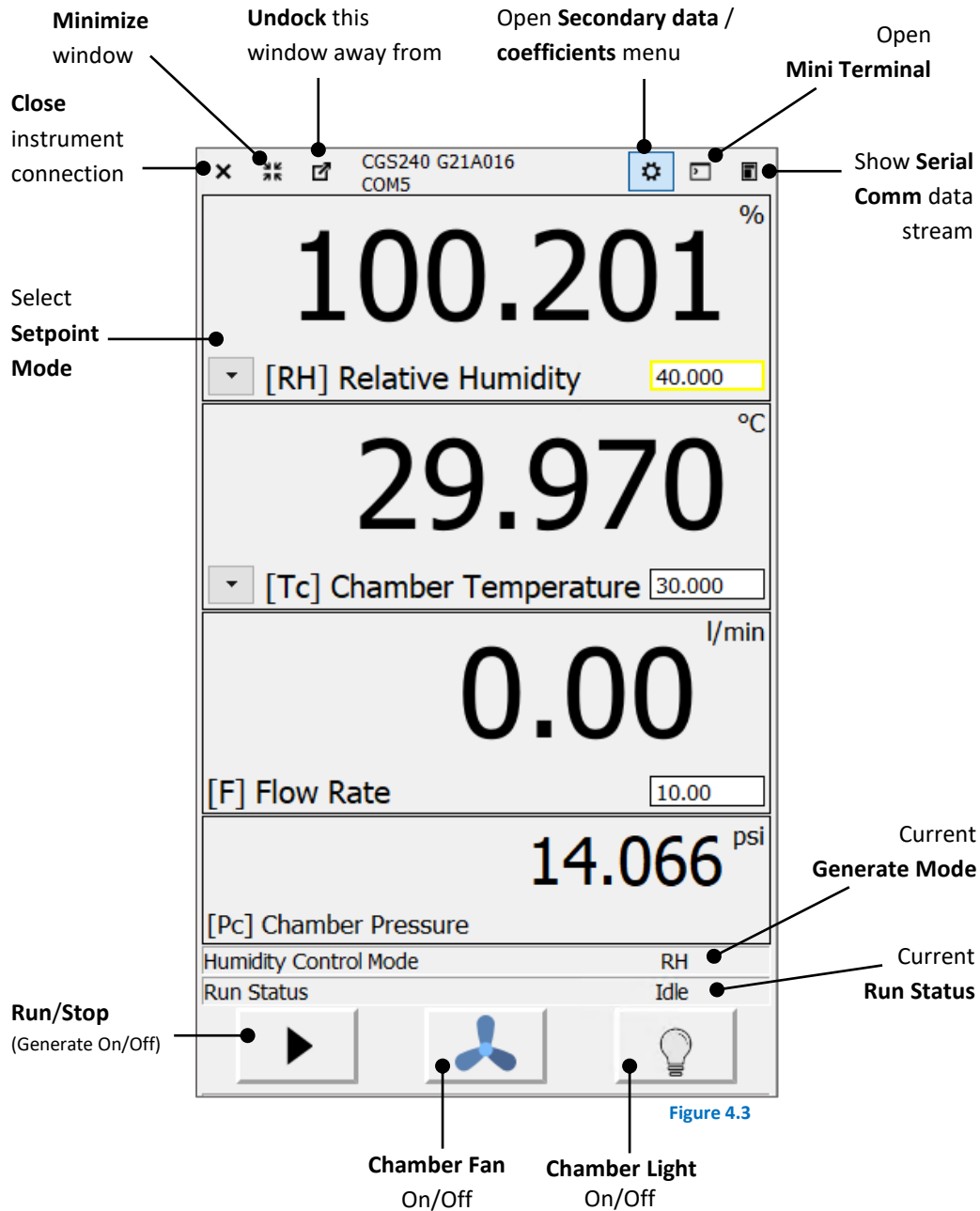
To connect:

1. If the instrument you want to connect with is not listed, ensure it is plugged into a USB port (via a USB/232 converter as needed), then press the **Search** button.
2. Click on any instrument(s) listed. The selected line(s) will highlight.
3. Click the **Connect** button. If there are no further instruments listed, the window closes automatically. If other instruments are still listed, the window remains open.
4. To close the window, press the **Close** button.



### 4.3 ENTER SET POINT

A unique window appears within the main screen for each connected instrument. The following window is typical of a CGS-240.



All fields within the Setpoint column that are white in color are user editable.

The Setpoint Mode Selection is a drop-down menu that allows selection of the following control modes:

- RH
- Frost Point
- Dew Point
- Saturator Pressure

The fields to the right of the Setpoint Mode Selection will change according to the control mode selected.

#### 4.4 SELECTING CONTROL MODE AND INITIATING GENERATE

The CGS-240 can control in one of several different humidity control modes which automatically picks suitable parameters for saturation temperature and saturation pressure. As an alternative, it may also be operated by entering setpoints for saturation temperature and saturation pressure directly.

##### 4.4.1 HUMIDITY CONTROL MODE

While in a valid humidity control mode (RH, FP, DP), the CGS-240 automatically determines suitable target values for saturation temperature and saturation pressure.

1. Click the drop-down menu to reveal the various control mode options.

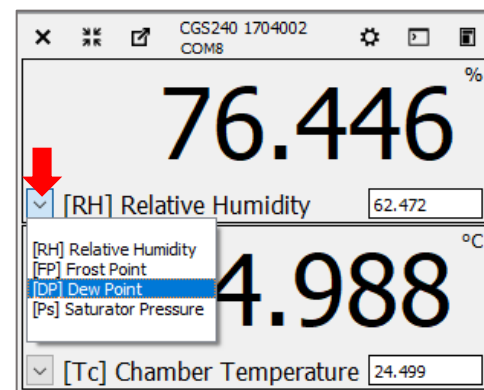


Figure 4.4

2. Select one of the listed control modes.

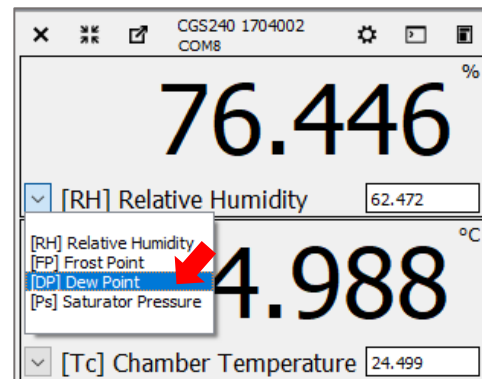


Figure 4.5

- Click the value in the Setpoint field.

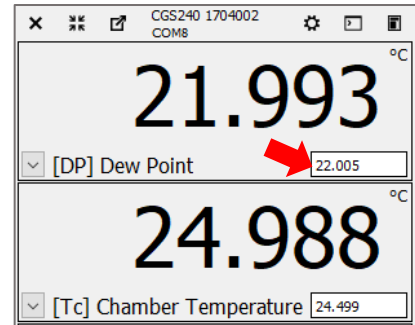


Figure 4.6

- The field border highlights red. Edit the value and press **Enter**.

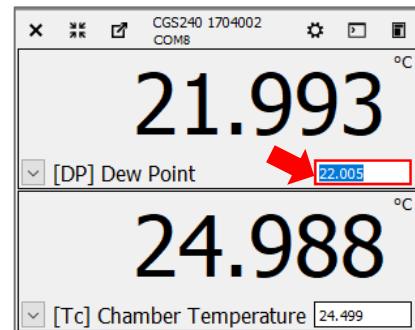


Figure 4.7

After pressing Enter, the highlight changes color to yellow to indicate the new setpoint is being sent.

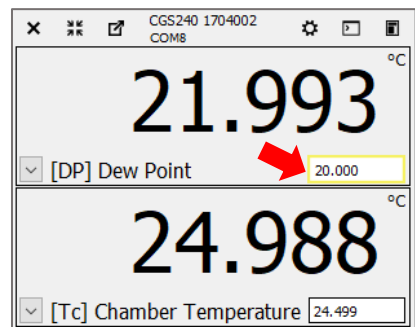


Figure 4.8

- Once the setpoint is sent to the generator and accepted, the highlight disappears. A new value is then read from the CGS-240 and will be displayed. Saturation Temperature and Saturation Pressure setpoints will be automatically recomputed if needed.

Set point values are a limit by the system to prevent out of range entries.

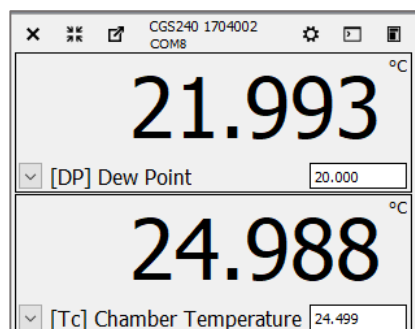


Figure 4.9

The CGS-240 automatically determines a suitable saturation temperature setpoint when entering a new humidity setpoint. The saturation temperature it determines depends on the available system pressure. If the system is unable to reach the desired humidity setpoint using pressure alone, it will automatically adjust saturation temperature as needed to generate the desired humidity value. Once saturation temperature is determined and being controlled, the system continually adjusts saturation pressure to bring about the desired humidity output.

Changing the humidity drop down menu does not change the humidity control mode, but altering the setpoint of the humidity line causes the control mode to switch to that selected control mode.

#### 4.4.2 RUN/STOP THE HUMIDITY GENERATION PROCESS

Start the generator by pressing the **Run** button.

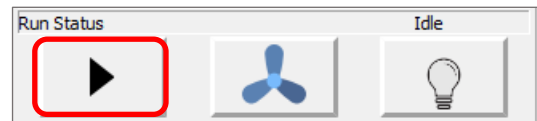


Figure 4.9  
Idle

It toggles to a **Stop** button which you may press to stop the generating process.

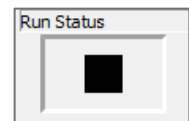


Figure 4.10  
Generating

#### 4.4.3 CHAMBER FAN OPERATION

The chamber fan turns on and off automatically with the **Run/Stop** button. When the system is run, the fan also runs. When the system is stopped, the fan also stops. The fan may be turned ON or OFF manually at any time by pressing the FAN button.

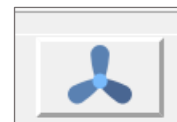


Figure 4.11  
Fan Off

The status will be indicated by a changed icon and a visually depressed look of the button.

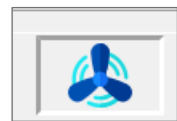


Figure 4.12  
Fan On

#### 4.4.4 CHAMBER LIGHT

The chamber light is normally off. Turn the chamber light on/off at any time by pressing the **Light** button. The status will be indicated by a changed icon and a visually depressed look of the button. The light is on an automatic timer and will remain on for only 30 seconds at a time.



Figure 4.13  
Light Off



Figure 4.14  
Light On

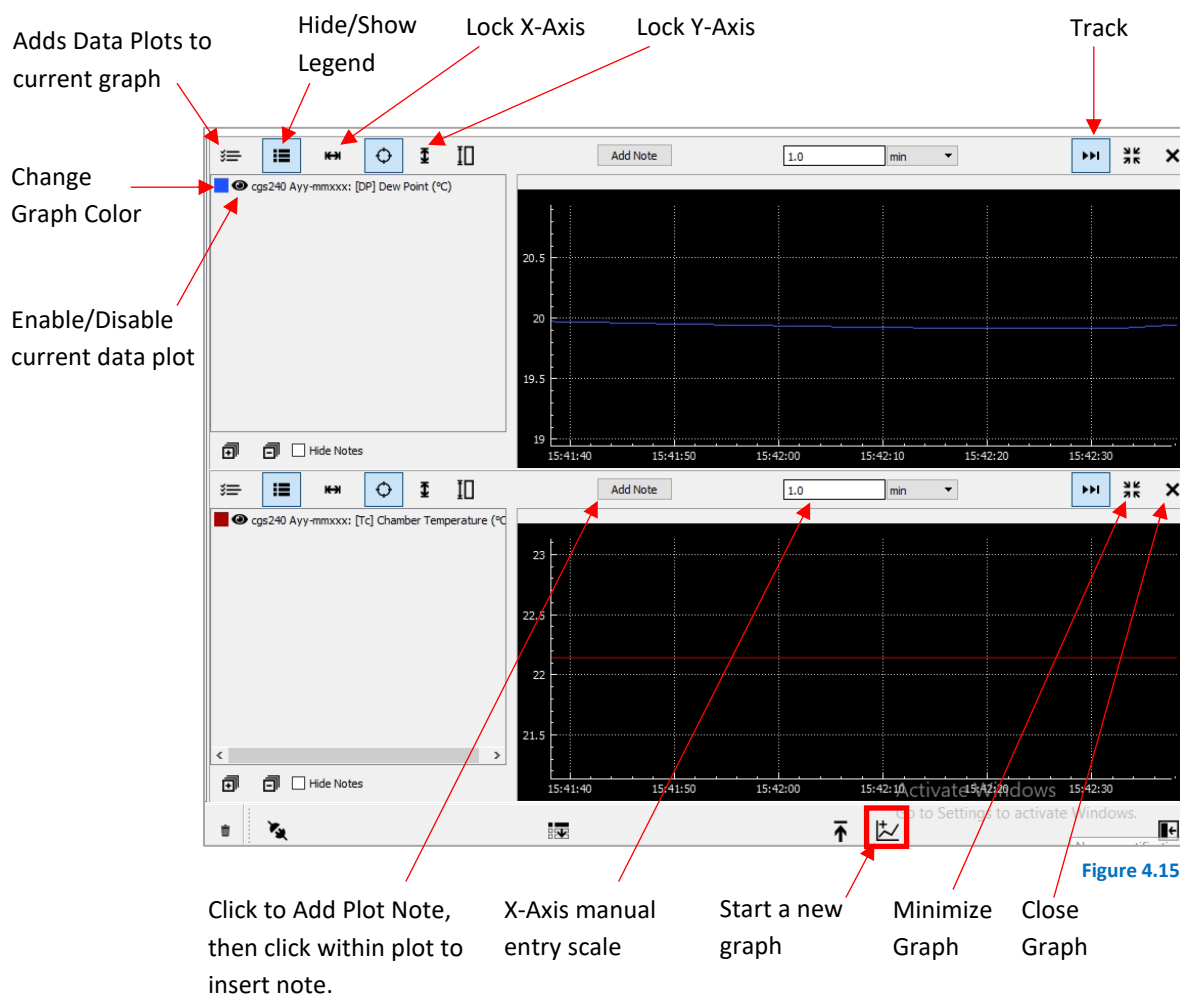


## 4.5 VIEWING DATA NUMERICALLY AND GRAPHICALLY

Data may be viewed numerically, or as a graph. You may show several graphs at one time, each with independent variables, axes, and timing. All graphs have the ability to show fixed data, or running strip-chart-style data where it is always up to date with current information.

Graphs may show a combination of data from any connected instruments. Each parameter may be shown in a different color and may be quickly and easily shown or hidden during analysis.

Graphs respond to normal pinch-and-zoom, multi-touch gestures of the touch screen. They also work with a mouse to move/zoom/scale as desired.



### 4.5.1 AUTO PROFILING

In addition to direct, real-time, user setpoint input, an auto-profile can be prepared on screen giving the system a set of future, time-based, setpoint instructions. With auto-profiling, an entire series of setpoints with associated run times is pre-programmed on screen for subsequent execution of the sequence. Or it may be stored to disk for later retrieval and execution. Auto-profiling allows the system to run full sequences of humidity/temperature/flow points completely unattended, storing system and instrument data the entire time. In addition, if other instruments are also connected to RHS Control (such as RHS/MBW Chilled Mirror Hygrometers), they too may be sent commands as part of the auto-profile sequence. In this way, any available connected instrument may be included to accept commands from auto-profiling.

Press the Auto Profile button at the bottom of the screen to open the Auto Profile window.

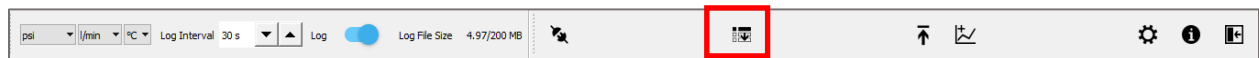


Figure 4.16

The Auto Profile window appears.

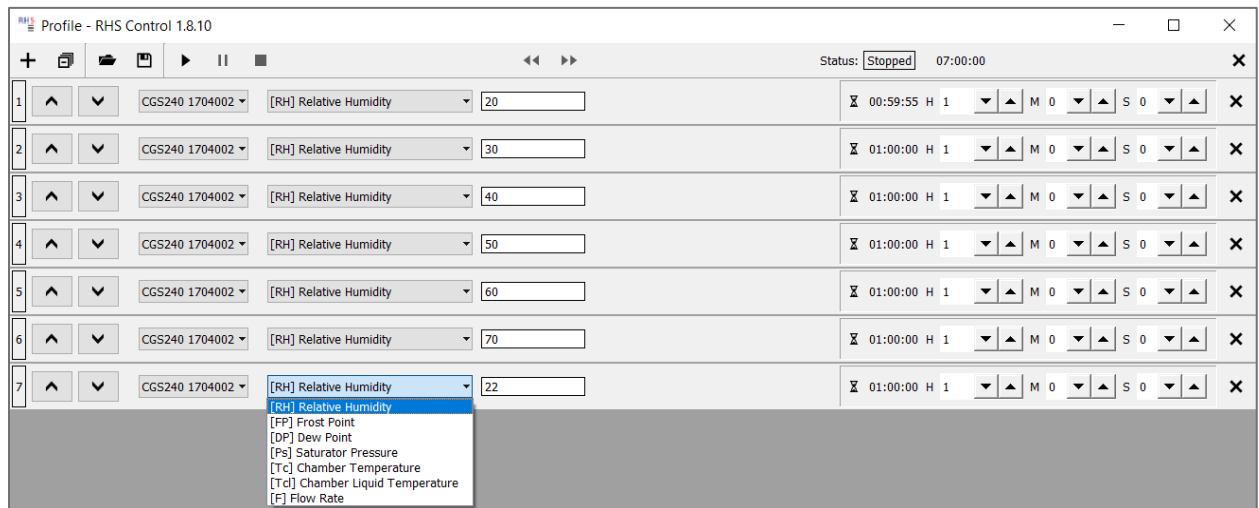
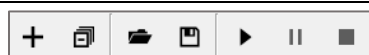


Figure 4.17

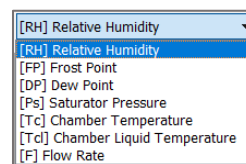


From left to right:

- Add set-point
- Clear set-point
- Open profile
- Save profile
- Start profile
- Pause profile
- Stop profile

CGS240 1704002

Connected instrument pull-down



Control pull-down

Status: Stopped 07:00:00

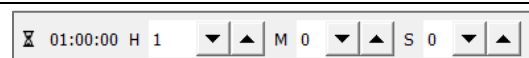
Profile Total Time

22

Set point entry



Move set-point up/down



Timer and set-point controls for run time

## 4.6 CHANGE UNITS

Changing the units may be done at any time using the Units bar at the lower left corner of RHS Control. The units will change globally (numerically and graphically). This will affect the displayed units for each and every instrument connected to RHS Control. This does not affect the units logged during data collection. Data is always logged in units of pa, l/min, and degrees Celsius, regardless of the units being displayed.

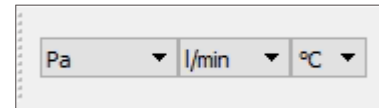


Figure 4.18

## 4.7 CONNECTION OF OTHER INSTRUMENTS

A variety of other instrument may also be connected to RHS Control. If the instrument has a serial port, connected via one of the four serial ports (left on CGS-240) or via a USB/232 converter connected to one of the USB ports (right side of the CGS-240), and a properly written description file (.json file), the Connection window should be able to find and connect to it. The system is already supplied with several .json files for connection to most RHS brand instruments. The .json files may also be written to communicate with other brands of instruments. The .json files are stored in RHS Control\configs\. Further information may be obtained by contacting RH Systems, LLC.

Add instrument connections at any time using the **Connect** button.



Figure 4.19

The Connection window appears and automatically searches for physically present instruments it finds that are not currently connected to RHS Control. (See section 4.2 Connection Window)

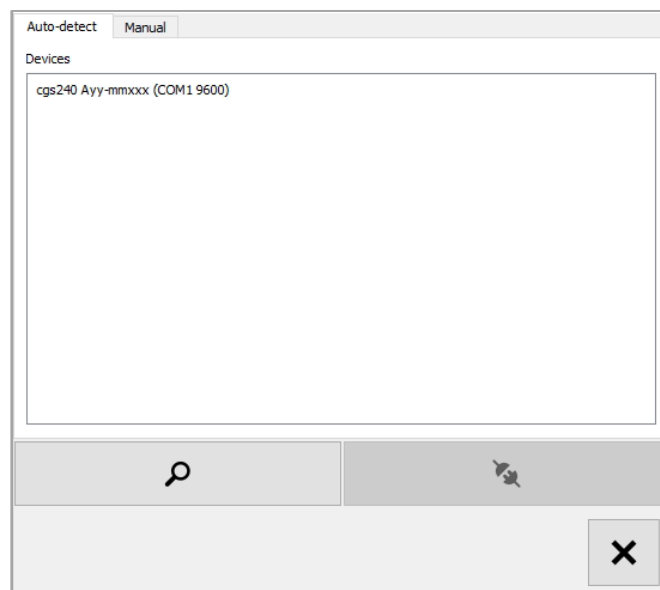


Figure 4.20

#### Four Serial Port Panel CGS-240 (optional on CGS-240)

These ports mimic the operation and pinout of standard PC serial ports and can independently operate at a variety of baud rates and communication protocols.



RS232 Pin Out	
Pin #	Signal
1	DCD
2	RX
3	TX
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

Generally, instrument connections are made using an RS-232 Extension Cable with male connection on one end, female connection on the other end, and wired straight through (pins 1-1, 2-2, 3-3, ... , 9-9.) Note that all RH Systems branded instruments connect directly using only a straight

through extension cable. If manufacturing your own cables, generally only pins 2, 3, and 5 are required for connection to most instruments.

If a Null-Modem adapter would normally be required for the instrument to communicate with a standard PC, a Null-Modem adapter (which crosses pins 2 and 3) will then also be required when connecting to these ports of the CGS-240.

## 4.8 DATA LOGGING

All instrument data is stored in log files. Logging is defaulted to ON upon startup of RHS Control. Each connected instrument has a separate log file with common time stamps for easy post-run analysis using Excel or other programs of your preference. Data files are stored in CSV (comma separated value) format for easy import.

The data is logged at a time interval defined by the 'Log Interval' spinbox located at the lower left corner of RHS Control.

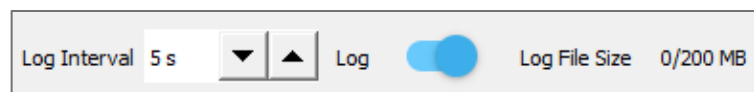


Figure 4.21

Located to the immediate right of the **Log Interval** spinbox is the **Log** toggle switch. The Toggle switch will be blue in color when logging is *enabled*, and red in color when logging is *disabled*. Yellow color indicates that the size is approaching its maximum. The act of toggling this OFF will close the file and stop data collection for all instrumentation connected to RHS Control. Toggling it back to ON will start a new log file.

Log files are stored in: `RHS Control\logs\`

Files names are identifiable by instrument name, serial number, and time stamp.

The current log file size is indicated. If the file reaches the maximum size limit, the file closes and a new file is automatically started.

Maximum log file size is user selectable by accessing the System Settings window.

## 4.9 SYSTEM SETTINGS

The **Settings** button provides access to the Settings Window.



Figure 4.22

**System Info** allows for selection/deselection of the on-screen keyboard. It also allows for a light and dark mode theme (light mode is shown throughout this manual).

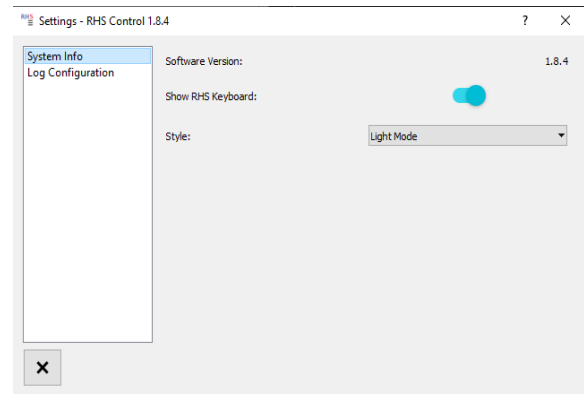


Figure 4.23

**Log Configuration** allows for changes to the log file data formatting options. It also allows setting the maximum log file size. Once the size is reached, the file will close and a new log file will automatically be generated.

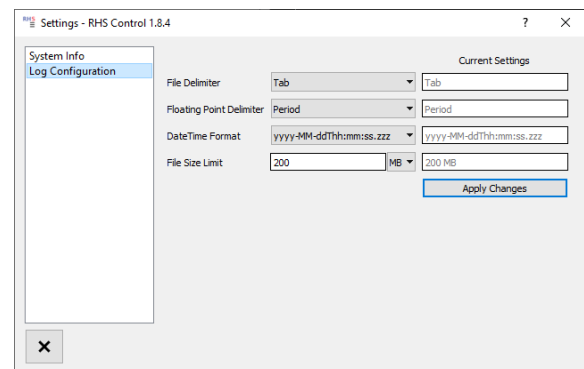


Figure 4.24

#### 4.10 CHAMBER

The chamber utilizes a robust design, with a cable management system for the chamber temperature probe, sample gas injection to center of chamber, local pressure measurement, an optional heat dispersion plate, and a shelving system. It is equipped with comprehensive heat insulation in all sides and doors of the test chamber and features sealed edges with a soft silicone profile seal for gas tightness.

An integrated fan with control provides internal air circulation and ensures uniformity and stability throughout the chamber. The chamber design features a false wall for a fully air-jacketed approach. The air-jacket is encased within a fluid jacket to ensure unparalleled stability. The inside of the temperature chamber for demanding temperature simulations is constructed from stainless steel.



Figure 4.25

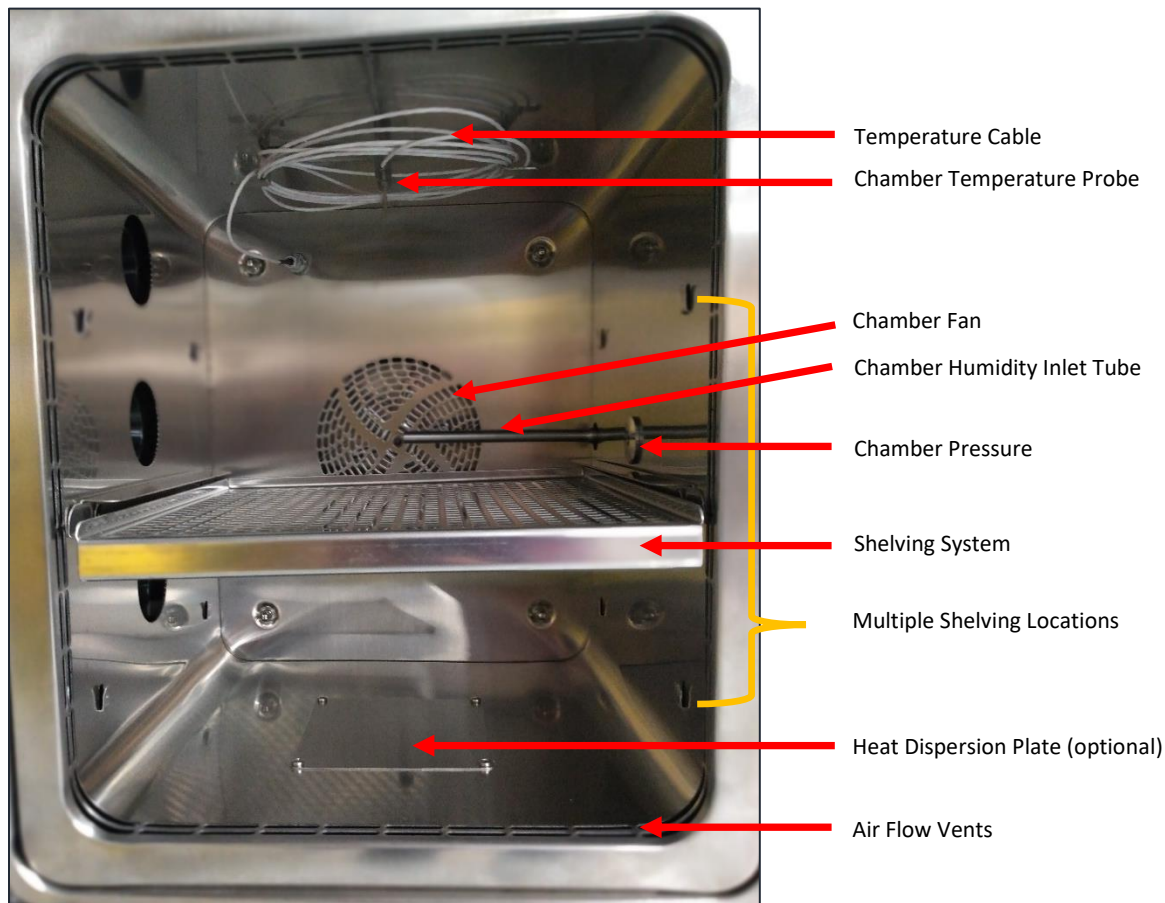


Figure 4.26

#### 4.11 DOOR

The liquid jacketed chamber door uses heavy duty hinges, a recessed latching mechanism, a built-in light, and built-in heaters for the door frame and window. The liquid jacketing of the door and window aid significantly in the chamber stabilization and temperature uniformity.



Figure 4.27



Figure 4.28



## 5 CALIBRATION

To ensure the best possible accuracy of the generator it is critical to perform routine calibration on the temperature probes and the pressure transducers.

Apparatus and equipment, including technical performance requirements.

a. Pressure reference

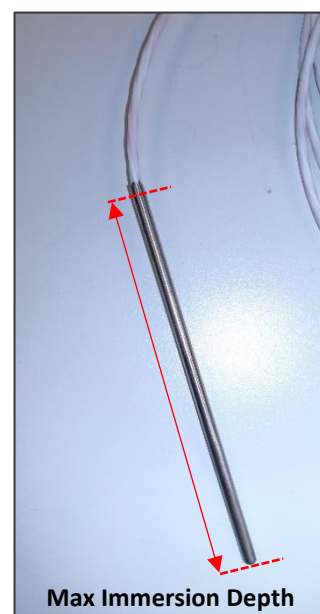
- **Low range:** Ambient to 25 psia, with  $\pm 0.001$  psia resolution or better,  $\pm 0.005$  psia accuracy or better.
- **High range:** Ambient to 150 psia, with  $\pm 0.01$  psia resolution or better,  $\pm 0.03$  psia accuracy or better.
- A stable gas supply (ambient to 150 psia) will be required to ensure the pressure transducers full range is covered. There is no need to check or calibrate below ambient pressure.

b. Temperature reference

Readout with  $0.01\text{ }^{\circ}\text{C}$  or better resolution, temperature standard (SPRT recommended)  $\pm 0.03\text{ }^{\circ}\text{C}$  or better accuracy. A temperature calibration bath with liquid immersion usable range of  $-20^{\circ}\text{C}$  to  $72\text{ }^{\circ}\text{C}$ . *Use of a non-conductive liquid such as 3M Fluorinert FC-770 is highly recommended.* Use of silicone oil is also suitable.

**NOTE: DO NOT USE WATER** as this may cause an internal short within the probe if the probe is accidentally submerged below the interface between sheath and cable. Leave approximately  $1/4''$  of the probe sheath unsubmerged to prevent liquid from contacting the interface.

- c. Environmental conditions: Generally, the required environmental temperature range during calibration is  $23 \pm 2\text{ }^{\circ}\text{C}$ . The required environmental relative humidity range during calibration is 5 to 95 %, non-condensing.



### 5.1 PRESSURE CALIBRATION

Both transducers measure absolute pressure and must be calibrated in *absolute* pressure. *Gauge* mode calibration is not possible.

**NOTE:** If sending the sensors to an independent calibration lab, rather than performing the in-System calibration, refer to Section 5.1.4 – *Alternative Pressure Calibration Procedure*.

#### Required Equipment

- Stable pressure source, pressure range capable of:
  - Ambient to 25 psia for low range transducer
  - Ambient to 150 psia for high range transducer
- Pressure controller and/or standard, detailed in section 5.
- $9/16''$  open end wrench.



Using the in-system calibration method, the transducers will be disconnected from the pneumatic system of the CGS-240 but will remain electrically connected.

Adjustment is performed by altering coefficients  $a_0$ ,  $a_1$ ,  $a_2$ , and  $a_3$  to the 3<sup>rd</sup> order polynomial:

$$P_{\text{actual}} = a_0 + a_1 \cdot P_{\text{sensor}} + a_2 \cdot (P_{\text{sensor}})^2 + a_3 \cdot (P_{\text{sensor}})^3$$

To alter that calibration using the CGS-240 in-system calibration method, those coefficients will be adjusted to bring the out-of-tolerance  $P_{\text{sensor}}$  readings to in-tolerance  $P_{\text{actual}}$  readings. Expected coefficient ranges following in-system calibration adjustment are:

Coefficient	Default	Acceptable Range	Notes
<b>a0</b>	0	-7000 < a0 < +7000	This range allows just over $\pm 1$ psi of offset/bias.
<b>a1</b>	1	0.9 < a1 < 1.1	This is a slope term and should remain near 1.
<b>a2</b>	0	Exponent of a2 coefficient should be no larger E-5.	E-4, E-3... are out of range.
<b>a3</b>	0	Exponent of a3 coefficient should be no larger than E-6.	E-5, E-4... are out of range.

Values that exceed the above ranges indicate either a bad probe or faulty calibration data (such as from data entry errors).

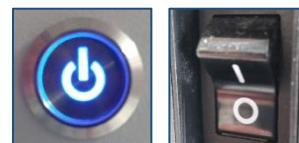
If the default coefficients are used, then  $P_{\text{actual}} = P_{\text{sensor}}$  and no in-system adjustment takes place.

With these coefficients, it is assumed that the sensor itself is internally (independently) calibrated.

### 5.1.1 REMOVAL OF PRESSURE TRANSDUCERS

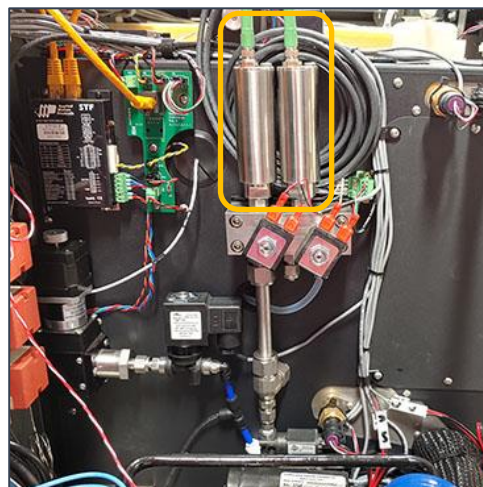
1) Power down the CGS-240:

- Press the front panel power button and wait for the unit to complete shutdown.
- Switch the main power Off.



2) Remove the back, right-side, and top panels to access the pressure transducers. Tools are not required for the removal of any access panels. As they are retained by a spring clip, a light pull is all that is necessary.

**NOTE:** Because the pressure ranges for  $P_L$  and  $P_H$  are different, these pressure sensors must be calibrated separately.



- 3) Disconnect the pressure transducers electrically.  
Do so by unscrewing and removing the green circular connector.
- 4) Using a 9/16" open ended wrench, remove the pressure transducer from the manifold.




---

### 5.1.2 CALIBRATION OF PRESSURE TRANSDUCERS

Bring the CGS-240 to a pressure source with a pressure controller and/or standard, or the pressure controller and/or standard may be brought to the CGS-240 if a suitable pressure source is available at location.

- 1) Following the operator's manual for the pressure controller/standard (or internal procedures), connect the pressure standard to the pressure sensor. The transducer should be mounted vertically.

**NOTE:** The transducer port is a 1/4" AN female. You may remove the CGS-240 adapter fitting (1/4" AN male, 7/16-20 straight thread), currently attached to the transducer, in order to use your own AN male adapter compatible with your pressure calibrator.

- 2) Connect the pressure transducers electrically by reattaching the green circular connector.

- 3) Power up the CGS-240:

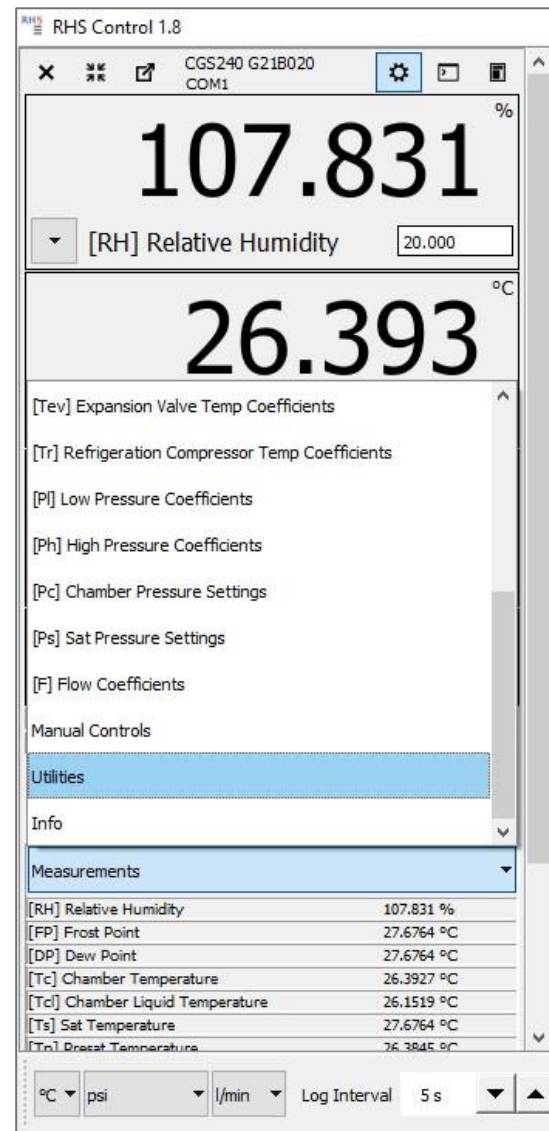
- a. Switch the main power On.
- b. Press the front panel power button and wait for the unit to completely startup.



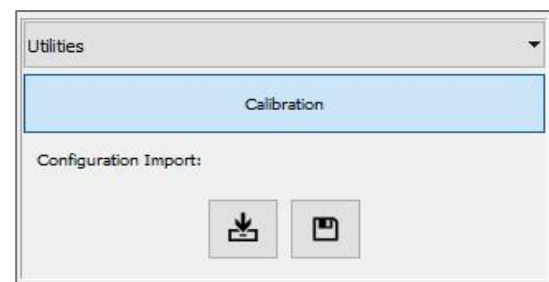
- 4) Once the system fully boots up, launch **RHS Control** (if it did not auto-launch at power-up).



- 5) Open **Cal Mode** by selecting **Utilities** from the drop-down menu.



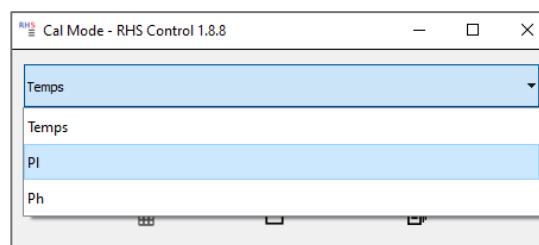
- 6) Click the **Calibration** button.



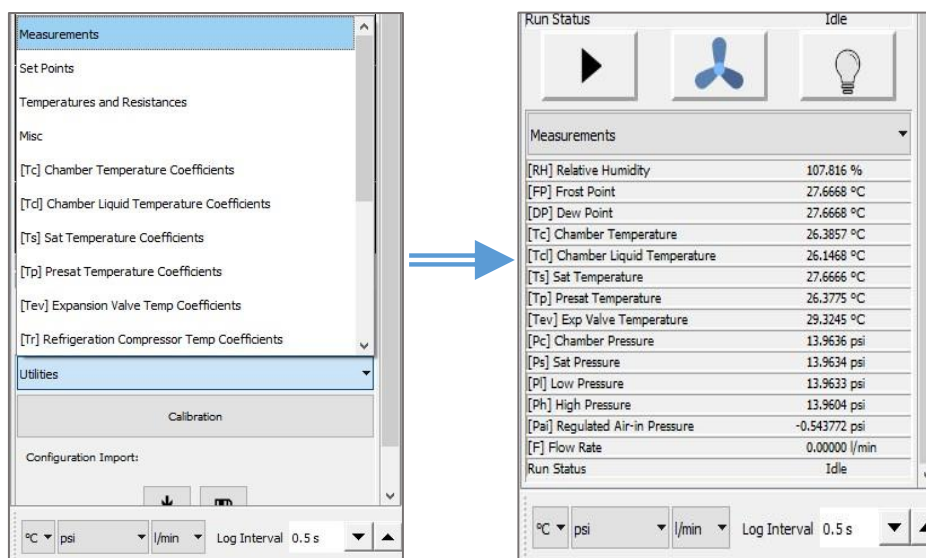
By default, the Cal Mode window opens with the Temperature sensors (Ts and Tc) selected.



- 7) Select the sensor you want to calibrate, **PL** or **PH**.



- 8) Following the operator's manual for the pressure controller/standard (or internal procedures), connect the PL or PH sensor to your pressure standard and control the following approximate pressures for a duration of at least 2 to 5 minutes *per point*:
- For the [PL] Low Pressure Sensor, the Calibration range is ambient to 25 psia. Calibrate this sensor with *approximate* pressures of **ambient**, **17.5**, **20.0**, **22.5**, and **25.0 psia**.
  - For the [PH] High Pressure Sensor, the Calibration range is ambient to 150 psia. Calibrate this sensor with *approximate* pressures of **ambient**, **25**, **50**, **75**, **100**, **125**, and **150 psia**.
- 9) Monitor the PL or PH sensor value by selecting **Measurements** from the drop-down menu.



- 10) When data is stable and ready to take a measurement, type in the **Reference** value and click the **Enter** button.

	Reference (psi)	PL Read (psi)	PL Raw (psi)	
Pt1	12.00	-	-	Enter

The current data point will be captured and a new row will appear for your next measurement.

	Reference	PL Read (psi)	PL Raw (psi)	
Pt1	12.00	11.9995	12.006	Remove
Pt2		-	-	Enter

- 11) When you are ready to take another measurement, type in the next Reference value and click **Enter**. Repeat this step for each Reference reading, until the desired number of values are recorded.

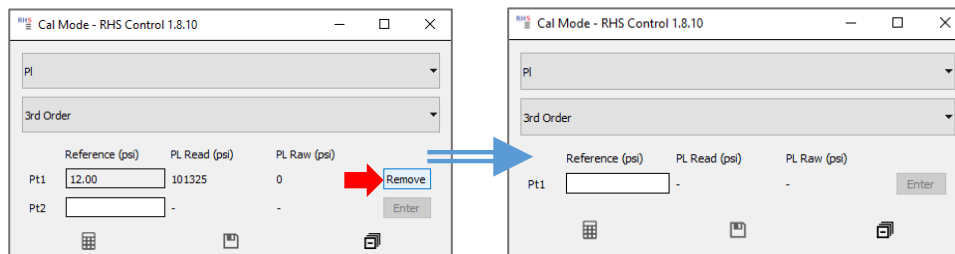
	Reference	PL Read (psi)	PL Raw (psi)	
Pt1	12.00	11.9995	12.006	Remove
Pt2	15.00	-	-	Enter


The Calculate button remains disabled until the minimum number of values are entered.

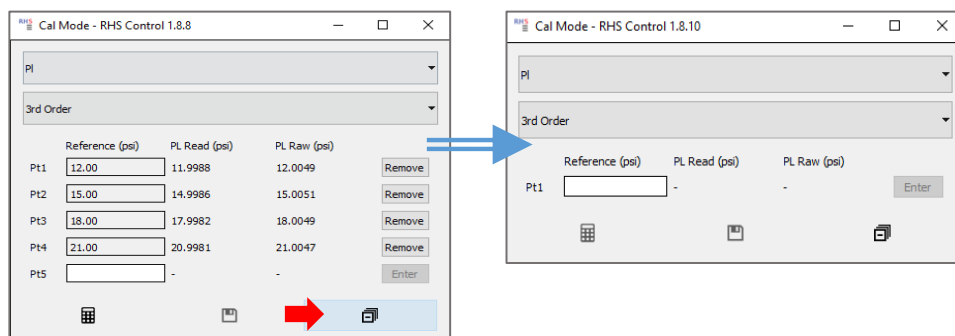
- 3<sup>rd</sup> order polynomial – minimum of 5 points
- 2<sup>nd</sup> order polynomial – minimum of 4 points
- Linear – minimum of 3 points

**NOTE:** You can remove a bad measurement (single value) by clicking the **Remove** button, or remove all recorded measurements by clicking the **Clear All** icon.

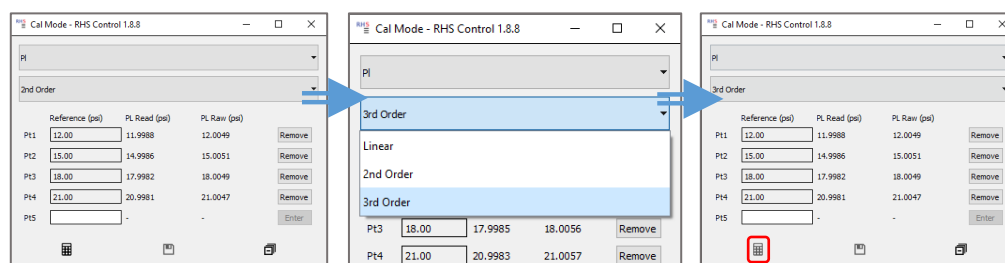
Example: Click **Remove** to remove a single recorded measurement.



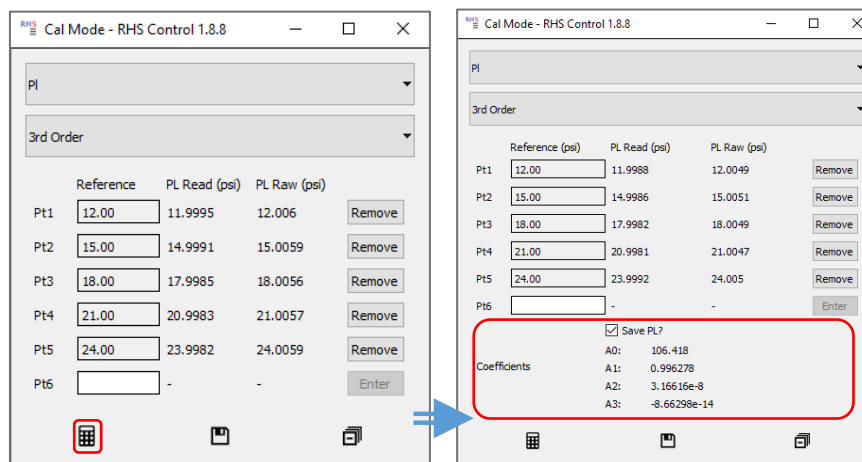
Example: Click  to remove all recorded measurements



**NOTE:** For pressure calibration, Cal Mode uses the 3<sup>rd</sup> order polynomial setting by default. You can select a different order if something other than 3<sup>rd</sup> order is appropriate. If you change calculation mode and have insufficient data points, the Calculate icon will be disabled. As shown in the example below, changing from the 2<sup>nd</sup> order to 3<sup>rd</sup> order polynomial will disable the Calculate icon if the minimum number of values have not yet been entered.

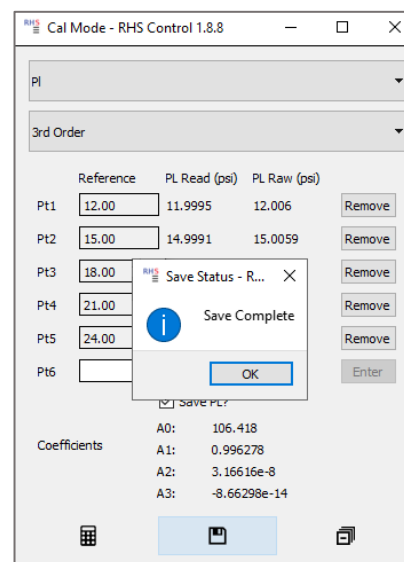


- 12) When ready to perform the calculation, click the **Calculate** icon.  
The new coefficients will appear on the bottom portion of the window.



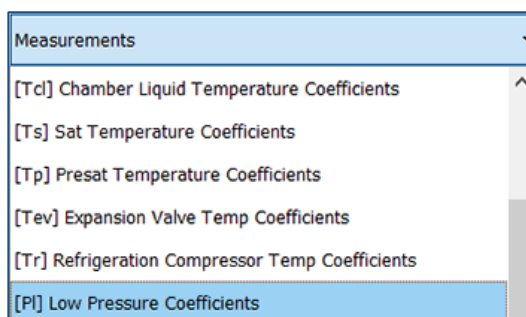
**NOTE:** If your reference and PL Read, or PH Read, are within expected tolerance, proceed to Section 5.1.3, Pressure Sensor Reinstallation. Otherwise, continue with Step 13 to save the new coefficients.

- 13) When you are ready to save the new coefficients to the CGS-240, click the **Save** icon. A pop-up message confirms completion of the save.

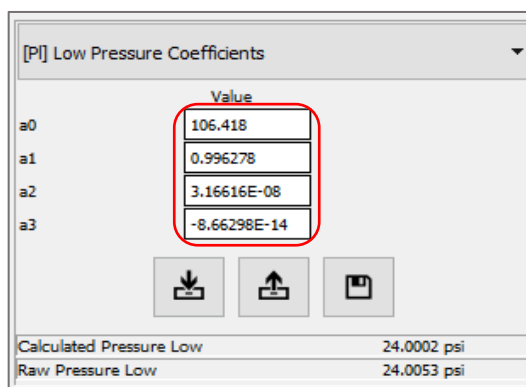


- 14) After saving, observe the corresponding coefficients window to verify your coefficients were properly saved:

Depending on which probe was calibrated, select either **[PI] Low Pressure Coefficients**, or **[Ph] High Pressure Coefficients**, from the drop-down menu.



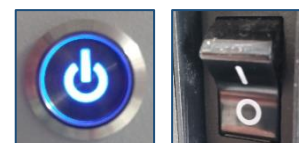
Ensure that the displayed coefficients reflect those saved in the previous step.



Repeat steps 4 through 14 for the other pressure sensor.

### 5.1.3 PRESSURE SENSOR REINSTALLATION

- 1) Power down the CGS-240:
  - a. Press the front panel power button and wait for the unit to complete shutdown.
  - b. Switch the main power Off.



If you removed the AN-7/16-20 adapter, use a new copper sealing gasket between the transducer and the AN side of the fitting. Each sensor has either an O-ring or a bonded washer to seal it at the manifold.

If the O-ring or bonded washer are worn/damaged, replace them when reinstalling the transducer to the manifold. Note that  $P_H$  is installed to the left, and  $P_L$  is installed to the right. The green circular connectors are universal and are not associated to either sensor, so it does not matter which connector goes to which sensor.

### 5.1.4 ALTERNATIVE PRESSURE CALIBRATION PROCEDURE: INDEPENDENT SENSOR CALIBRATION

This procedure assumes the sensors are calibrated independently of the CGS-240

Refer to section 5.1.1 for instructions on pressure sensor removal.



- 2) Send the pressure sensors to a lab that has the capability to calibrate them independent of the CGS-240.
  - a. The lab must be able to power them and communicate with them over RS-485.
  - b. The lab must be able to perform absolute pressure calibration, read data via RS-485, compute calibration coefficients, and store these calibration coefficients in the transducer's memory.

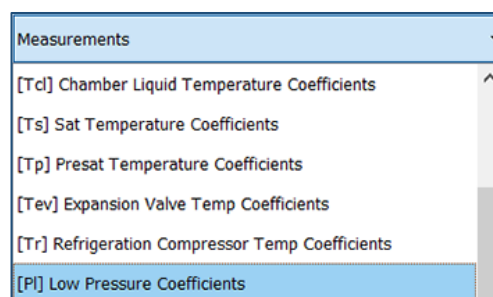
**Sensor Parameters:** The sensors are Mensor CPT6020, with a required supply voltage of 12VDC, and communicating via RS-485 at 9600/8-N-1. Sensor P<sub>L</sub> is on Address 0, P<sub>H</sub> is on Address 1, and the units are in Pascal (Pa).

**IMPORTANT:** If the lab changes any of the parameters during calibration, the sensors should be returned to the above sensor parameters by the calibration lab prior to return and subsequent re-installation.

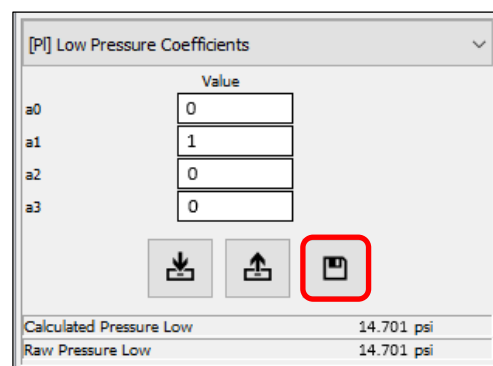
- 3) Upon return of the fully calibrated sensors, the CGS-240 must have *Default Coefficients* entered. The use of default coefficients ensures that the instrument will not perform any post-measurement corrections to the newly calibrate pressure sensor data.

Coefficient	Default
a0	0
a1	1
a2	0
a3	0

- 4) Select the Settings icon, then select **[PI] Low Pressure Coefficients**.



- 5) Enter the default coefficients a0, a1, a2 and a3 (as shown), then click the **Save** button.



Repeat steps 5 and 6 for [PH] High Pressure Coefficient.

Refer to Section 5.1.3 *Pressure Sensor Reinstallation*.

## 5.2 TEMPERATURE CALIBRATION

To maintain system accuracy, the following two temperature probes should be calibrated periodically.



[Ts] Saturator Temperature Probe



[Tc] Chamber Temperature Probe

The temperature probe calibrations should be performed as a system. The probes will be removed from the insertion points of the CGS-240 but will remain connected to the electrical system. Both probes can be run simultaneously.

### Required Equipment

- Temperature readout with 0.01 °C or better resolution, temperature standard (SPRT recommended)  $\pm 0.03$  °C or better accuracy.
- Temperature calibration bath, detailed in section 5.
- 7/16" deep access T-wrench (supplied with the system).

Adjustment is performed by altering the coefficient values to the CVD equation:

$$R = R_0 (1 + aT + bT^2 + c(T-100)T^3)$$

Default (uncalibrated) Temperature Coefficients and Expected Coefficient Ranges (post-adjustment):

Coefficient	Default	Acceptable Range
<b>R0</b>	100	$99 < R_0 < 101$
<b>a</b>	0.0039083	$0.0037 < a < 0.0041$
<b>b</b>	-5.775E-7	$-4.0E-7 > b > -7.5E-7$
<b>c</b>	-4.183E-12	Exponent of coefficient c should be no larger than E-10. For example, coefficients of E-10, E-11, E-12 and so on, are acceptable, but E-9 would be outside of the acceptable range.

### 5.2.1 TEMPERATURE PROBE REMOVAL

1) Power down the CGS-240:

- a. Press the front panel power button and wait for the unit to complete shutdown.
- b. Switch the main power Off.

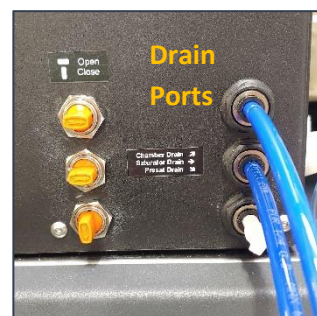


2) Remove the back, top, and right-side panels.

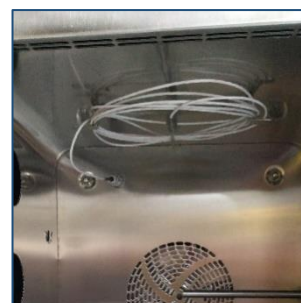
Tools are not required for the removal of any access panels.  
As they are retained by a spring clip, a light pull is all that is necessary.

3) Before removing the temperature probes, drain one gallon of the water/glycol mixture:

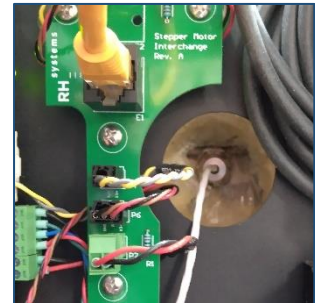
- a. Remove the white drain plugs and connect tubing to the Chamber and Saturator Drain Ports.
- b. Open the Vent Valve.
- c. Open the Chamber and Saturator drain valves
- d. Collect one (1) gallon of the fluid into a clean container to retain for later use during reinstallation of the probes.
- e. Close the Chamber and Saturator drain valves.



4) Open the chamber door to access the Chamber temperature probe [Tc].



- 5) Remove the probe and uncoil the cable, but leave it plugged into its electrical connector.
- 6) Remove the cover and insulation to expose the Saturator temperature probe [Ts]. Loosen the nut about one (1) turn and remove the probe by pulling it straight out. The nut should remain in place.



**Note:** Removal of the Saturation Temperature Probe requires the 7/16" deep-access T-wrench that is supplied with the system (RHS Sat Temp Removal Tool, pictured to the right).



- 7) Uncoil the cable, but do not unplug it from the temperature measurement board.

---

### 5.2.2 CALIBRATION OF $T_s$ AND $T_c$ PROBES

- 1) Bring the CGS-240 to a location which has a suitable calibration bath and temperature standard, or the calibration bath and temperature standard may be brought to the CGS-240.

- 2) Power up the CGS-240:

- a. Switch the main power On.
- b. Press the front panel power button and wait for the unit to completely startup.



- 3) Once the system fully boots up, launch RHS Control (if it did not auto-launch at power-up).

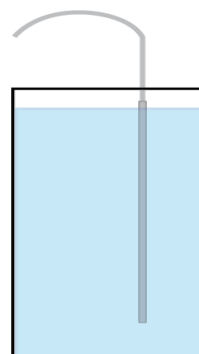


- 4) Following the operator's manual for the calibration bath (or internal procedures):

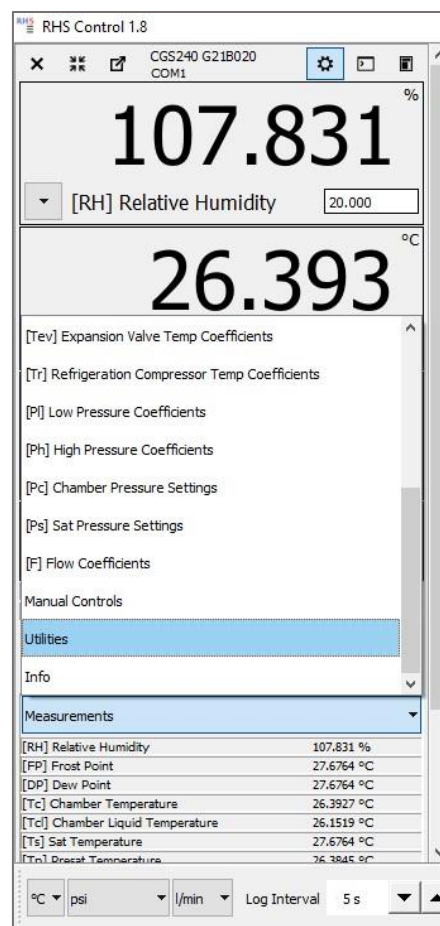
- a. Insert the temperature probes into the calibration bath.

**Caution:** Do not submerge the probe to the point where the interface between cable and sheath goes below the liquid surface. Doing so could damage the probes.

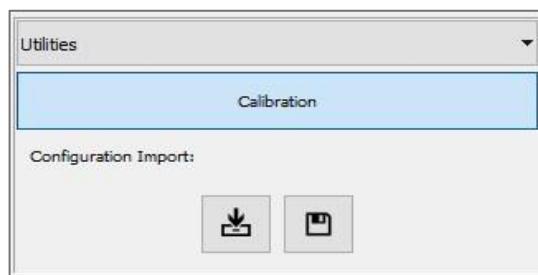
- b. Set the bath temperature to a setpoint below 0 °C (-20 °C is recommended).



- 5) Open Cal Mode by selecting **Utilities** from the drop-down menu.



- 6) Click the **Calibration** button.



- 7) Select **Temps** from the calibration drop-down list. It is recommended that both temperature sensors be calibrated simultaneously.

	Reference (°C)	TS Read (°C)	TS Raw (Ω)	TC Read (°C)	TC Raw (Ω)
Pt1	10.01	10.818809	104.2206	10.827468	104.22318

- 8) Monitor temperatures for stability by selecting Temperatures and Resistances from the drop-down menu. You may also graph the Tc and Ts values.

- 9) When the temperature probes and reference thermometer are stable at the desired calibration point within the bath, type in the reference value, taking note of the units.

	Reference (°C)	TS Read (°C)	TS Raw (Ω)	TC Read (°C)	TC Raw (Ω)
Pt1	10.01	10.818809	104.2206	10.827468	104.22318
Pt2	20.02	20.22551	107.8793	20.296852	107.90858
Pt3	30.4	30.837568	112.00331	30.100674	111.72833
Pt4	40.47	41.498177	116.07666	40.08667	115.56516
Pt5	49.56	50.810772	119.77467	48.605804	118.90041
Pt6	60.77	62.764328	124.36208	59.75008	123.20878
Pt7	70.4	72.485352	128.06541	69.316864	126.85271
Pt8					

- 10) Repeat step 10 for values approximately 0, 25, 50 and 75 °C.

**Note:** These exact temperature values are not necessary.

The calibration requires 4 to 5 distinct points over the probe range.

*A minimum of 5 reference values must be entered before the Calculate icon is enabled.*

- 11) If the **TS Read** and **TC Read** values compare with the reference temperature, within the expected tolerance, record your data manually and close the window, then proceed to Section 5.2.3, *Temperature Probe Reinstallation*.

Otherwise, continue with steps 10 through 12 in order to calculate and save new coefficients.

- 12) After entering the minimum required number of readings, or more, click the Calculate icon. The new coefficients will appear on the bottom portion of the window.

	Reference (°C)	TS Read (°C)	TS Raw (Ω)	TC Read (°C)	TC Raw (Ω)
Pt1	10.01	10.818809	104.2206	10.827468	104.22318
Pt2	20.02	20.22551	107.8793	20.296852	107.90858
Pt3	30.4	30.837568	112.00331	30.100674	111.72833
Pt4	40.47	41.498177	116.07666	40.08667	115.56516
Pt5	49.56	50.810772	119.77467	48.605804	118.90041
Pt6	60.77	62.764328	124.36208	59.75008	123.20878
Pt7	70.4	72.485352	128.06541	69.316864	126.85271
Pt8					

☒ Save TS?      ☒ Save TC?

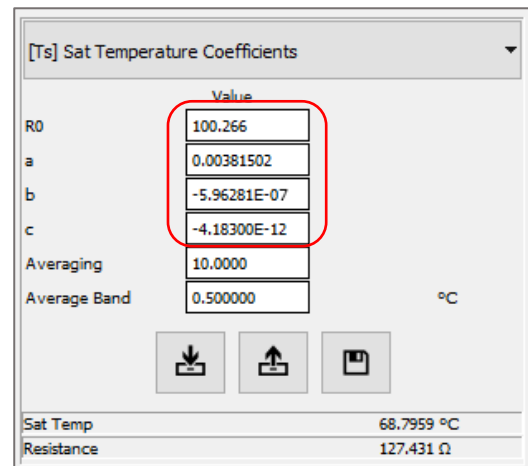
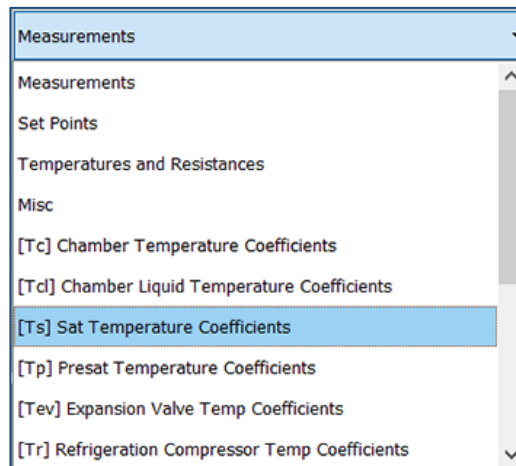
Coefficients      CVD0: 100.266      CVD0: 100.561  
                          CVD1: 0.00391502      CVD1: 0.00362204  
                          CVD2: 1.96281e-5      CVD2: 1.32119e-5  
                          CVD3: -4.183e-12      CVD3: -4.183e-12

- 13) After calculating temperature coefficients, select which sensor (or both) you would like to save, then click the **Save** icon.



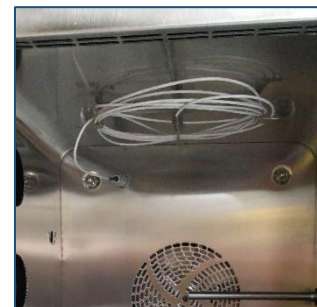
- 14) After saving, observe the corresponding coefficients windows to verify your coefficients were properly saved:

- Select **[Ts] Sat Temperature Coefficients** from the drop-down list and verify the new coefficients.
- Select **[Tc] Chamber Temperature Coefficients** from the drop-down list and verify the new coefficients.



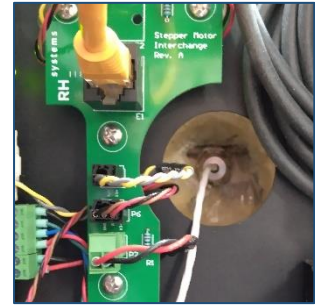
### 5.2.3 TEMPERATURE PROBE REINSTALLATION

- Clean any residue from the probes after removing them from the bath.
- Place the chamber temperature probe in the chamber, coiling it around the cable holder, as needed.





- 3) Insert the Sat temperature probe into the cavity and through the Swagelok nut from which it had been previously removed. Insert it so that only 1/8" to 1/4" of the probe's metal sheath remains visible.

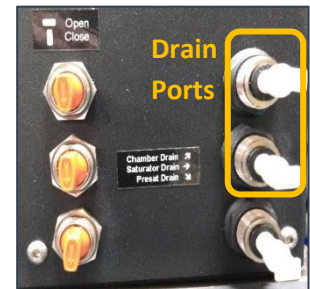


- 4) Tighten the nut using the deep access T-wrench. The T-wrench prevents overtightening.



- 5) Wrap the foam insulating plug over the cable and push into the cavity.
- 6) Place the round plastic plug over the cable and insert it fully to cap the hole.
- 7) Coil any excess cable and reattach at the clamp near the front of the saturator box, where it was previously removed.

- 8) Ensure the saturator and chamber drains are closed, then remove the tubes and reinsert the 1/4" drain plugs.



- 9) Pour the previously drained fluid back into the fluid tank (located behind the chamber).
- 10) After running the system for several minutes, be sure to close the vent valve located behind the chamber (top, center) near the tank.



With the vent valve open, air can more easily escape from the system. However, an open vent valve causes the water tank to heat and cool with the chamber and saturator. The system operates more efficiently with a closed vent valve, which then provides some isolation of the tank from the chamber and saturator temperatures.



## 6 SUBSYSTEMS

This section provides details of the functional systems within the humidity generator. These subsystems include the Electrical System, Pneumatic System, Fluid System, Refrigeration System, and Heaters.

### 6.1 ELECTRICAL SYSTEM

The humidity generator requires 200-240 VAC, 50/60 Hz, single phase power. Configuration for the AC input can be either

- LINE1, LINE2, GND (as is often the case for connection in the U.S., Canada, Mexico, Japan and Taiwan where LINE1 and LINE2 are of opposing phase while each is approximately 100-120 VAC with respect to GND), resulting in 200-240 VAC between Line 1 & Line 2;
- LINE, NEUTRAL, GND (often for Europe and many countries of Asia when LINE is approximately 200-240 VAC with respect to NEUTRAL, with NEUTRAL and GND at the same potential.)

AC power enters the system via the power connector located at the back panel, transferring AC into the system via a 2 pole, 15 AMP circuit breaker switch. When this switch is turned on, AC power is also applied to the input of a 2-pole mechanical circuit breaker inside the system behind the right door at the main control panel. This circuit breaker, CB8, is labeled “Main Power.”

Traveling through the circuit breaker, power is then branched to several locations. AC power is applied to a 5V power supply. Line 1 and line 2 power are also applied to solid-state relays, one for each power phase. These two solid-state relays, SSR7 and SSR8, act as master control to enable or disable heating and refrigeration, compressor and fan, and all other AC activated components in the system. AC power is also applied to solid-state relay, SSR6, which controls a 24V DC power supply for powering the internal embedded computer, and a 12V DC power supply, which runs the user interface PC.

#### 6.1.1 DC POWER SUPPLIES

There are 3 independent DC power supplies in the system, each operating various functions.

##### 6.1.1.1 5V DC POWER SUPPLY

A small 5V DC power supply, PSU1, provides excitation power only to operate a few solid-state relays. The 5V DC power is applied through the main front panel power switch mounted below the computer monitor. When the power switch is pressed, this 5V DC applies an enable signal to the two master control solid-state relays, SSR7 and SSR8, mentioned in the previous section. These two solid-state relays apply power to the bank of AC Circuit breakers on the lower portion of the control panel.

When the main power switch is on, the 5V DC is also supplied through a diode, D2, to the solid-state relay, SSR6, which energizes the 12V and 24V power supplies.

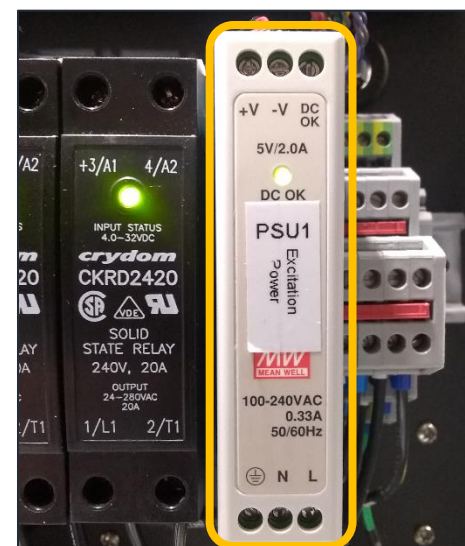


Figure 6.1

### 6.1.1.2 12 VDC POWER SUPPLY

The 12V DC power supply is used to provide DC power to the monitor on the front panel only.

When the front panel switch is enabled, the 5V DC activates the solid-state relay, SSR6, which activates the 12V DC power supply, PSU2, which turns on the front panel monitor.



Figure 6.2

### 6.1.1.3 24 VDC POWER SUPPLY

The 24V DC power supply, PSU3, provides power to nearly all functions of the main control system. It provides power to the PC, the main controller board, some heaters, motors, sensors, relays and solenoids. When the front panel power switch is enabled, 5V DC from PSU1 activates the solid-state relay, SSR6, which applies AC power to the 24V DC power supply. Which, in turn, activates the PC, the control computer, and remainder of the system.

## 6.1.2 EMBEDDED CONTROL BOARD

The Embedded Control Board, ECB, operates the humidity generator by performing all functions required for system control and humidity generation. All temperature, pressure, flow, and liquid levels are continuously monitored and controlled by actuation of valves, relays, pumps, heaters, and other outputs. It communicates to the outside world (for instance, to the embedded PC) through one of three independent bidirectional RS-232 serial communication ports. All data and control parameters are communicated via these serial ports.

The humidity generator's ECB software resides within the ECB's Flash memory. The ECB software consists of RHS custom developed code, coupled with a high-speed multi-tasking real-time operating system. Via this multi-tasking embedded software, the ECB orchestrates the second-to-second operation of the humidity generator based

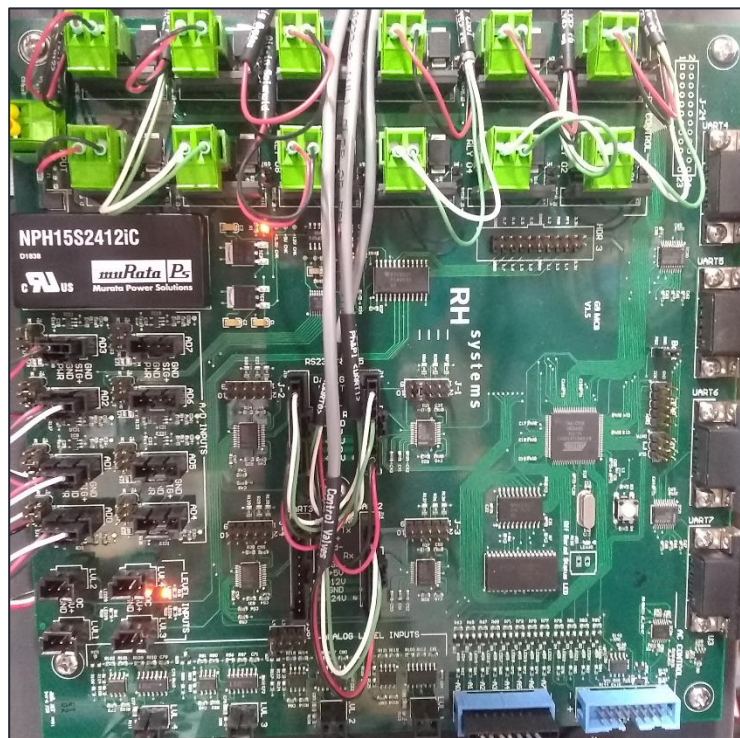


Figure 6.3

on command input from any of the RS-232 ports. Supervisory operation such as set points (RH, dew point, flowrate, etc.) are transmitted to the controller board via the touch monitor and PC. The job of the ECB is to accept these set points, continuously measure the various analog and digital sensors, and control the various electro-mechanical actuators in order to bring about and maintain the desired set point conditions.

Instrument specific configuration and calibration information, such as sensor coefficients, may also be written and read via any of the three RS-232 ports and resides within the ECB's Electrically Erasable Read Only Memory (EEPROM). All coefficients and other parameters are available via the touch monitor.

Voltage regulators on the ECB take the 24VDC input power and generate local +12VDC, +5VDC, and +3.3VDC needed for various components on and off the board. DC power for sensors, relays, pumps, and others are supplied directly from the ECB.

### 6.1.3 PRECISION TEMPERATURE MEASUREMENT BOARD, PT12

A Precision Temperature Measurement Board containing a multi-channel, 24-bit, analog-to-digital converter measures all temperature sensors. Two of the channels are dedicated to system reference resistors. In addition to the reference resistors, the following temperature probes are measured:

<b>Tp</b>	Presaturator Temperature
<b>Ts</b>	Saturation Temperature
<b>Tc</b>	Chamber Temperature
<b>Tcl</b>	Chamber Fluid Temperature
<b>Tev</b>	Expansion Valve Temperature
<b>Tr</b>	Refrigeration Compressor Temperature
<b>Tpu</b>	Access Port Upper Temperature
<b>Tpc</b>	Access Port Center Temperature
<b>Tpl</b>	Access Port Lower Temperature

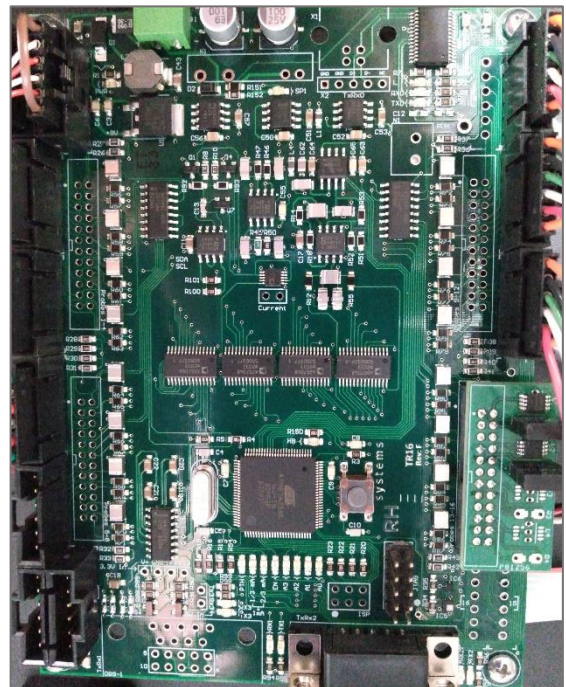


Figure 6.4

All temperature sensors in the humidity generator are 100Ω Platinum Resistance Thermometers (PRT's).

The board measures all thermometers using full current reversal DC pulse mode excitation. It ratio-metrically compares these raw probe measurements to measurements of the precision reference resistors to determine their precise resistance values.

The resistance values are then computed into individual temperatures using each probe's specific coefficients. The results are provided to the ECB via an RS-232 connection on UART7. The Precision Resistance Measurement Board requires 12 VDC which is supplied from the AD3 port of the ECB.

#### 6.1.4 SOLID-STATE AC POWER RELAYS

There are 5 solid-state relays labeled SSR1-SSR5 connected to the main controller board. The main controller board provides them with the 5V control signals. The AC side of these solid-state relays are connected to the various components and provide AC power to those components when activated and when their associated circuit breakers are turned on.



Figure 6.5

##### 6.1.4.1 R134A COMPRESSOR POWER

SSR1 is activated by output A0 of the ECB main controller board. When activated, AC power is applied from circuit breaker, CB2, through SSR1 to the refrigeration compressor.

##### 6.1.4.2 PRE-SATURATOR HEAT

SSR2 is powered by output A1 of the ECB main controller board. When activated, SSR2 applies AC power through circuit breaker, CB3, to the pre-sat heater. The amount of heat applied is controlled by pulse with modulation of that output A1 on the main controller board.

##### 6.1.4.3 SATURATOR HEAT

SSR3 is activated by output A2 of the ECB main controller board. When activated, AC power is applied through SSR3 and circuit breaker, CB4, to the Sat Heater. Control of heat is regulated by the pulse with output from main controller board output A2.

##### 6.1.4.4 CHAMBER HEAT

SSR4 is activated by output A3 of the ECB main controller board. When activated, AC power is applied to the chamber heater through SSR4 and circuit breaker, CB5, to power the heater. Control of heater power is maintained by pulse width modulation of the main controller boards output A3.

##### 6.1.4.5 CHAMBER FAN

Output A4 of the ECB main controller board activates SSR5. When activated, AC power is applied through SSR5 and circuit breaker, CB6, to the chamber fan activating the fan. The fan is generally on or off and is not speed controlled.



#### 6.1.4.6 POWER SUPPLY UNIT RELAY

Output A5 of the ECB Main Controller board activates SSR6. When activated, SSR6 applies AC power to the 12VDC power supply, PS2, and the 24VDC power supply, PS3. The 12VDC power supply powers the monitor and the 24VDC power supply powers all other functions within the machine.

#### 6.1.4.7 MAIN POWER RELAYS

The AC main power relays, SSR7 and SSR8, are used to apply power to the rest of the system. They are activated through 1 of 2 methods. Method 1: The 5V power supply, PSU1, applies 5V power to activate the relays via the front panel power switch, just below the monitor. Method 2: If the computer is up and running, it also provides a 5V signal to keep the relays activated.

SSR7 and SSR8 are initially turned on by the front panel power switch but are allowed to remain on by the computer. Now, if the front power panel switch is then turned off, the two SSR's remain on because they are remaining activated by the computer at that time. Once the computer shuts itself off, it removes the power from the SSR activation and those two relays shut off, removing AC power from the rest of the system. When SSR7 and SSR8 are off, the only portion of the system activated is just the 5V power supply.



Figure 6.6

#### 6.1.5 DC RELAYS

There are two DC relays used for powering heaters within the system. These two heaters provide power to heat the outer windowpane when needed, and/or the window frame.

##### 6.1.5.1 DC RELAY 1, DCR1

The DC relay 1, DCR1, is activated by the main controller boards A5 output. When activated, DCR1 applies 24V DC power to the window outer pane heater.

##### 6.1.5.2 DC RELAY 2, DCR2

DCR2 is activated by the main controller board, A6 output. When activated, DCR2 provides 24V DC power to heat the window frame.



Figure 6.7

#### 6.1.6 CHAMBER LIGHT

The chamber is illuminated by an LED strip mounted on the outside of the window. It is powered by 24VDC through ECB RLY 14. When the light is turned on, the ECB RLY 14 sources 24VDC to active the light. An LED at RLY 14 also indicates the relay status. When the LED is on, the chamber light is on.

## 6.2 PNEUMATIC SYSTEM

The pneumatic system is responsible for control of gas flow and pressures throughout the system. The pneumatic system consists of the following major components: air dryer/filter, pressure regulator, flow meter, air inlet valve, flow control valve, presaturator, saturator, expansion valve, and gas outlet.

Pressurized air first passes through an integrated air dryer and filter assembly, and then feeds the pressure regulator where it is regulated to the desired value as set by the regulator knob. The pressure is indicated by the dial gauge and an over-pressure safety relief valve is also connected at this point. Upon leaving the pressure regulator, the gas flows to the flow meter.

The flow meter measures both the flow rate and the regulated gas pressure. Gas flows through the flow meter to the air inlet solenoid, SOL 1. This solenoid is only open (energized) during system operation (while generating humidity). During times the system is idle, or the power is off, this solenoid remains closed, removing inlet pressure from the remaining portions of the system.

During operation, when the Air Inlet Solenoid, SOL 1, is activated, gas travels to the flow control valve.

The flow control valve, V1, is a specially designed stepper-motor-driven graduated-orifice plug valve, used for controlling flow rates as low as approximately 1 l/min to as high as 100 l/min (depending on system design). To increase system flow rate, the stepper motor will rotate the plug to a position with larger orifice.

To reduce the flow rate, the stepper motor will rotate the plug in the opposite direction to a position of smaller orifice. Flow rate is therefore maintained by the rotational position of the plug. The position is controlled by the stepper motor, under control of the ECB, using feedback from the flowmeter.

The gas then takes one of two paths through the presaturator system; it flows either through the presaturator (to humidify the air) or through a pre-saturator bypass (if pre-saturation is not needed at the current conditions). The desired gas path is established by momentary activation of latching solenoid SOL 3S to select the presaturator gas path, or latching solenoid SOL 3B to bypass the presaturator. After flowing through or bypassing the presaturator, gas then flows through the saturator (to precisely stabilize the air temperature and condense out any excess water vapor), and finally to the expansion valve, V2. Like the flow control valve, the expansion valve is also a specially designed stepper-motor-driven graduated-orifice plug valve.

The expansion valve is used as a back-pressure regulator to control the pressure of the gas flowing through the saturator. Saturator pressure is controllable from near ambient to nearly as high as the regulated inlet pressure. Saturator pressure control is achieved and maintained, at a given flow rate, by the rotational position of the plug which is set by the stepper motor under control of the ECB using feedback from Saturator Pressure,  $P_s$ . Saturator pressure is determined by measuring the high range pressure sensor,  $P_H$  (for sat pressure 25 psi and higher) or by low range pressure sensor  $P_L$  (for Sat pressure below 25 psi).

As the high-pressure gas from the saturator passes through the expansion valve, V2, it is expanded to a lower pressure, typically ambient pressure. After leaving the expansion valve, the gas passes through a heat exchanger to condition its temperature before being directed into the chamber. Gas may exhaust from the chamber through intentionally open ports, or via the dedicated exhaust port through the rear chamber wall. Gas exhausts to the room.

A normally open solenoid valve, SOL 2, is used to depressurize the saturator during shutdown and whenever the humidity generator is powered off.

Chamber pressure,  $P_c$ , is measured by the Low Range Pressure Sensor,  $P_L$ , when SOL 5 is active. When the saturation pressure is below 25 psia, SOL 4 may activate, deactivating SOL 5, and allowing the saturation pressure,  $P_s$ , to be measured by the Low Range Pressure Sensor,  $P_L$ . For saturation pressure higher than 25 psia, saturation pressure,  $P_s$ , is measured by the High Range Pressure Sensor,  $P_H$ .

### 6.2.1 FLOW METER, FL1

The flow meter, FL1, measures the flow rate of the incoming gas stream at the inlet of the presaturator. It is powered from 24 VDC and is read via RS-232 communication. It is connected directly to the ECB's UART0. 12 VDC to the flowmeter is provided by UART0\_+12 and UART0\_GND. Measurements from the flow meter are queried and received via RS-232. Queries go out from the ECB on UART0\_Tx. Replies from the flow meter are received on UART0\_Rx. Signal ground connection is at UART0\_GND. Typical communication is at 9600 baud, 8 data bits, 1 stop bit, no parity. The flowmeter is pneumatically connected just after the inlet pressure regulator. In addition to the flow measurement function, the flow meter also incorporates a pressure sensor used to measure the regulated gas pressure. This air-in pressure sensor is an integrated part of the flow meter and is read by the system along with the flow measurement.



Figure 6.8

The pressure regulator is used to set the air-in pressure which is also indicated on the dial gauge (Figure. 6.8).

### 6.2.2 AIR-INLET SOLENOID, SOL 1

The Air-Inlet solenoid valve, SOL 1, allows airflow to the system. When the humidity generator is generating, the ECB's DC CONTROL – RLY 8 sources 24 VDC to activate the Air-In solenoid. An LED at RLY 8 also indicates the relay status. When the LED is on, the solenoid is activated, allowing gas flow.



Figure 6.9

### 6.2.3 FLOW CONTROL VALVE, V1

The flow control valve (V1), shown in Figure 6.10, is a stepper-motor-drive valve used for controlling flow rate through the system. The stepper motor is positioned by a stepper controller, SD1. The ECB communicates with the stepper controller via UART2 configured for 2-wire RS-245 communication. Commands are sent to and received from the stepper controller via UART2\_D+ and D-.

SD1 is configured for communication on address 0 at 9600 baud, 8 data bits, 1 stop bit, no parity. SD1 is powered by 24VDC from UART2\_ +24V and UART2\_ GND.

Based on positioning commands from the ECB, the stepper controller actuates the stepper motor. A single, optical limit switch, SW1, connects to the stepper controller's X3 digital input and identifies the valve's fully closed (home) position.



Figure 6.10

#### 6.2.4 PRESAT SELECT SOL 3S / PRESAT BYPASS, SOL 3B

Gas leaving the flowmeter is directed toward the presaturator. When generating at low temperature and humidity conditions, it may be advantageous to bypass presaturation and inject the gas directly toward the saturator. A latching valve is driven by two solenoids (SOL 3S for presaturator selection and SOL 3B for presaturator bypass) that work together to create the select/bypass function. Momentarily energizing SOL 3S via a short pulse of 24 VDC from ECB RLY3 latches the valve to the presaturator gas path. Momentarily energizing SOL 3B via a short pulse of 24 VDC from ECB RLY4 latches the valve to the preset bypass gas path.

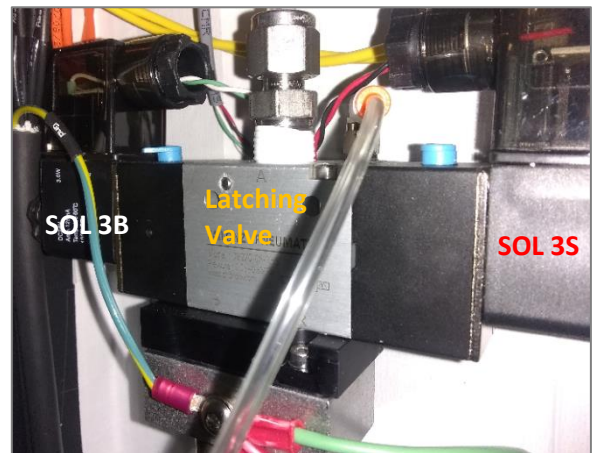


Figure 6.11

As the latching valve is a pressure assisted valve (externally piloted valve), external pilot pressure is obtained from the system's regulated air inlet pressure.

#### 6.2.5 EXPANSION VALVE, V2

The expansion valve, V2, is a stepper-motor-drive valve used for controlling saturation pressure at any given flow rate through the system. The stepper motor is positioned by a stepper controller, SD2. The ECB communicates with the stepper controller via UART2 configured for 2-wire RS-485 communication. Commands are sent to and received from the stepper controller via UART2\_ D+ and D-. SD2 is configured for communication on address 1 at 9600 baud, 8 data bits, 1 stop bit, no parity. SD2 is powered by 24VDC from UART2\_ +24V and UART2\_ GND.

Based on positioning commands from the ECB, the stepper controller actuates the stepper motor. A single, optical limit switch, SW2, connects to the stepper controller's X3 digital input and identifies the valves fully closed (home) position.

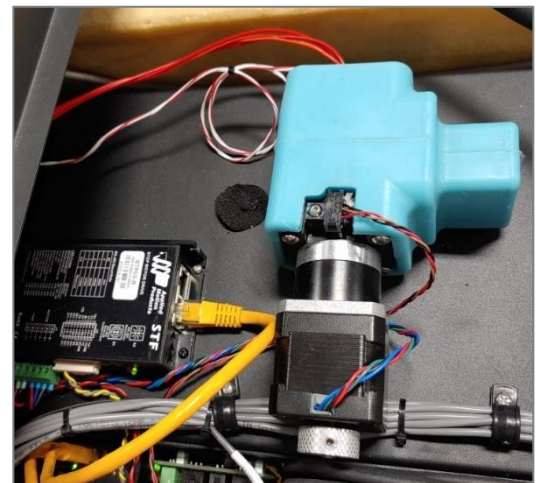


Figure 6.12



### 6.2.6 HIGH RANGE PRESSURE SENSOR, $P_H$

The high range pressure sensor,  $P_H$ , measures the saturation pressure continuously. It is powered from 12 VDC and is read via RS-485 communication on device address 01. It is connected directly to the ECB's UART1. 12 VDC to the pressure sensor is provided by UART1 12+ and UART1 GND. Measurements from the pressure sensor are queried and received via addressable RS-485, 2-wire, half-duplex mode. RS-485 connection between the ECB and pressure sensor on UART1 D+ and D-. Communication parameters are set at 9600 baud, 8 data bits, 1 stop bit, no parity. Since UART1 is configured for RS-485 communication, it connects to both the saturation pressure sensor (using address 01) and the low range pressure sensor,  $P_L$  (using address 0).

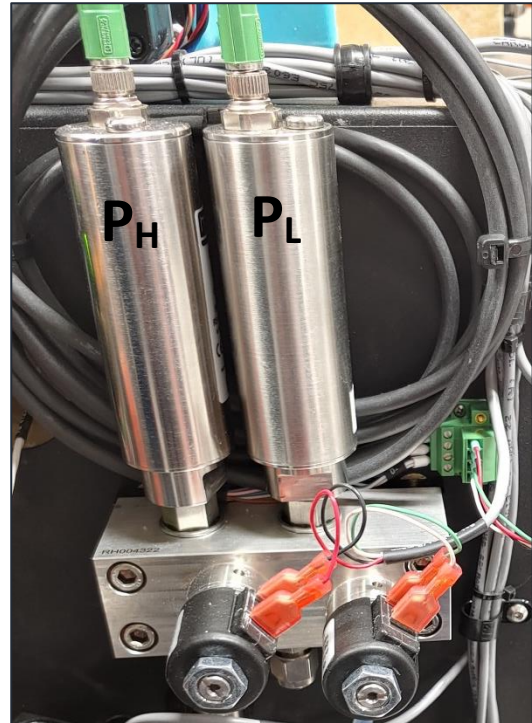


Figure 6.13

### 6.2.7 LOW RANGE PRESSURE SENSOR, $P_L$

The low range pressure sensor,  $P_L$ , is connected a selectable pressure manifold and typically measures the ambient chamber pressure. The pressure sensor is powered from 12 VDC and is read via RS-485 communication on device address 0. It is connected directly to the ECB's UART1. 12 VDC to the pressure sensor is provided by UART1 12+ and UART1 GND.

Measurements from the pressure sensor are queried and received via addressable RS-485, 2-wire, half-duplex mode. RS-485 connection between the ECB and pressure sensor on UART1 D+ and D-. Communication parameters are typically set at 9600 baud, 8 data bits, 1 stop bit, no parity. Since UART1 is configured for RS-485 communication, it connects to both the saturation pressure sensor (using address 01) and the external pressure sensor (using address 0).

To enhance accuracy of generated humidity, the low range pressure sensor is allowed to alternately measure chamber pressure and saturator pressure when saturator pressure is low (meaning relative humidity is high). When sat select solenoid, SOL 4, is activated via 24VDC from ECB RLY 9, the low range sensor connects pneumatically to the saturator to measure sat pressure. For measurement of chamber pressure, SOL 4 is deactivated and chamber select solenoid, SOL 5, is activated via 24VDC from ECB RLY 10. The low range sensor connects pneumatically to the chamber. SOL 4 and SOL 5 are never activated at the same time.

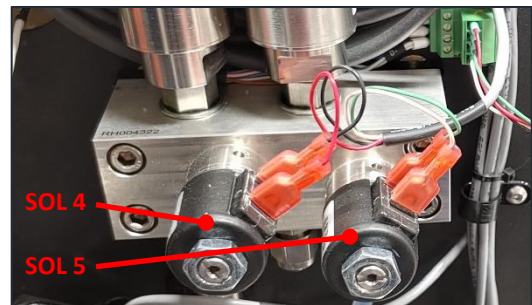


Figure 6.14

When sat pressure is below 25 PSIA, SOL 4 and SOL 5 alternately switch ON/OFF to allow the low range pressure sensor to alternately measure saturator and chamber pressure. When sat pressure is higher than 25 psia, SOL 5 activates to ensure the low range sensor measures only the chamber pressure during that time.

### 6.2.8 VENT VALVE, SOL 2

The vent valve, SOL 2, is used to vent pressure from the saturator during shutdown and whenever the system is not generating humidity. It is configured as a normally-open valve, meaning that it vents whenever it is de-energized (whenever there is no power applied).

When the humidity generator is generating humidity, SOL 2 is energized to allow the saturator to pressurize normally. When the humidity generator is generating, the ECB's DC CONTROL – RLY 13 sources 24 VDC to energize the vent solenoid causing it to stop venting. An LED on RLY 13 also indicates the relay status. When the LED is on, the solenoid coil is energized and the valve is not venting. Note that during normal operation of the humidity generator, the coil is energized and the valve will be hot to the touch.



Figure 6.15

### 6.2.9 DRYER BLEED, SOL 10 (OPTIONAL)

The air dryer operates by continuously bleeding a small flow of air past a water permeable membrane. The air dryer may optionally be equipped with a dryer bleed valve. When the system is running, the bleed valve energizes to activate the drying operation. While drying, a few liter/min of air bleeds from the dryer. When the system is shut down and dry air is no longer required, the valve deactivates, preventing air from bleeding unnecessarily. If no bleed valve is installed, the dryer bleeds continuously regardless of system run status or dry air demand.

## 6.3 FLUID SYSTEM

There are several separate and distinct fluid systems in the humidity generator. The saturator fluid circulation system, utilizing a 30-50% mixture of propylene glycol and water, is used to control the temperature of the saturator. The fluid in this system, while thermally coupled to the saturator, never comes in direct contact with the gas stream.

The chamber fluid circulation system, utilizing a 30-50% mixture of propylene glycol and water, is used to control the temperature of the chamber and window. The saturator and chamber fluid circulation systems, while independently controlled, utilize a common fluid expansion tank and therefore share a common fluid source.

A separate fluid system, utilizing distilled water only, is used to humidify the incoming gas, and is the main source of humidity in the system's outgoing gas stream. Humidification is accomplished by maintaining a set water level within the presaturator. This liquid level control system requires sufficient distilled water supply level be maintained by the operator. A distilled water reservoir tank is located within the lower cabinet.

### 6.3.1 DISTILLED WATER SUPPLY

Distilled water is required and must be maintained at a sufficient level in the distilled water reservoir tank in the lower cabinet. This tank is connected via a suction tube to the presaturator via the preset fill pump.

The operator is responsible for maintaining distilled water in this tank, filling it when required.

While the initial fill of a new system may require up to 2 liters of distilled water to reach the desired presaturator water level needed, ongoing water usage by the system is rather low.

The tank may be refilled (or topped-up) at any time, even while the system is running. The distilled water supply tank should always have a minimum level of at least a few inches (several centimeters) of water, keeping the suction tube inlet below the water level.

It is the operators responsibility to ensure that there is sufficient water in this supply tank at all times. When full, there is sufficient water for at least 24 hours continued operation at the highest temp/humidity generator conditions.

Use of deionized water is not recommended as it tends to be ionically aggressive to stainless steel and may cause pitting of the presaturator and saturator. Distilled water, even that which is purchased at local grocery or discount stores, is generally preferred over deionized water.

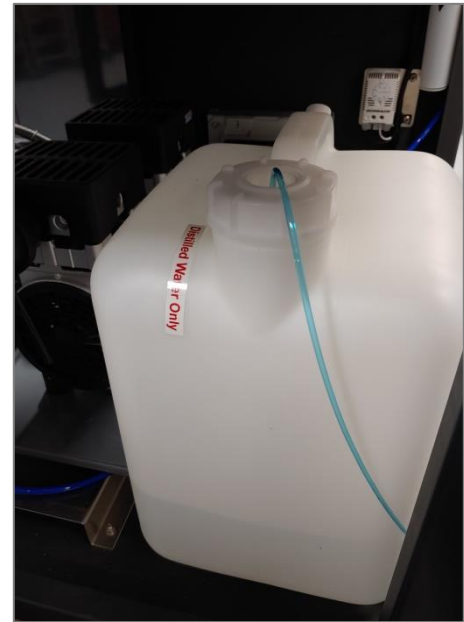


Figure 6.16

### 6.3.2 PRESATURATOR LIQUID LEVEL SYSTEM

The presaturator liquid level system maintains the water level within the presaturator. This is done automatically utilizing an electronic tube liquid presence sensor, a high-pressure pump, P2, and a liquid level sensor within the presaturator. When activated, the pump P2 pulls water from the distilled water supply, through a suction tube, past the tube liquid presence sensor and into the high pressure pump P2. Water is pressurized through P2 and enters the presaturator. Since this high-pressure pump can fill the presaturator while the system is generating humidity, the system can operate for extended periods without the need to shut down.

The water level of the presaturator is detected by the ECB with a conductivity measurement of the liquid level probe, LLP, which is connected to ANALOG LEVEL INPUTS - LVL 4. This circuit converts the conductivity analog signal to a digital signal level and routes it through jumper 4 to the digital LEVEL INPUTS – LVL4 to be sensed by the ECB software. An LED at LEVEL INPUTS - LVL4 indicates a low water level when ON.

This low presaturator water level is sensed by the ECB software which then activates the high-pressure pump, P2, by creating a 24 VDC square wave on DC CONTROL - RLY 4. The square wave sequentially activates/deactivates the solenoid of P2 causing it to pump water into the presaturator. When water is detected at the preset liquid level sensor, the LED turns off.

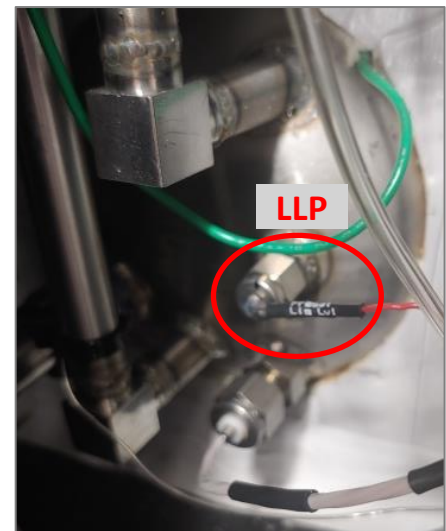


Figure 6.17



Figure 6.18



Pumping is then halted by the software by deactivating the square wave at RLY 4. When not actively pumping, the output of RLY 4 is off, and the pump's solenoid remains in a de-energized state.

The tube liquid presence sensor, LLT, looks for large air gaps within the suction tube. Air gaps in this suction tube give warning of low tank water, and if detected, the system will shut down with a corresponding error code.

Inside the back panel (Figure 6.19) is a drain valve and port, labeled Presat Drain, and is used to manually drain water from the preset if desired.



Figure 6.19

### 6.3.3 SATURATOR FLUID CIRCULATION SYSTEM

The Saturator Fluid Circulation System is a circulating mixture of propylene glycol and water used to control the temperature of the saturator. Controlling the temperature of the fluid controls the temperature and stability of the saturator and the resulting generated humidity. The fluid circuit consists of several significant components, fluid pump, heater, refrigeration evaporator, saturator, and the fluid expansion tank.

Water circulated from the fluid pump, P3, exits the top of the pump, passes through a the refrigeration evaporator, cooling as necessary. The fluid then passes through the saturator fluid heater, H2, and is heated as necessary. From there, it flows through the saturator and ultimately back to the inlet at the bottom of the pump.

A small expansion tank is also connected to the bottom pump inlet allowing for temperature induced variation in the overall fluid volume.

When the system is generating, 24 VDC is sourced from the ECB's DC CONTROL – RLY 1 to the fluid pump P3. An LED at RLY 1 indicates when it is active and power is applied to the pump. Note that the fluid pump has built-in circuitry to protect against dry run conditions and may therefore take several seconds to power up to full speed when activated.

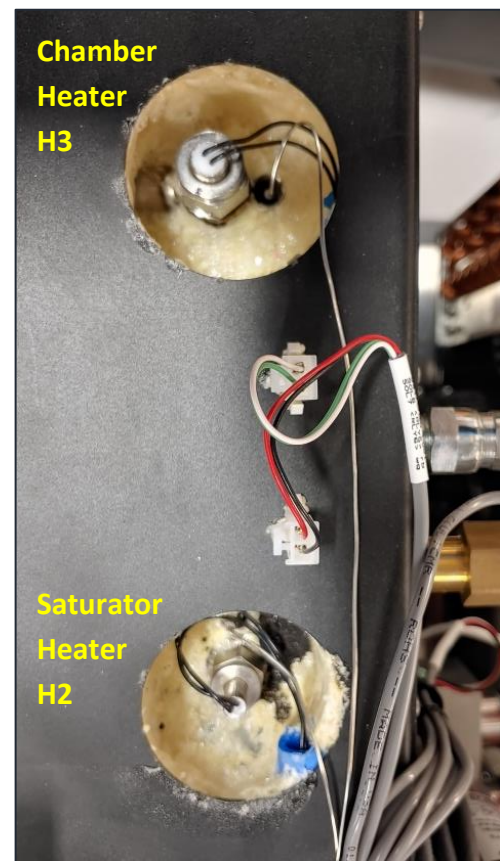


Figure 6.20

Both the saturator fluid circulation system and chamber fluid circulation system share a common expansion tank. The tank is located at the upper left-hand corner of the system, behind the chamber.

### 6.3.4 CHAMBER FLUID CIRCULATION SYSTEM

The Chamber Fluid Circulation System is a circulating medium of water (or a mixture of water and anti-freeze) used to control the temperature of the saturator. Controlling the temperature of the fluid controls the temperature and stability of the chamber and the resulting generated humidity. The fluid circuit consists of several significant components, fluid pump, heater, refrigeration evaporator, saturator, and the fluid expansion tank.

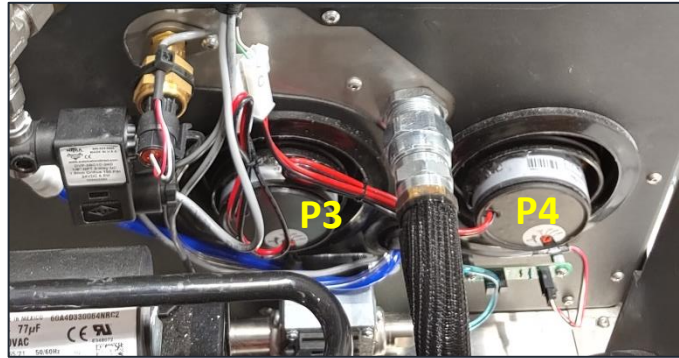


Figure 6.21

Water circulated from the fluid pump, P4, exits the top of the pump, passes through a refrigeration evaporator, cooling as necessary. The fluid then passes through the chamber fluid heater, H3, and is heated as necessary. From there, it flows through the chamber jacket and the inner pane of the door window and ultimately back to the inlet at the bottom of the pump.

A small expansion tank is also connected to the fluid loop allowing for temperature induced variation in the overall fluid volume.

When the system is generating, 24 VDC is sourced from the ECB's DC CONTROL – RLY 2 to the fluid pump, P4. An LED at RLY 2 indicates when it is active and power is applied to the pump. Note that the fluid pump has built-in circuitry to protect against dry run conditions and may therefore take several seconds to power up to full speed when activated.

Both the saturator fluid circulation system and chamber fluid circulation system share a common expansion tank. The tank is located at the upper left-hand corner of the system, behind the chamber.



Figure 6.22

## 6.4 REFRIGERATION SYSTEM

The refrigeration system is a hermetically sealed, closed-loop cooling system used to cool the circulation fluids of the saturator and chamber. The refrigeration system is charged with 35 ounces (1 Kg) of R134A refrigerant.

Refrigerant is compressed into a heat-laden high-pressure gas by the R134A Compressor. The high-pressure hot gas is passed through the air-cooled condenser. The refrigerant cools and condenses to a high-pressure liquid as it passes through the condenser. The high-pressure liquid accumulates in the receiver. Liquid from the receiver passes through the filter/drier and the sight glass. This high-pressure liquid is



Figure 6.23

then metered into the evaporator via the Sat Cool solenoid and chamber cool solenoid, absorbing heat (cooling) as it expands to a low-pressure gas. The low pressure, heat-laden gas is then returned to the suction side of the R134A compressor where the process repeats itself. This refrigerant suction side pressure is measured by a pressure transducer, Prl. The refrigerant high side pressure is measured by a pressure transducer, Prh.

The Sat Cool solenoid is controlled by the ECB using pulse width modulation based on the bath temperature. The Chamber Cool solenoid is controlled by the ECB using pulse width modulation based on chamber temperature.

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#### 6.4.1 COMPRESSOR

The R134A compressor is a hermetic refrigeration compressor, COMP1, which is capable of pulling to low pressures on the input side, and producing high pressures on the discharge side.

During times of normal cooling demand, the compressor runs continuously. When there is no cooling demand for a period of time, such as when the system is being heating to a warmer temperature, the compressor is turned off completely until the system once again requires cooling control.

The refrigeration compressor is activated by ECB A0, activating the solid-state relay, SSR1, which applies AC power to the compressor through circuit breaker, CB2. LEDs at ECB-A0 and SSR1 are lit when power is applied to the compressor. Even with the LEDs on, power may be removed from the compressor by turning off CB2.

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#### 6.4.2 CONDENSER AND FAN

The refrigeration condenser cools the high-pressure high temperature gas output from the refrigeration compressor, condensing it into a room temperature liquid. Heat from the condenser is exhausted into the room by the condenser fan. The fan runs continuously whenever power is applied to the system provided the R-134A fan CB1 is ON.

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#### 6.4.3 SAT COOL SOLENOID, SOL 6

The saturator temperature is maintained by heating or cooling the circulating fluid as needed. Cooling is accomplished by refrigerant injection through the sat cool solenoid valve, SSOL 6. This valve is actuated by a 24VDC pulse width modulated signal. When energized, the valve opens allowing refrigerant to be injected into the evaporator, causing it to cool the circulating fluid. The pulse width of the valve directly controls the amount of refrigerant injected, thereby affecting the temperature of the fluid. The valve is generally pulsed at a fixed interval with varying pulse width. When the system requires cooling, the ECB's DC CONTROL – RLY 5 sources 24 VDC to the sat cool solenoid, causing it to open and inject refrigerant into the evaporator. An LED at RLY 5 also indicates the relay status. When the LED is ON, the valve is energized. Saturator temperature is measure by temperature probe, Ts.

---

#### 6.4.4 CHAMBER COOL SOLENOID, SOL 7

The chamber temperature is maintained by heating or cooling the circulating fluid as needed. Cooling is accomplished by refrigerant injection through the sat cool solenoid valve, SOL 7. This valve is actuated by a 24VDC pulse width modulated signal. When energized, the valve opens allowing refrigerant to be



Figure 6.24



injected into the evaporator, causing it to cool the circulating fluid. The pulse width of the valve directly controls the amount of refrigerant injected, thereby affecting the temperature of the fluid. The valve is generally pulsed at a fixed interval with varying pulse width. When the system requires cooling, the ECB's DC CONTROL – RLY 6 sources 24 VDC to the sat cool solenoid, causing it to open and inject refrigerant into the evaporator. An LED at RLY 6 also indicates the relay status. When the LED is ON, the valve is energized. Chamber fluid temperature is measured by temperature probe, T<sub>cl</sub>. Chamber temperature is measured by temperature probe, T<sub>c</sub>.

#### 6.4.5 EVAPORATORS

The refrigeration evaporators are brazed plate heat exchanger thermally coupling the sat and chamber fluids with the R134A refrigerant system. One side of each evaporator is connected to the refrigeration system, while the circulating fluid flows through the other side. As liquid refrigerant is injected into the evaporator, it expands into gas. This expansion causes cooling (by absorbing heat), which lowers the temperature of the circulating fluid flowing through the other side.

Saturator fluid flows through one evaporator to cool the saturator. Chamber fluid flows through the other evaporator to cool the chamber.

#### 6.4.6 REFRIGERATION PRESSURE SENSORS, P<sub>RL</sub> & P<sub>RH</sub>

The refrigeration low-side pressure sensor, P<sub>RL</sub>, measures the suction side pressure of the refrigeration compressor. Readings from this sensor are in gauge (relative) pressure. The sensor is powered from 12 VDC and has a 1-5 VDC output. The sensor is connected to the ECB at A/D INPUTS – AD1. Power for the sensor is applied from AD1 12V+ and AD1 GND. The sensor's voltage output in the range of 1 to 5 VDC is connected to AD1 SIG.

The refrigeration high-side pressure sensor, P<sub>RH</sub>, measures the discharge side pressure of the refrigeration compressor. Readings from this sensor are in gauge (relative) pressure. The sensor is powered from 12 VDC and has a 1-5 VDC output. The sensor is connected to the ECB at A/D INPUTS – AD0. Power for the sensor is applied from AD0 12V+ and AD0 GND. The sensor's voltage output in the range of 1 to 5 VDC is connected to AD0 SIG.

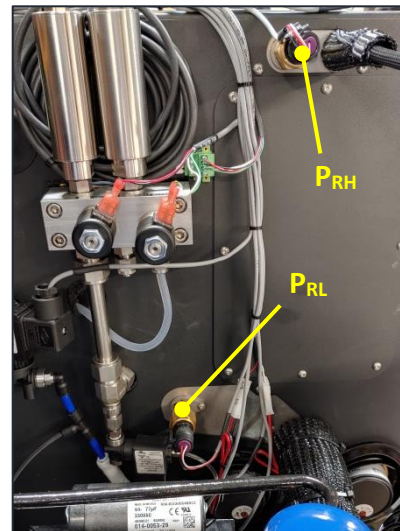


Figure 6.25

#### 6.4.7 EVAPORATOR BYPASS SOLENOID, SOL 8

The evaporator bypass solenoid, SOL 8, is used to cool the compressor during times of high demand when cooling from high temperatures to low. It injects refrigerant directly into the compressor suction line to overcome the heat removed from the system in an attempt to keep the compressor cool. This valve is actuated by a 24VDC pulse width modulated signal. When energized, the valve opens allowing refrigerant to be injected directly into the suction line, cooling the compressor. The pulse width of the valve directly controls the amount of refrigerant injected, thereby affecting the temperature of the fluid. The valve is generally pulsed at a fixed interval with varying pulse width. When the system

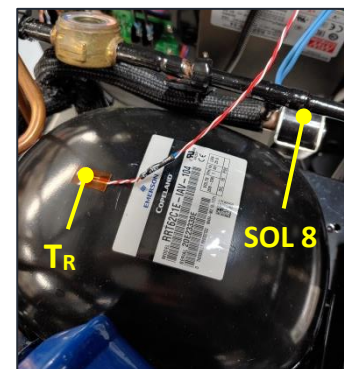


Figure 6.26

requires cooling, the ECB's DC CONTROL – RLY 7 sources 24 VDC to the sat cool solenoid, causing it to open and inject refrigerant. An LED at RLY 7 also indicates the relay status. When the LED is ON, the valve is energized. The refrigeration compressor temperature is measured by temperature probe,  $T_R$ .

## 6.5 HEATERS

The humidity generator requires several different heating zones to properly create and maintain humidity without fear of adverse condensation. Heating is required in the presaturator, circulating fluids, and expansion valve.

### 6.5.1 PRESATURATOR HEATER, H1

The presaturator warms the incoming gas to oversaturate it with water vapor. This is accomplished through heating of the presat water. A 1500-watt stainless steel insulated immersion heater provides this function. The presat water is warmed to and maintained at setpoint through pulse width modulation of the heater using feedback from the presat temperature sensor,  $T_P$ .

When heating is required, the ECB's AC CONTROL – A1 digital output activates solid state relay SSR3 which completes the AC current path through circuit breaker CB3 to the presaturator heater. A1's digital output is visually indicated with an adjacent LED.

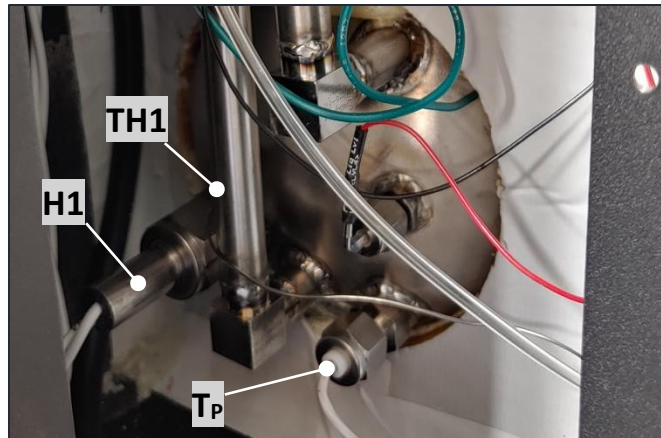


Figure 6.27

The heater ON status is also indicated with an LED on the solid-state relay SSR2. AC power to the heater is also protected by a thermal cutout switch, TH1, which removes AC power in the event of over temperature. The presat temperature is measured by temperature probe,  $T_P$ .

### 6.5.2 SATURATOR FLUID HEATER, H2

The saturator temperature is maintained by heating or cooling the circulating fluid as needed. Heating is accomplished by activating a 500-watt stainless steel insulated immersion heater, H2, inserted in the circulating fluid. The circulating fluid temperature is warmed to and maintained at setpoint through pulse width modulation of the fluid heater using feedback from the saturator temperature sensor,  $T_S$ . When heating is required, the ECB's AC CONTROL – A2 digital output activates solid state relay SSR3 which completes the AC current path through circuit breaker, CB4, to the fluid heater.

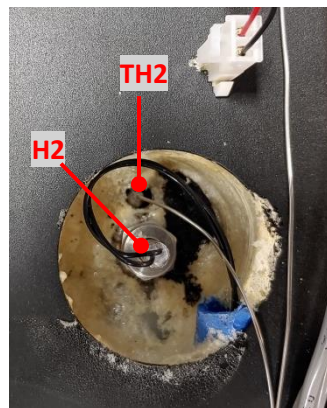


Figure 6.28

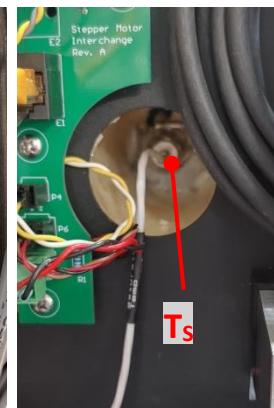


Figure 6.29

A2's digital output is visually indicated with an adjacent LED. The heater ON status is also indicated with an LED on the SSR3. AC power to the heater is also protected by a thermal cutout switch, TH2, which removes AC power in the event of over temperature.



### 6.5.3 CHAMBER FLUID HEATER, H3

The chamber temperature is maintained by heating or cooling the circulating fluid as needed. Heating is accomplished by activating a 700-watt stainless steel insulated immersion heater, H4, inserted in the circulating fluid. The circulating fluid temperature is warmed to and maintained at setpoint through pulse width modulation of the fluid heater using feedback from the chamber fluid temperature sensor,  $T_{CL}$ .

When heating is required, the ECB's AC CONTROL – A3 digital output activates solid state relay SSR4 which completes the AC current path through circuit breaker, CB5, to the fluid heater.

A3's digital output is visually indicated by an adjacent LED.

The heater ON status is also indicated with an LED on the SSR4.

AC power to the heater is also protected by a thermal cutout switch, TH3, which removes AC power in the event of over temperature. Chamber fluid temperature influences chamber temperature. Chamber temperature is measured by temperature probe,  $T_c$ , mounted inside the chamber.

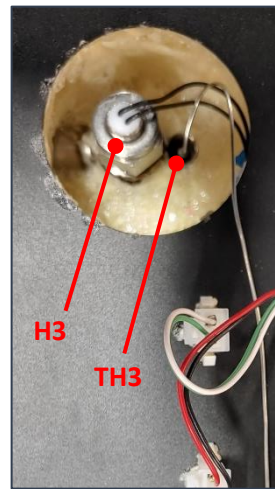


Figure 6.30

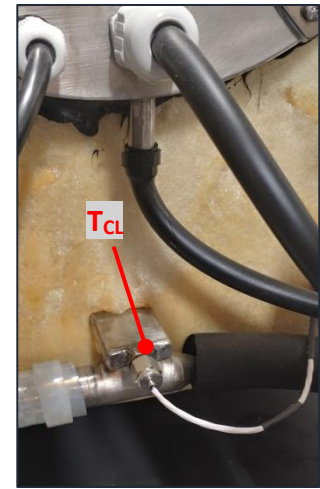


Figure 6.31

### 6.5.4 EXPANSION VALVE HEATER, H4

As the gas expands from a high pressure to a lower pressure, it cools. To offset this cooling effect, and also to prevent unwanted condensation in the expansion valve, V2, the valve is heated.

Heater H4 is comprised of a small heater installed in the valve plug, and a custom heater foil adhered to the outside of the valve body. They are connected in parallel.

Expansion valve heating is accomplished by activating the ECB's DC CONTROL – RLY 12 to source 24 VDC to the heaters.

RLY 12's output is visually indicated with an adjacent LED. When the LED is ON, the heaters are active.

The expansion valve is heated and maintained at temperature through pulse width modulation of RLY 12 using feedback from the expansion valve temperature sensor,  $T_{EV}$ . The valve is normally wrapped in a custom molded thermal insulator (not shown in Figure 6.32).

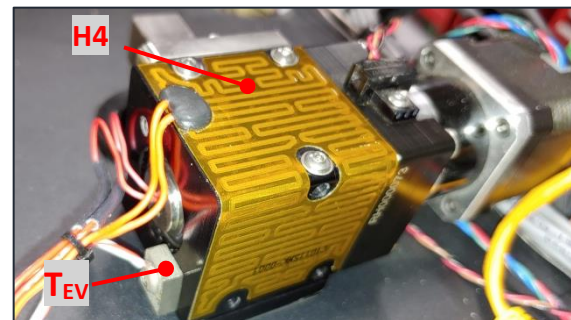


Figure 6.32

### 6.5.5 ACCESS PORT HEATERS

The system has three access ports on the left side of the chamber. Figure 6.33 shows the three ports, as seen when the side panel is removed.

To prevent condensation during high temp/high humidity generation, each port is equipped with independent temperature measurement and control. The ports are heated and maintained at desired temperature through pulse width modulation of their respective relays, using feedback from their associated temperature sensors.

The upper access port temperature,  $T_{PU}$ , is measured on temperature channel T10. A low-wattage heater, H7, is connected to RLY 16. Heating is accomplished by activating the ECB's DC CONTROL – RLY 16 to source 24 VDC to the heaters. RLY 16's output is visually indicated with an adjacent LED. When the LED is ON, the heater is active.

The center access port temperature,  $T_{PC}$ , is measured on temperature channel T11. A low-wattage heater, H8, is connected to RLY 17. Heating is accomplished by activating the ECB's DC CONTROL – RLY 17 to source 24 VDC to the heaters. RLY 17's output is visually indicated by an adjacent LED. When the LED is ON, the heater is active.

The lower access port temperature,  $T_{PL}$ , is measured on temperature channel T12. A low-wattage heater, H9, is connected to RLY 18. Heating is accomplished by activating the ECB's DC CONTROL – RLY 19 to source 24 VDC to the heaters. RLY 19's output is visually indicated with an adjacent LED. When the LED is ON, the heater is active.



Figure 6.33

## 6.6 CONNECTIONS TO THE ECB

The Embedded Controller Board (ECB) has many different inputs and outputs used to operate the system. Grouped by functional type, the following tables in this chapter list the various inputs and outputs of the ECB and reference the specific sections of this manual where each input or output is discussed.

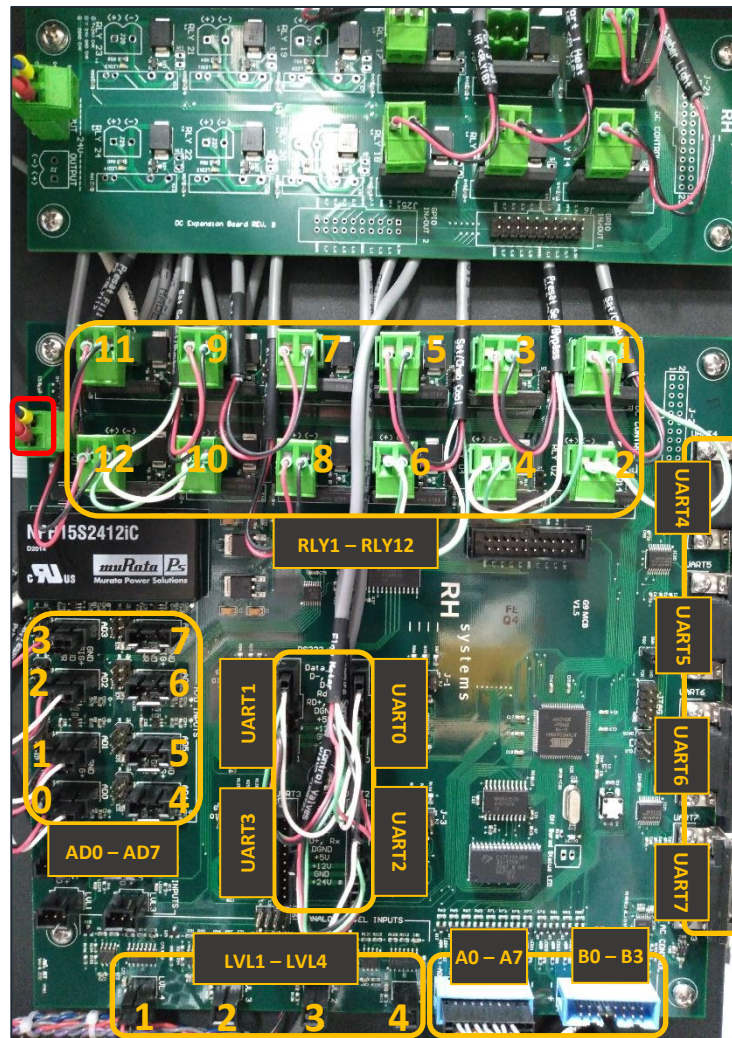


Figure 6.34

### 6.6.1 DC CONTROL

The ECB's DC CONTROL section (RLY1 through RLY18) powers valves, motors, heaters, fan, etc. These devices receive their 24 VDC power directly from the relay connector. These relay outputs power their connected devices directly, sourcing up to 2 amps each. The (+) pin of each relay connector is hard wired to 24 VDC. The (-) pin of each channel switches in ground via the relay. Each output channel has an adjacent LED. When an LED is on, it indicates that the connector's (-) pin is pulled to ground, allowing current to flow through a connected device.

Relay	Description	Reference
RLY 1	P1, Saturator Fluid Pump	Section 6.3.3
RLY 3	SOL 9, Presat Select	Section 6.2.4
RLY 5	SOL 6, Saturator Cooling Solenoid	Section 6.4.3
RLY 7	SOL 8, Evaporator Bypass Solenoid	Section 6.4.7
RLY 9	SOL 4, P <sub>L</sub> Sat Select	Section 6.2.6, 6.2.7
RLY 11	P2, Presat Fill Pump	Section 6.3.4
RLY 13	SOL 2, Vent Valve	Section 6.2.8
RLY 15	SOL 10, Dryer Enable/Disable (Optional)	
RLY 17	H8, Middle Access Port Heater	Section 6.5.5

Relay	Description	Reference
RLY 2	P2, Chamber Fluid Pump	Section 6.3.4
RLY 4	SOL 3, Presat Bypass	Section 6.2.4
RLY 6	SOL 7, Chamber Cooling Solenoid	Section 6.4.3
RLY 8	SOL 1, Air-In Solenoid	Section 6.2.2
RLY 10	SOL 5, P <sub>L</sub> Chamber Select	Section 6.2.6, 6.2.7
RLY 12	H4, Expansion Valve Heat	Section 6.5.4
RLY 14	L1, Chamber Light	Section 6.1.6
RLY 16	H7, Upper Access Port Heater	Section 6.5.5
RLY 18	H9, Lower Access Port Heater	Section 6.5.5

### 6.6.2 AC CONTROL

The ECB's AC CONTROL section (A0-A7) are digital outputs at a 5-volt logic level. They are primarily used as the control signals for high power AC relays. LEDs adjacent to each output indicate the status. When an LED is on, it indicates the digital output is active and it's (-) pin is being pulled to a logic low. The (+) pin of each digital output is hard wired to +5 VDC.

Digital Output	Description	Reference
A0	Comp 1, Compressor	Section 6.4.1
A1	H1, Presat Heater	Section 6.1.4.2
A2	H2, Sat Heater	Section 6.1.4.3
A3	H3, Chamber Heater	Section 6.1.4.4
A4	FAN 2, Chamber Fan	Section 6.5.2
A5	H5, Window Pane Heater	Section 6.1.5.1
A6	H6, Window Frame Heater	Section 6.1.5.2
A7	N/A	

### 6.6.3 A/D INPUTS

The ECB's A/D INPUTS section (AD0-AD7) has an 8 channel, 14-bit, 5-volt analog to digital converter system. Each connector also has 12 VDC power available to directly power the connected devices or sensors.

Analog Input	Description	Reference
AD0	P <sub>RH</sub> , Refrigeration High-side Pressure Sensor	Section 6.4.6
AD1	P <sub>RL</sub> , Refrigeration Low-side Pressure Sensor	Section 6.4.6
AD2	L <sub>LT</sub> , Tube Liquid Presence	Section 6.3.3
AD3	Temp Board power	Section 6.1.3
AD4-AD7	N/A	

### 6.6.4 LEVEL INPUTS

The ECB's LEVEL INPUTS are 5 volt digital inputs used for liquid level controls. The generator does not use these digital inputs directly. On the generator, an analog liquid level probe is used. For this configuration, the analog probe is connected to the ANALOG LEVEL INPUTS section of the ECB. The output from this analog section is a digital signal which is then tied to the digital LEVEL INPUTS section via a jumper.

Digital Input	Description	Reference
LVL1-LVL3	N/A	
LVL4	Presat level from ANALOG LEVEL INPUTS – LVL 4	Section 6.3.2

#### 6.6.5 ANALOG LEVEL INPUTS

The ECB's ANALOG LEVEL INPUTS are configured for capacitive liquid level probes. A comparator in the circuit converts the analog signal to a digital output. A jumper associated with each channel then allows the digital output from an analog circuit to be fed into the associated digital LEVEL INPUTS channel.

Analog Input	Description	Reference
LVL 1-LVL 3	N/A	
LVL 4	LLP, Presat level probe	Section 6.3.2

**NOTE:** The ECB component labels for the Analog and Digital Level Inputs are similarly labeled.

#### 6.6.6 UARTS

The ECB contains 8 fully independent Universal Asynchronous Receiver Transmitter (UART) serial ports which are configurable for either RS-232 or RS-485 communication. The following table lists the configuration and connected devices for each of these serial ports.

Serial Port	Connected devices	Protocol	Addr	Reference
UART0	Flowmeter & inlet pressure gauge	RS-232, 9600, 8, 1, N	A	Section 6.2.1
UART1	Prl, Pressure sensor	RS-485, 9600, 8, 1, N	0	Section 6.2.6
	Prh, Pressure sensor	RS-485, 9600, 8, 1, N	1	Section 6.2.6
UART2	V1, Flow Control Valve	RS-485, 9600, 8, 1, N	0	Section 6.2.3
	V2, Expansion Valve	RS-485, 9600, 8, 1, N	1	Section 6.2.4
UART3	N/A		-	
UART4	External RS-233	RS-232, 9600, 8, 1, N	-	Section 3.3.1
UART5	Internal PC	RS-232, 9600, 8, 1, N	-	Section 3.3.1
UART6	N/A	RS-232, 9600, 8, 1, N	-	
UART7	Temperature Board	RS-232, 9600, 8, 1, N	-	Section 6.1.3



## 6.7 TEMPERATURE MEASUREMENTS

The Precision Temperature Measurement board is a multi-channel, 24-bit, A/D converter system used to measure all temperatures in the humidity generator. It connects to the ECB either of its RS-232 port. While two of the A/D converter channels are configured for reference resistor measurements, the remaining channels are configured for connection of 100 $\Omega$  platinum resistance thermometers (PRTs). The following table lists the probe channels and functions of the humidity generator.

Channel	Probe name	Function	Reference
CH 1	T <sub>p</sub>	Presat Temp	Section 6.5.1
CH 2	T <sub>s</sub>	Sat Temp	Section 6.4.3, 6.5.2
CH 3	T <sub>c</sub>	Chamber Temp	Section 6.4.4, 6.5.3
CH 4	T <sub>CL</sub>	Chamber Fluid Temp	Section 6.4.4, 6.5.3
CH 5	T <sub>EX</sub>	Expansion Valve Temp	Section 6.5.4
CH 6	T <sub>R</sub>	Refrigerant Low-side Temp	Section 6.4.7
CH 7-9	N/A	N/A	
CH 10	T <sub>PU</sub>	Upper Access Port Temp	Section 6.5.5
CH 11	T <sub>PC</sub>	Center Access Port Temp	Section 6.5.5
CH 12	T <sub>PL</sub>	Lower Access Port Temp	Section 6.5.5
CH 13	R <sub>ref1</sub>	Reference Resistor	Section 6.7
CH 14	R <sub>ref2</sub>	Optional Reference	Section 6.7
CH 15	R <sub>ref3</sub>	Reference Resistor	Section 6.7
CH 16	R <sub>ref4</sub>	Optional Reference	Section 6.7

All probes are wired to the temperature board as 4-wire, 100 $\Omega$  PRTs. All probe connections are made via straight single row, 6-pin Molex plugs. The reference resistor pack houses two individual reference resistors (R<sub>60</sub> and R<sub>140</sub>) and connects via a dual row header. The reference resistors are known stable resistances, whose values are programmed into the reference resistor pack. These resistors are measured and their known values are queried and used in determination of all PRT resistances. Since the reference resistor pack is constructed with memory chips, the temperature measurement board accepts any reference values mounted to any of channels 13-16. The system requires a minimum of 2 reference resistors but can utilize up to 4 references resistors if present. The Precision Resistance Measurement board communicates via RS-232 to the ECB UART 7.

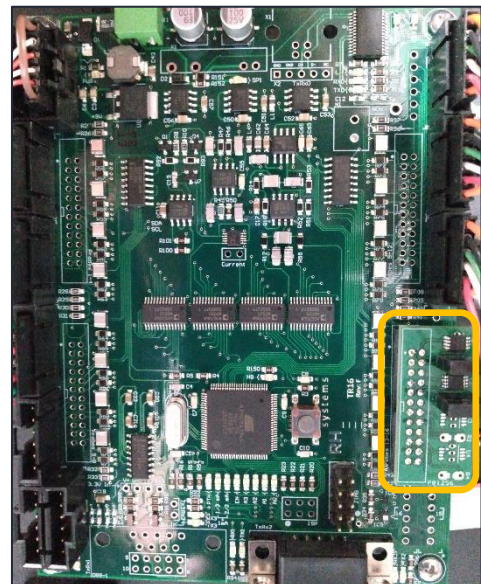


Figure 6.35

## 7 TROUBLESHOOT/MAINTENANCE

### 7.1 PREVENTATIVE MAINTENANCE

This section details the required preventative maintenance for the humidity generator.

#### 7.1.1 DAILY

The humidity generator requires daily maintenance actions, which are listed in the following sections.

##### 7.1.1.1 MAINTAIN DISTILLED WATER LEVEL

Check the distilled water level in the tank below the system. The tank is located in the lower cabinet. The tank can be filled at any time, during operation or otherwise. The tank level should be checked and filled daily.



#### 7.1.2 WEEKLY

The humidity generator requires weekly maintenance actions, which are listed in the following sections.

##### 7.1.2.1 TEST AIR COMPRESSOR AUTO-DRAIN

The air compressor tank should be checked daily for presence of water. The air compressor tank is located below the system in the lower cabinet. There is a mechanical valve located at the bottom of the air tank. Slowly open the valve to ensure there is no presence of water. If there is water, drain the water from the tank before proceeding.

To test the air compressor's automatic drain, click the "Test" button.

**Important:** The air compressor power must be **OFF** prior to performing the test.

*The tank should vent for approximately ½ second.*



##### 7.1.2.2 CHECK COOLING FLUID LEVEL

This check should be performed when the system is at approximately room temperature (25±5 °C).

This system requires an adequate level of cooling fluid in order to maintain the temperature of the saturator, the chamber, and the window. The cooling fluid level has an expansion bottle, located at the upper left rear corner of the system. Remove the top and rear panels to check the fluid level of the tank. The level should be between the minimum and maximum marks indicated on the tank.





For instance, if it is low, add fluid (with a concentration of approximately 30-50% propylene glycol in water) to the tank. If the level is above the maximum, drain out the excess amount to bring it within the minimum and maximum marks. (Refer to Figure 9.13 for location of the drain port.)

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### 7.1.3 MONTHLY

The humidity generator requires monthly maintenance actions, which are listed in the sections below.

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#### 7.1.3.1 CONDENSOR EXHAUST FAN

The refrigeration system requires adequate air flow to work properly. The condenser and fan assembly can get clogged with dust and dirt. It should be cleaned with either compressed air or a vacuum cleaner. To perform cleaning, remove the upper rear panel and with either compressed air or a vacuum, clean the condenser grill and fan area to remove the debris.

---

#### 7.1.3.2 LOWER CABINET FAN

The lower cabinet fan requires periodic cleaning to maintain performance. To clean the cabinet fan, remove the exterior vent cover then, using either compressed air or a vacuum, blow out any collected dust and debris. The vent cover should also be cleaned/washed prior to re-attachment.

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### 7.1.4 QUARTERLY

The humidity generator requires quarterly maintenance actions, which are listed in the sections below.

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#### 7.1.4.1 AIR COMPRESSOR TEST

As with all mechanical systems, the air compressor may wear out over time, limiting its performance. To test its operation, it is important to run it at a known flow rate and make sure it maintains its pressure requirement. To perform this test, set the generator for operation at 20 l/min and 25% RH at 25°C. Press the run button to ensure the generator is operating. Once the system is stabilized and it is flowing approximately 20 l/min, check the output of the PSI pressure indicator on the front panel, or the pressure gauge on the pressure regulator. It should be approximately 50 - 60 psi.

If it is not at least 50 psi, the air compressor may require service or replacement.




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#### 7.1.4.2 PRESSURE TRANSDUCER ALIGNMENT CHECK

The pressure transducer alignment test is to verify that the two pressure transducers have not drifted too far apart from each other. This test is only to be performed at approximately ambient atmospheric pressure. To perform the test, ensure the system is not generating, but is powered on. Looking at the front panel indications of low range pressure and high range pressure, compare the two readings. If they differ by more than 1 psi, the pressure transducer calibration should be performed. If they are within 1 psi, no further action is required, as the system will automatically correct for this.

### 7.1.5 ANNUALLY

The humidity generator requires annual maintenance actions, which are listed in the sections below.

#### 7.1.5.1 TEMPERATURE CALIBRATION

Temperature calibration should be performed annually following the instructions in section 5.2 of this manual.

#### 7.1.5.2 PRESSURE CALIBRATION

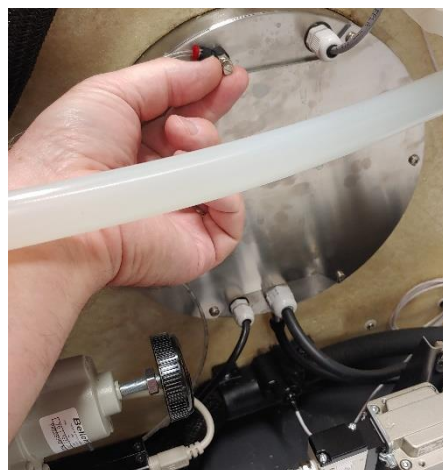
Pressure calibration should be performed annually following the instructions in section 5.1 of this manual.

#### 7.1.5.3 PRESSURE REGULATOR ADJUSTMENT/SERVICE

**Important:** You must have a supply pressure in order to perform regulator adjustment.

To gain access to the pressure regulator, remove the upper rear panel. The pressure regulator and its dial indicator are located behind the chamber.

- 1) With a small screwdriver, press the red button in and rotate a quarter turn clockwise to lock it into position. That activates the air flow to the regulator.
- 2) Turn the adjusting knob on the pressure regulator counterclockwise to lower the indicated pressure to 0.
- 3) Then tare the flow meter using the top right button on the flow meter front panel.
- 4) While the pressure regulator knob is counterclockwise, if the threads appear dry apply a small amount of lubricating grease.
- 5) Using the knob on the pressure regulator, now turn it clockwise until the regulator dial indicates approximately 50 - 55 psi if using the internal air supply or at least 5 psi below your incoming external air pressure.
- 6) Adjust the Chamber Fan Box air-bleed to indicate 0.5 l/min ( $\pm 0.1$ ) on flowmeter display. Finger tighten the lock ring.
- 7) Tare the flow meter again as done in step 3.
- 8) Unlock the red button by rotating a quarter turn counterclockwise. The indicated pressure on the regulator gauge will slowly drop towards 0, this is normal.



#### 7.1.5.4 FLOW VALVE AND EXPANSION VALVE SERVICE

The flow control valve and expansion valve require periodic inspection and maintenance to make sure it is working properly. The following instructions are for disassembly of these items.

1. Remove the three (3) m3x40mm and three (3) m4 x10mm screws from the valve being disassembled.

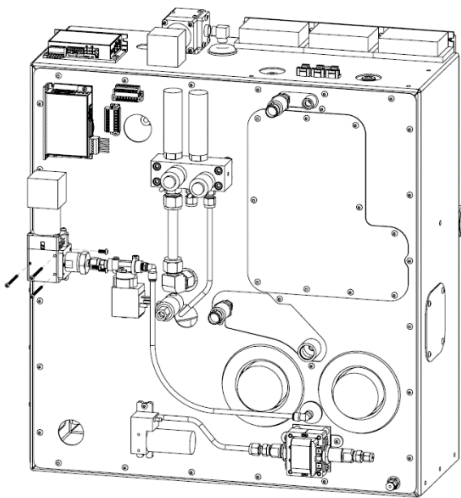


Figure 7.1

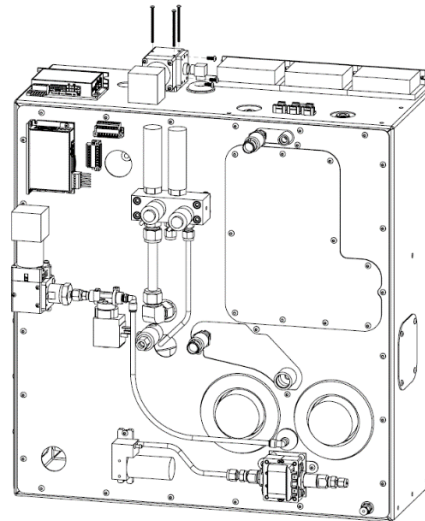


Figure 7.2

2. Remove the valve from the Saturator box. Take note not to lose the wave spring around the Teflon seal (seen in figure 7.5).

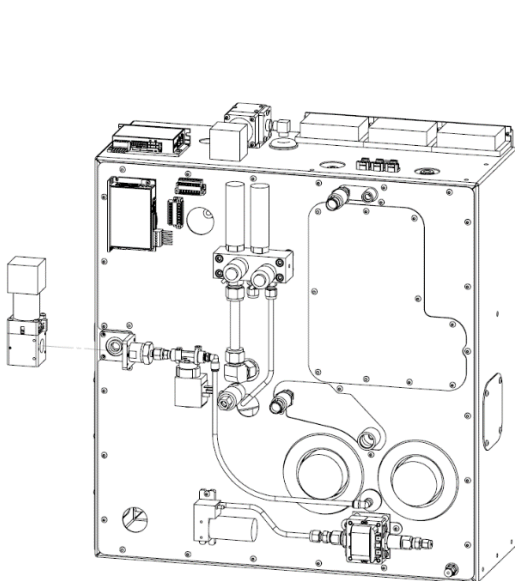


Figure 7.3

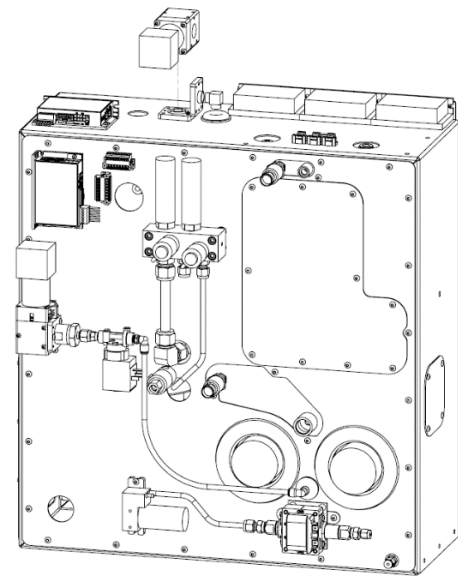


Figure 7.4

3. Remove the Teflon seal, wave spring, and retaining clip.

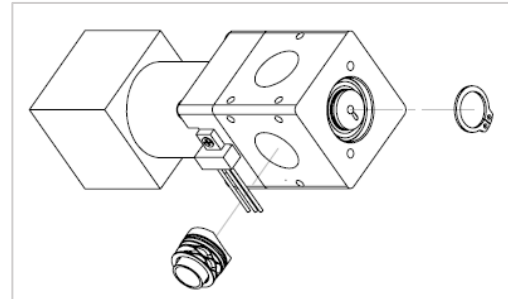


Figure 7.5

4. Remove the four (4) m4x22mm screws from the motor mount. Also remove the m2x2.5mm screw and optical sensor from the motor mount.

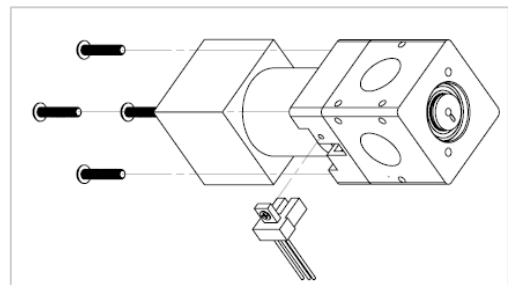


Figure 7.6

5. Carefully separate the valve body from the motor and valve plug assembly.

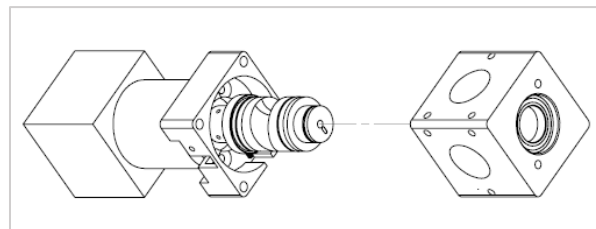


Figure 7.7

6. Once separated (as seen in Figure 7.8) inspect the O-rings for damage. Replace as necessary. The plug O-rings are Viton -115. Grease lightly with a silicone-based O-ring lubricant. Tighten the set screws that secure the motor shaft to the plug.

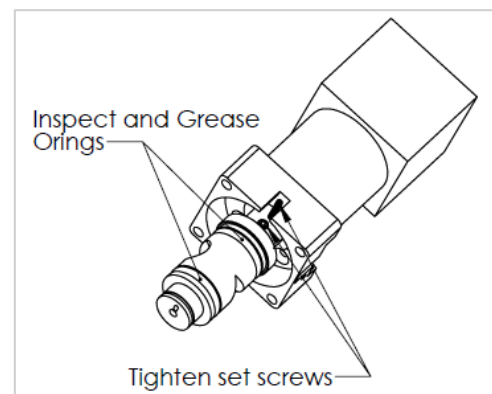


Figure 7.8

7. The Teflon seal has a -016 Viton O-ring that should be checked and lightly greased upon reassembly.
8. Assembly is the reverse of disassembly.

## 7.2 TROUBLESHOOTING

### 7.2.1 ERROR CODES

There are two types of error conditions in the system: emergency shutdown (ESD) conditions and warnings. An ESD will show red in RHS Control and shut the machine down. A warning will show up as yellow in RHS Control and will not influence the machine's running. If warning or errors persist after you've performed the resolution, perform full power cycle before contacting the Support team at RH Systems ([support@rhs.com](mailto:support@rhs.com)).

EMERGENCY SHUTDOWN CODES		DESCRIPTION	RESOLUTION
6	[PI/Ph] Bad pressure Sensor Calibration	The difference between the high range and low range pressure sensors is too high.	Pressure sensors need recalibration.  Faulty Saturator/Chamber select solenoids (SOL4 & SOL5) (see section 6.2.7).
17	[Tp] Presat Temperature Missing	Presat temperature sensor is not reading and is possibly disconnected.	Check pre saturator temperature sensor (Ch1) connection or check temperature measurement board (see section 6.7 or 6.1.3).
18	[TS] Sat Temperature Missing	Sat temperature sensor is not reading and is possibly disconnected.	Check saturator temperature sensor (Ch2) connection or check temperature measurement board (see section 6.7 or 6.1.3).
19	[Tev] Expansion Valve Temperature Missing	Expansion valve temperature sensor is not reading and is possibly disconnected.	Check expansion valve temperature sensor (Ch5) connection or check temperature measurement board (see section 6.7 or 6.1.3).
20	[Tcl] Chamber Liquid Temperature Missing	Chamber liquid temperature sensor is not reading and is possibly disconnected.	Check chamber liquid temperature sensor (Ch4) connection or check temperature measurement board (see section 6.7 or 6.1.3).

21	[Tc] Chamber Temperature Missing	Chamber temperature sensor is not reading and is possibly disconnected.	Check chamber temperature sensor (Ch3) connection or check temperature measurement board (see section 6.7 or 6.1.3).
22	[Pai] Regulated Air-in Pressure Missing	Regulated air in pressure sensor is not communicating.	Check flow meter power and connection (see section 6.2.1 or 6.6.6)
23	[Ps] Saturator Pressure Missing	Saturator pressure sensor is not communicating.	Check pressure sensor power and connection (see section 6.2.6 or 6.6.6).
24	[Pc] Chamber Pressure Missing	Chamber pressure sensor is not communicating.	Check pressure sensor power and connection (see section 6.2.7 or 6.6.6).
26	[Prl] Refrigeration Pressure Low Missing	Low side refrigeration pressure sensor is not communicating.	Check pressure sensor power and connection. (see section 6.4.6 or 6.6.3)
27	[Prh] Refrigeration Pressure High Missing	High side refrigeration pressure sensor is not communicating.	Check pressure sensor power and connection. (see section 6.4.6 or 6.6.3)
29	[Ph] Pressure High Range Missing	High range pressure sensor is not communicating.	Check pressure sensor power and connection (see section 6.2.6 or 6.6.6).
30	[Pl] Pressure Low Range Missing	Low range pressure sensor is not communicating.	Check pressure sensor power and connection (see section 6.2.7 or 6.6.6).
33	[Tp] Presat Temperature Out of Range	Pre saturator temperature is out of operating range.	Verify pre saturator temperature.  Check pre saturator temperature sensor (Ch1) connection or check temperature measurement board (see section 6.7 or 6.1.3).
34	[Ts] Sat Temperature Out of Range	Saturator temperature is out of operating range.	Verify saturator temperature.  Check saturator

			temperature sensor (Ch2) connection or check temperature measurement board (see section 6.7 or 6.1.3).
35	[Tev] Expansion Valve Temperature Out of Range	Expansion valve temperature is out of operating range.	<p>Verify expansion valve temperature.</p> <p>Check expansion valve temperature sensor (Ch5) connection or check temperature measurement board (see section 6.7 or 6.1.3).</p>
36	[Tcl] Chamber Liquid Temperature Out of Range	Chamber liquid temperature is out of operating range.	<p>Verify chamber liquid temperature.</p> <p>Check chamber liquid temperature sensor (Ch4) connection or check temperature measurement board (see section 6.7 or 6.1.3).</p>
38	[Pai] Regulated Air-in Pressure Out of Range	Regulated air in pressure is out of operating range.	<p>Check that supply pressure is above 20psi.</p> <p>Check flow meter power and connection (see section 6.2.1 or 6.6.6)</p> <p>Check pressure indication on dial gauge (see section 6.5.5).</p>
39	[Ps] Saturator Pressure Out of Range	Saturator pressure is out of operating range.	<p>Verify saturator pressure.</p> <p>Check supply pressure (see section 6.2.1).</p> <p>Check flow and expansion valves (see section 6.2.3 and 6.2.5)</p> <p>Check pressure sensor power and connection (see section 6.2.6 or 6.6.6).</p>



40	[Pc] Chamber Pressure Out of Range	Chamber pressure is out of operating range.	<p>Verify chamber pressure.</p> <p>Check pressure sensor power and connection (see section 6.2.7 or 6.6.6).</p> <p>Faulty Saturator/Chamber select solenoids (SOL4 &amp; SOL5) (see section 6.2.7).</p>
41	[Lp] Presat Liquid Level not filling	The pre saturator remains dry while the fill pump has exceeded it's max run time.	<p>Check distilled water reservoir (see section 3.3.2.2)</p> <p>If error persists after reservoir has been filled you may need to re-prime the presat fill pump (see section 3.3.2.3 and 6.3.2).</p> <p>Faulty Saturator/Chamber select solenoids (SOL4 &amp; SOL5) (see section 6.2.7).</p>
42	[PrL] Refrigeration Pressure Low Out of Range	Low side refrigeration pressure sensor is out of operating range.	Check pressure sensor power and connection. (see section 6.4.6 or 6.6.3)
43	[Prh] Refrigeration Pressure High Out of Range	High side refrigeration pressure sensor is out of operating range.	Check pressure sensor power and connection. (see section 6.4.6 or 6.6.3)
45	[Ph] Pressure High Range Out of Range	High range pressure sensor is out of operating range.	<p>Verify pressure.</p> <p>Check supply pressure (see section 6.2.1).</p> <p>Check flow and expansion valves (see section 6.2.3 and 6.2.5)</p> <p>Check pressure sensor power and connection (see section 6.2.6 or 6.6.6).</p> <p>Faulty Saturator/Chamber select solenoids (SOL4 &amp; SOL5) (see section 6.2.7).</p>
46	[PL] Pressure Low Range Out of Range	Low range pressure sensor is out of operating range.	<p>Verify pressure.</p> <p>Check pressure sensor</p>

			power and connection (see section 6.2.7 or 6.6.6). Faulty Saturator/Chamber select solenoids (SOL4 & SOL5) (see section 6.2.7).
47	[Lt] Presat Liquid Sensor Dry	The liquid tube sensor remains dry while the fill pump has exceeded it's max run time.	Check distilled water reservoir (see section 3.3.2.2)  If error persists after reservoir has been filled you may need to re-prime the presat fill pump (see section 3.3.2.3 and 6.3.2).
148	Flow or Pressure stepper error	Stepper motor error on flow valve or expansion valve.	Check flow or expansion valve stepper controllers (see section 6.2.3 or 6.2.5)

WARNING CODES		DESCRIPTION	RESOLUTION
225	[Tp] Presat temperature high	Pre saturator temperature is too high.	Verify pre saturator temperature.  Check pre saturator temperature sensor (Ch1) connection or check temperature measurement board (see section 6.7 or 6.1.3).
227	[Tev] Expansion valve temperature high	Expansion valve temperature is too high.	Verify expansion valve temperature.  Check expansion valve temperature sensor (Ch5) connection or check temperature measurement board (see section 6.7 or 6.1.3).
230	[Pai] Regulated Air-in Pressure high	Regulated air-in pressure is too high.	Check that supply pressure is below 175psi.  Check pressure indication on dial gauge (see section

			6.2.1). Check flow meter power and connection (see section 6.2.1 or 6.6.6)
240	[Tpu] Upper chamber port temperature high	Upper chamber access port temperature is too high.	Verify upper chamber access port temperature.  Check upper chamber access port temperature sensor (Ch10) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).  Check upper access port heater (see section 6.5.5).
241	[Tpc] Center chamber port temperature high	Center chamber access port temperature is too high.	Verify center chamber access port temperature.  Check center chamber access port temperature sensor (Ch11) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).  Check upper access port heater (see section 6.5.5).
242	[Tpl] Lower chamber port temperature high	Lower chamber access port temperature is too high.	Verify lower chamber access port temperature.  Check lower chamber access port temperature sensor (Ch12) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).
244	[Tp] Presat temperature low	Pre saturator temperature is too low.	Verify pre saturator temperature.  Check pre saturator temperature sensor (Ch1) connection or check temperature measurement board (see section 6.7 or 6.1.3).

246	[Tev] Expansion valve temperature low	Expansion valve temperature is too low.	<p>Verify expansion valve temperature.</p> <p>Check expansion valve temperature sensor (Ch5) connection or check temperature measurement board (see section 6.7 or 6.1.3).</p>
249	[Pai] Regulated Air-in Pressure low"	Regulated air-in pressure is low.	<p>Check that supply pressure is above 20psi.</p> <p>Check pressure indication on dial gauge (see section 6.2.1).</p> <p>Check flow meter power and connection (see section 6.2.1 or 6.6.6).</p>
252	[Lp] Presat liquid level low	Pre sat liquid level is low. This warning could possibly display while the pump is running if the pre sat liquid sensor is reading low.	<p>If pump is operating normally and reservoir is full, this warning should clear once the pump finishes running.</p> <p>Check distilled water reservoir (see section 3.3.2.2)</p> <p>If error persists after reservoir has been filled you may need to re-prime the presat fill pump (see section 3.3.2.3 and 6.3.2).</p>
259	[Tpu] Upper chamber port temperature low	Upper chamber access port temperature is too low.	<p>Verify upper chamber access port temperature.</p> <p>Check upper chamber access port temperature sensor (Ch10) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).</p> <p>Check upper access port heater (see section 6.5.5).</p>

260	[Tpc] Center chamber port temperature low	Center chamber access port temperature is too low.	<p>Verify center chamber access port temperature.</p> <p>Check center chamber port temperature sensor (Ch11) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).</p> <p>Check upper access port heater (see section 6.5.5).</p>
261	[Tpl] Lower chamber port temperature low	Lower chamber access port Temperature is too low.	<p>Verify lower chamber access port temperature.</p> <p>Check lower chamber access port temperature sensor (Ch12) connection or check temperature measurement board (see section 6.5.5 or 6.1.3).</p> <p>Check upper access port heater (see section 6.5.5).</p>

## 8 ILLUSTRATED PARTS BREAKDOWN

### 8.1 PARTS LIST

Item	Title	Part Number	Manufacturer	Qty
1	Hinge	GN_127-76-60-b	Elsa+Ganter	9
2	Flush handle with fixing clips	19-7-3688	Pinet	2
3	Sliding Lock	MESAN_271	Mesan	14
4	Latch	PX-E3-11-25	Southco	1
5	Castor with brake	LDA-TPA-75K-FI-FK	Blickle	2
6	Castor without brake	LDA-TPA-75K-FK	Blickle	2
7	Washer	DIN 125 – A 6,4	generic	2
8	Washer	DIN 125 – A 5,3	generic	24
9	Washer	DIN 125 – A 4,3	generic	24
10	Washer	DIN 127 – A 5	generic	4
11	Hexagon domed cap nuts	DIN 1587 – M6	generic	4
12	Hexagon domed cap nuts	DIN 1587 – M5	generic	4
14	Hex nut	DIN 934 – M6	generic	4
15	Hex nut	DIN 934 – M5	generic	36
16	Hex nut	DIN 934 – M4	generic	23
17	Countersunk flathead screw	ISO 7046-1 – M6 x 20 – 4.8 - H	generic	36
18	Countersunk flathead screw	ISO 7046-1 – M5 x 20 – 4.8 - H	generic	10
20	Cross recessed panhead machine screw	ISO 7045 – M5 x 10 – 4.8 - H	generic	16
21	Cross recessed panhead machine screw	ISO 7045 – M5 x 25 – 4.8 - H	generic	4
22	Cross recessed panhead machine screw	ISO 7045 – M4 x 5 – 4.8 - H	generic	52
23	Cross recessed panhead machine screw	ISO 7045 – M4 x 6 – 4.8 - H	generic	18
24	Cross recessed panhead machine screw	ISO 7045 – M4 x 8 – 4.8 - H	generic	4
25	Cross recessed panhead machine screw	ISO 7045 – M3 x 4 – 4.8 - H	generic	8
26	Cross recessed panhead machine screw	ISO 7045 – M3 x 5 – 4.8 - H	generic	4
27	Hex-Head Bolt	DIN 933 - M6 x 10	generic	2
28	Hex-Head Bolt	DIN 933 - M5 x 10	generic	18
29	Cylinder Head Cap Screw	DIN 912 - M4 x 8	generic	14
30	Door Pass-Through	17.01/042.0	RH Systems	3
31	Housing Pass-Through	17.01/042.1	RH Systems	3
32	Housing Pass-Through - clip	17.01/042.2	RH Systems	2
33	Door Pass-Through - clip	17.01/042.3	RH Systems	3
34	Chamber seal	08.01K	RH Systems	1

Item	Title	Part Number	Manufacturer	Qty
35	Door seal A	A - 35.04K	RH Systems	2
36	Door seal B	B - 35.04K	RH Systems	2
37	Silicone o-ring	10x2.5	generic	3
38	Rubber spacer	873.01/224.0	RH Systems	14
39	Rubber leg	106663	RH Systems	4
40	Magnet	40x20x10	RH Systems	2
41	Washer 20-5	Washer 20-5	generic	2
42	LED light	DWLED1	RH Systems	1
43	Fan	EBM R2K150	ebm-pabst	1
44	Chamber	873.01/100.0	RH Systems	1
45	Pressure measurement connector	873.01/116.0	RH Systems	2
46	Gas inlet tube	873.01/120.0	RH Systems	1
47	Perforated shelf holder	873.01/131.0	RH Systems	4
48	Perforated shelf	873.01/132.0	RH Systems	1
49	Shoulder Nut	873.01/133.0	RH Systems	1
50	Thermal Block	873.01/134.0	RH Systems	1
55	Inner chamber	873.01/150.0	RH Systems	1
56	Inner chamber spacer	Cev 10x1_2.ipt	RH Systems	4
57	Gas outlet tube	873.01/160.0	RH Systems	1
58	Gas outlet tube seal	873.01/163.0	RH Systems	1
59	PT100 connector holder	873.01/171.0	RH Systems	1
60	PT100 holder	873.01/172.0	RH Systems	1
61	Fan housing	873.01/180.0	RH Systems	1
62	Fan housing cover	873.01/184.0	RH Systems	1
63	Housing	873.01/200.0	RH Systems	1
64	Rack	873.01/221.0	RH Systems	1
65	Cover lock plate	873.01/222.0	RH Systems	14
66	Control panel door holder	873.01/223.0	RH Systems	2
67	Exhaust connector	873.01/230.0	RH Systems	1
68	Connectors plate	873.01/241.0	RH Systems	1
69	Top housing cover	873.01/251.0	RH Systems	1
70	Right housing cover	873.01/252.0	RH Systems	1
71	Left housing cover	873.01/253.0	RH Systems	1
72	Back housing cover	873.01/254.0	RH Systems	1
73	Accessport cover plate	873.01/255.0	RH Systems	1
74	Accessport	873.01/261.0	RH Systems	3
75	Accessport plug	873.01/262.0	RH Systems	6

Item	Title	Part Number	Manufacturer	Qty
76	Access port ring	873.01/263.0	RH Systems	3
77	Latch strike	873.01/271.0	RH Systems	1
78	Chamber door	873.01/300.1	RH Systems	1
79	Latch cover	873.01/303.0	RH Systems	1
80	LED light housing	873.01/302.1	RH Systems	1
81	Light holder	873.01/305.0	RH Systems	1
82	Light holder M	873.01/305.1	RH Systems	1
84	Door glass	873.01/321.0	RH Systems	1
85	Distribution frame	873.01/330.0	RH Systems	1
86	Thermopane with heater	873.01/350.0	RH Systems	1
87	Control panel door	873.01/400.1	RH Systems	1
88	Accessory cabinet	873.01/500.0	RH Systems	1
89	Compressor mounting plate	873.01/521.0	RH Systems	1
90	Accessory cabinet side cover	873.01/551.0	RH Systems	2
91	Accessory cabinet back cover	873.01/552.0	RH Systems	1
92	Accessory cabinet right door	873.01/600.1	RH Systems	1
93	Magnet holder right	873.01/621.0	RH Systems	1
94	Accessory cabinet left door	873.01/700.1	RH Systems	1
95	Magnet holder left	873.01/621.1	RH Systems	1
96	Push to Connect bulkhead	KQ2LE06-00A	SMC	2
97	Compression fitting, 10mm	KFG2H1008-02S	SMC	1
98	Cable gland PG11	PG11	generic	1
99	Cable gland PG7	PG7	101711	1
100	Cable gland M12	Cable gland M12	generic	2
101	Air connection tube	PU FI6/4	generic	1
102	Expansion vessel	101711	RH Systems	1
103	Barbed Tubing T connector 3/8"	T connector 3/8"	generic	1
104	Expansion vessel supply tube	20-10_1	generic	1
105	Insulation Kaiflex 9-18	Kaiflex 9-18	Kaimann GmbH	1
106	Door return tube 1	12-10_1	RH Systems	1
107	Door return tube 2	12-10_2	RH Systems	1
108	Door supply tube	12-10_3	RH Systems	1
109	Drain tube	12-10_4	RH Systems	1
110	Expansion vessel drain tube	12-10_5	RH Systems	1
111	Insulation Kaiflex 9-10	Kaiflex 9-10	Kaimann GmbH	1
115	Main Power Switch Push Button	ULV4F2GSSG545	E-Switch	1
116	ehg_2b_306_cym	ehg_2b_306_cym	Lemo	1



Item	Title	Part Number	Manufacturer	Qty
117	fgg_2b_306_clam21	fgg_2b_306_clam21	Lemo	1
118	Main Power Entry	DF11.1089.0010.02	Schurter	2
220	PT100 probe	SmPT100-2	RH Systems	1
400	CGS240 Frame Assembly	CGS240Frame	RH Systems	1
401	CGS240 Cart Assembly	CGS240Cart	RH Systems	1
402	CGS240 Chamber Assembly	CGS240Chamber	RH Systems	1
403	CGS240 Saturator Assembly	CGS240Sat	RH Systems	1
404	CGS240 Refrigeration compressor, condensor assembly	CGS240Refrig	RH Systems	1
405	Rotary Flow Control Valve	A-RH5841	RH Systems	2
500	RS485 Stepper Motor Controller	STF03-R	Applied Motion	2
502	Mensor Pressure Sensor High Pressure (0-150 psi abs.)	CPT6020-AAPA000000-015000JS-4FL-Z#	Mensor	1
503	Mensor Pressure Sensor Barometric Pressure (0-25 psi abs.)	CPT6020-AAPA000000-002500JS-4FL-Z#	Mensor	1
504	Stepper motor driver	TB6600	Multiple	3
505	Refrigeration Pressure Sensor	PX2AF1XX300PSBGX	Honeywell	2
506	18-8 Stainless Steel Button Head Hex Drive Screw, 8-32 Thread Size, 3/8" Long	BHCS8-32x3/8	Generic	79
507	18-8 Stainless Steel Socket Head Screw, 1/4"-20 Thread size, 2" long, Full Thread	SHCS1/4-20x2	Generic	4
508	Manifold mount NC solenoid valve	A2016-8-MM-SB5-V-VO-C204	Gems Sensors	2
509	316 Stainless Steel Plug for 1/4 in. Swagelok Tube Fitting	SS-400-P	Swagelok	1
510	Refrigeration Valve Cover 1	P-RH013604	RH Systems	1
511	Refrigeration Valve Cover 2	P-RH013654	RH Systems	1
512	Laing Vario DC Bronze circulator pump. D5-38/710B	LMB15107976	Laing Thermotech	2
513	KIP Series 2 valve, 1/8" NPT ports, 3 way, NC, 24Vdc, stainless steel body, 1/32" orifice	U249040-0261-D	IMI Norgren	1
514	Push-to-Connect Tube Fitting for Air 90 Degree Elbow Connector, for 1/4" Tube OD	PTCE1/4-1/4	Generic	3
515	SS Swagelok Tube Fitting, 1/8 in. Tube OD x 1/8 in. Male ISO Parallel Thread	SS-200-1-2RS	Swagelok	1
516	ETG 150-P/C-24/50 Pump - SS Fittings G1/8"	G-111469	Gotec	1
517	SS Swagelok Tube Fitting, 1/4 in. Tube OD x 1/8 in. Male ISO Parallel Thread	SS-400-1-2RS	Swagelok	3
518	PFA Tubing, 1/4 in. OD x 0.047 in. Wall (Qty. in feet)	TPFA1/4	Generic	1
519	Diaphragm liquid pump 5002F	53001003	Gardner Denver	1
520	18-8 Stainless Steel Button Head Hex Drive Screw, 8-32 Thread Size, 1/2" Long	BHCS8-32x1/2	Generic	2

Item	Title	Part Number	Manufacturer	Qty
521	PUR tubing, 1/4" OD, 0.156" ID, Blue	TPUR1/4	Generic	6
522	solenoid valve, NC, 1/8in female NPT inlet, 1/8in female NPT outlet, 24 VDC	DVP-2DC1D-24D	Nitra	1
523	Push-to-Connect Tube Fitting, 90 Degree Swivel Elbow, 1/4" Tube OD x 1/8 NPT Male	PTCSE1/4x1/8MP	Generic	1
524	Stainless Steel Swagelok Tube Fitting, Union Elbow, 1/2 in. Tube OD	SS-810-9	Swagelok	1
525	SS Swagelok Tube Fitting, 1/2 in. Tube OD x 1/4 in. Male ISO Parallel Thread	SS-810-1-4RS	Swagelok	1
526	Saturator slide on access cover	P-RH013848	RH Systems	1
527	Push-to-Connect Tube Fitting, 90 Degree Swivel Elbow, 1/4" Tube OD x 1/4 NPT Male	PTCSE1/4x1/4MP	Generic	2
528	M-Gas 50SLPM flow meter	M-50SLPM-D/5M	Alikat Scientific	1
529	SS Swagelok Tube Fitting, Male Connector, 1/4 in. Tube OD x 1/4 in. Male NPT	SS-400-1-4	Swagelok	1
530	SS Swagelok Tube Fitting, Male Tube Adapter, 1/4 in. Tube OD x 1/4 in. Male NPT	SS-4-TA-1-4	Swagelok	1
531	T70 Air Pressure Regulator, Mod no. 152, 250 psi supply max., 3-200 psi range	T70	Marsh Bellofram	1
532	Pressure Gauge, 200 psi max reading, 1/8" male NPT connection	15W1005H01B200#	Ashcroft	1
533	Stainless Steel, class 150, 1/4" male npt x 1/4" male npt connector	PipeUnionSS1/4x1/4	generic	1
534	Stainless Steel, class 150, 1/4" female npt tee	PipeTeeSS1/4	generic	1
535	ASME-Code Fast-Acting Pressure-Relief Valve, 225 psi, nickel-plated brass, 1/4 ,male NPT	5484T12	McMaster-Carr	1
536	316L Stainless Steel Butt-Weld Fitting, Tee Connector for 3/4" Tube OD	BTeeSS3/4	generic	1
537	High-Temperature Silicone Rubber Tubing, 5/8" ID, 7/8" OD, white, (qty. in feet)	TSil5/8x7/8	generic	6
538	High-Temperature Silicone Rubber Tubing, 5/16" ID, 9/16" OD, white, (qty. in feet)	TSil5/16x9/16	generic	2
539	Push-to-Connect Tube Fitting, 90 Degree Swivel Elbow, 12 mm Tube OD x 1/2 BSPP Male,	5225k576	McMaster-Carr	1
540	Push-to-Connect Tube Fitting, 90 Degree Swivel Elbow, for 3/8" Tube OD x 3/8 NPT Male	5779k159	McMaster-Carr	1
-	Push-to-Connect Tube Fitting, 90 Degree Elbow, for 12 mm Tube OD x 1/2 BSPP Male	5225k936	McMaster-Carr	1
541	18.5" Open Frame Multi Point Capacitive Touch 1366x768 Display, Ext. Power Supply Incl.	M18568C-OF	Mimo Monitors	1
542	Monitor Bracket	P-RH013775	RH Systems	2
543	NEMA-17 Bipolar Stepper with 26.85:1 Gearbox	42STH38	Dongzheng Motor	2
544	Button Head Hex Drive Screw, Passivated 18-8	BHCSM4x22	generic	8

Item	Title	Part Number	Manufacturer	Qty
	SS, M4 x 0.70 mm Thread, 22mm Long			
545	Nema 17 Rotary Valve Optic Holder	P-RH000073	RH Systems	2
546	External Retaining Ring for 15 mm OD, Black-Phosphate 1060-1090 Spring Steel, 1mm thick	ERR15	generic	4
547	Ball Bearing, Sealed, Trade No. 6802-2RS, for 15 mm Shaft Diameter	6802-2RS		4
548	Nema 17 Rotary Valve Plug	P-RH000070	RH Systems	2
549	Chemical-Resistant Viton O-Ring, 3/32 Fractional Width, Dash Number 115	ORV115	generic	4
550	Chemical-Resistant Viton O-Ring, 1/8 Fractional Width, Dash Number 210	ORV210	generic	4
551	Nema 17 Rotary Valve Body	P-RH000069	RH Systems	2
552	Button Head Hex Drive Screw, Passivated 18-8 SS, M3 x 0.50 mm Thread, 50mm Long	BHCSM3x50	generic	6
553	Chemical-Resistant Viton O-Ring, 1/16 Fractional Width, Dash Number 016	ORV016	generic	2
554	Nema 17 rotary valve face seal	P-RH000072	RH Systems	2
555	Button Head Hex Drive Screw, Passivated 18-8 SS, M4 x 0.70 mm Thread, 10mm Long	BHCSM4x10	generic	6
556	REDUX Wave Spring, 0.75"OD, 0.55"ID, 0.25" Free Length, 272 lb/inch spring rate	LW 075 22 0250	Lee Spring	2
557	Optical Switch, Panel / Chassis, 3.81 mm, 1.52 mm, 50 mA, 2V	OPB857Z	TT Electronics	2
558	Button Head Hex Drive Screw, Passivated 18-8 SS, M2.5 x 0.45 mm Thread, 6mm Long	BHCSM2.5x6	generic	2
559	18-8 Stainless Steel Cup-Point Set Screw, M4 x 0.7 mm Thread, 5 mm Long	CPSSM4x5	generic	2
560	Alloy Steel Cup-Point Set Screw, Black-Oxide, 2-56 Thread, 5/8" Long	CPSS4-26x5/8	generic	2
561	Fuse modular terminal block - UT 4-L/HESI (5X20)	3214325	Phoenix Contact	2
562	SSR RELAY SPST-NO 3A 1-60V	DR06D03	Crydom	2
563	Modular terminal block - UT 2,5-PE/L/L	3214301	Phoenix Contact	10
564	Solid State Relays - Industrial Mount DIN SSR 280VAC/30A 4.5-32VDC In,ZC	CKRD2430	Crydom	3
565	Solid State Relays - Industrial Mount DIN SSR 280VAC/20A 4.5-32VDC In,ZC	CKRD2420	Crydom	1
566	Solid State Relays - Industrial Mount DIN SSR 280VAC/10A 4.5-32VAC In,ZC	CKRD2410	Crydom	4
567	DIN Rail Power Supplies 60W 12V 5A 180-550Vin DIN	WDR-60-12	Mean Well	1
568	DIN Rail Power Supplies 10W 5V 2A	MDR-10-5	Mean Well	1
569	Ground modular terminal block - UT 6-PE	3044157	Phoenix Contact	1

Item	Title	Part Number	Manufacturer	Qty
570	Circuit Breakers 15A D Characteristic 2 Pole	2DU15R	Altech Corp	2
571	MODULAR DIR PWR FEED FOR 1-3 PH BUSBAR	P50UB	Altech Corp	2
572	Circuit Breakers 6A D Characteristic 2 Pole	2DU6R	Altech Corp	3
573	Circuit Breakers 1A D Characteristic 2 Pole	2DU1R	Altech Corp	2
574	Circuit Breakers 10A D Characteristic 2 Pole	2DU10R	Altech Corp	1
575	Plug-in bridge - FBS 4-5	3030178	Phoenix Contact	2
576	Plug-in bridge - FBS 3-5	3030174	Phoenix Contact	2
577	2 Phase busbar, 18SQMM, pin type, 14lugs	2P18U3/14	Altech Corp	1
578	PT12 Temperature Measurement Board	PT12	RH Systems	1
579	Embedded Controller Board	ECB	RH Systems	1
580	Embedded Controller Board Expansion Board	ECBEXP	RH Systems	1
581	TERM BLOCK PLUG 2POS 5.08MM	EDZ1100/2	On Shore Tech	13
582	TERM BLOCK PLUG 2POS STR 5.08MM	EDZ950/2	On Shore Tech	3
583	CONN HOUSING 6POS .100 W/LATCH	50579406	Molex	5
584	CONN HOUSING 4POS .100 W/LATCH	50579404	Molex	3
585	CONN HOUSING 4POS .100 W/LATCH	50579402	Molex	1
586	CONN HOUSING 4POS .100 W/LATCH	50579410	Molex	4
587	Thermal Safety Cutout Switch	TH101	RH Systems	3
588	Switching Power Supplies 751.2W 24V 31.3A Power Supply W/PFC	RSP-750-24	Mean Well	1
589	Control Computer	NUC7i5DNFE	SimplyNUC	1
590	Bubbler Bypass Valve	3V220-08-RHS	RH Systems	1
591	Bubbler Bypass Valve Mounting Plate	P-RH014074	RH Systems	1
592	PreSat Heater, 1/2" 1500W	J10E-15020	Watlow	1
593	Sat Heater, 1/4" 600W	2088-7818	Watlow	1
594	Bath Heater, 3/8" 1500W	2087-0976	Watlow	1
595	Water Separator	AMG150C-N02BC	SMC	1
596	Mist Separator	AMH150C-N02C-T	SMC	1
597	Membrane Air Dryer	IDG5-N02	SMC	1
598	Spacer	Y200-A	SMC	2
599	Air Dryer Assembly Bracket	AMG150C-N02BCBracket	SMC	1
600	AirDryerMount	P-RH013993	RHSsystems	1

8.2 ILLUSTRATIONS

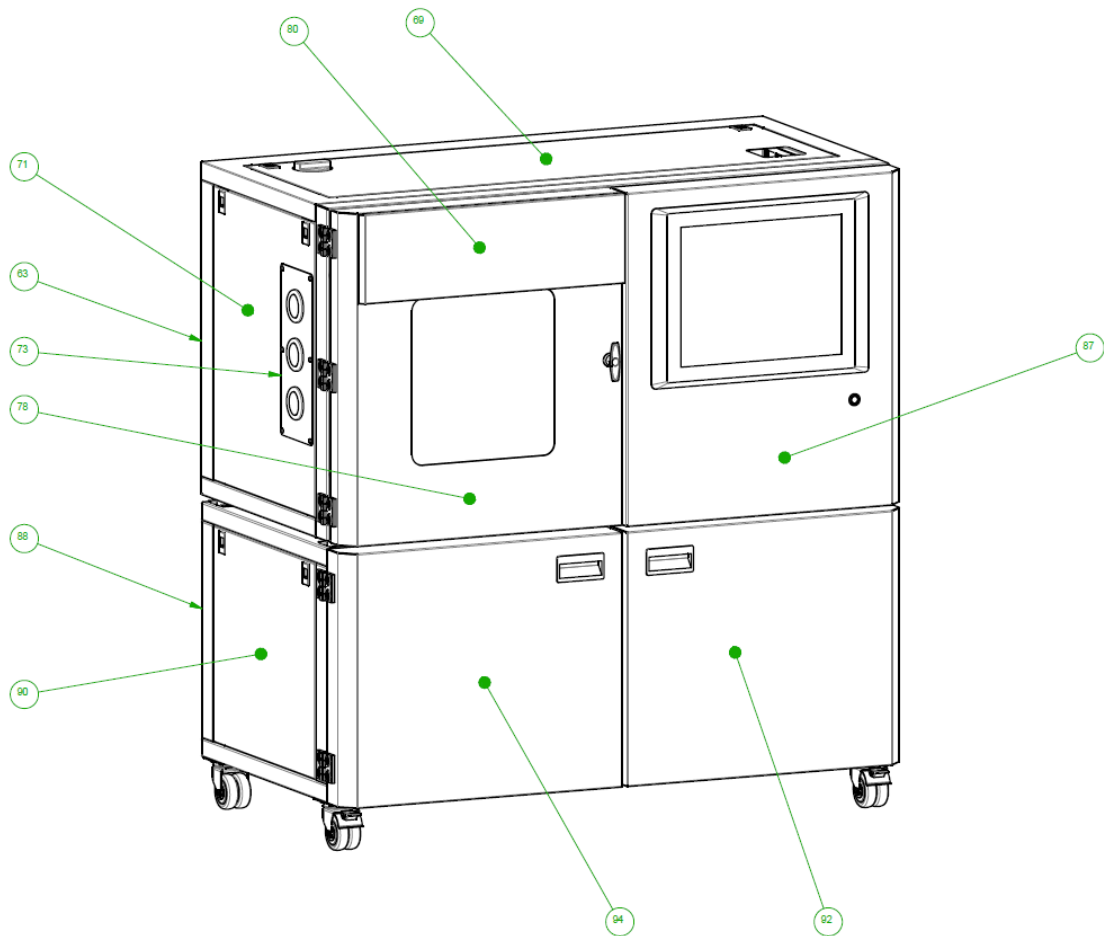


Figure 8.1: CGS-240

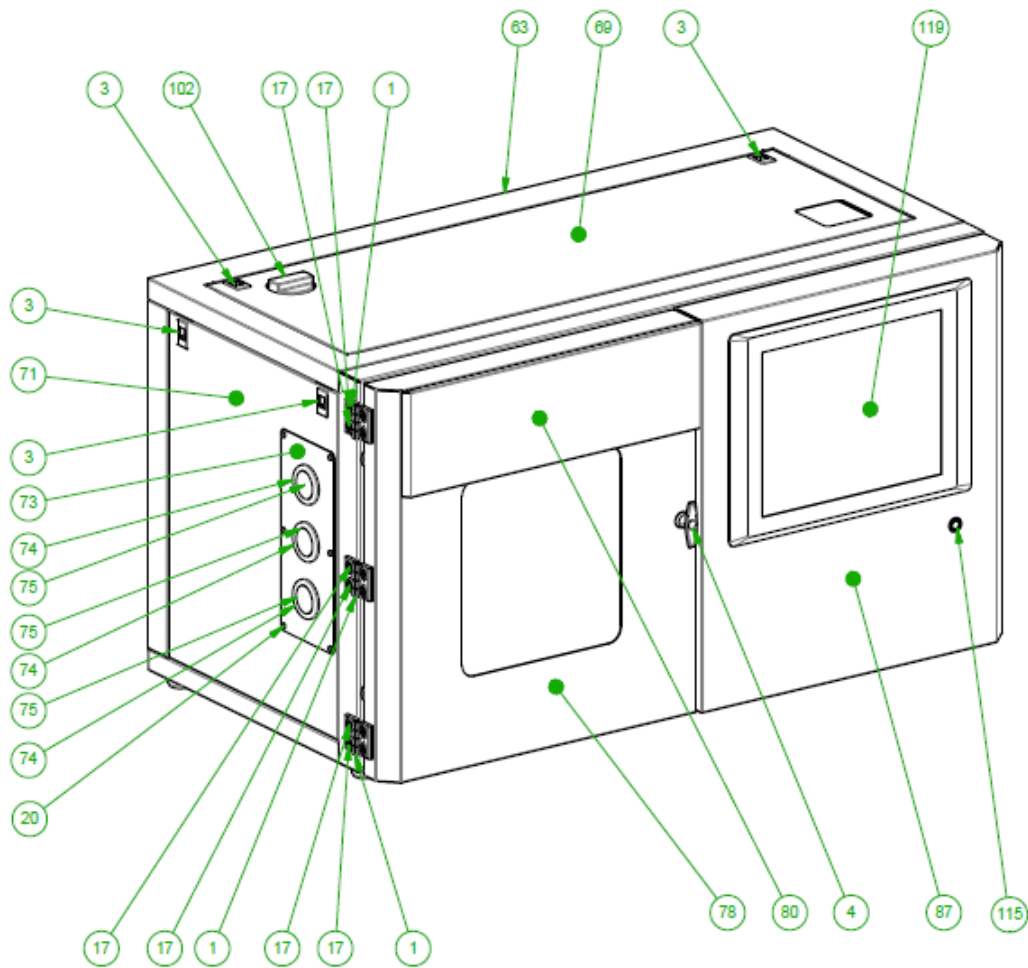


Figure 8.2

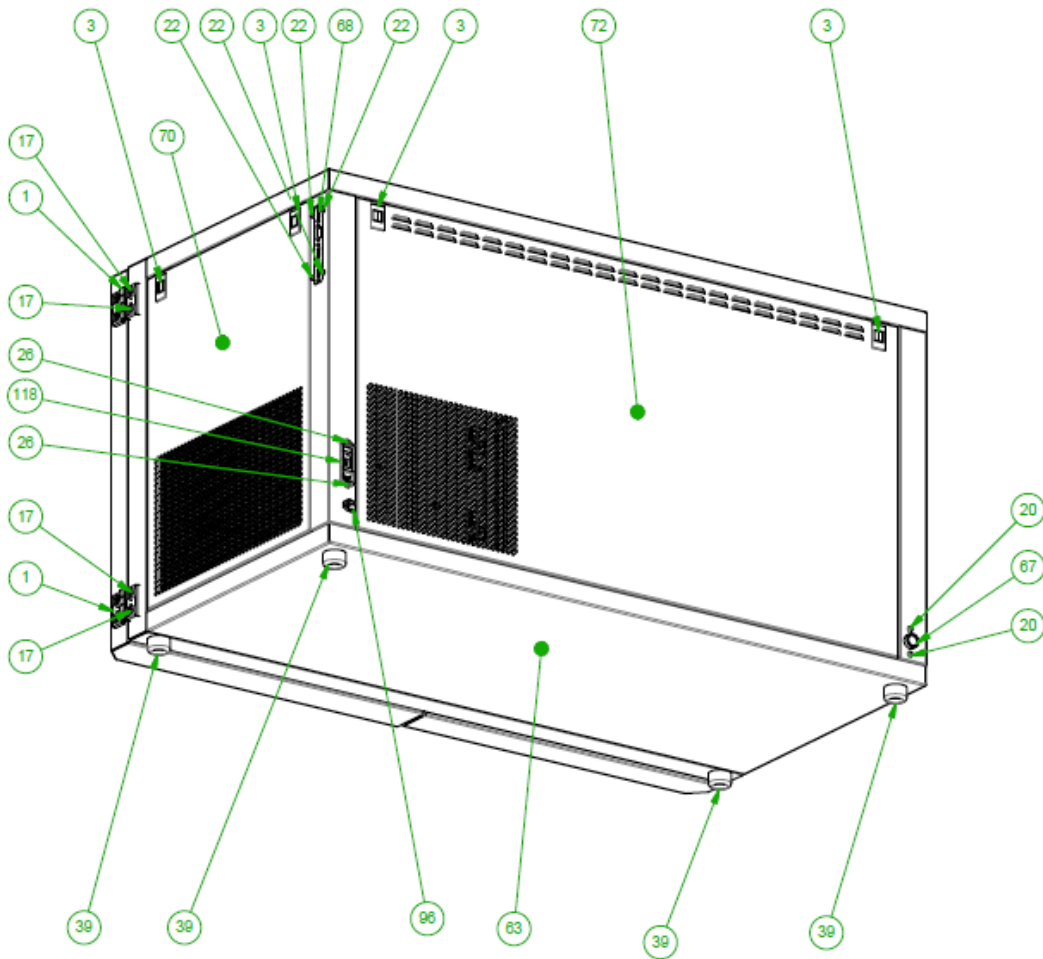


Figure 8.3



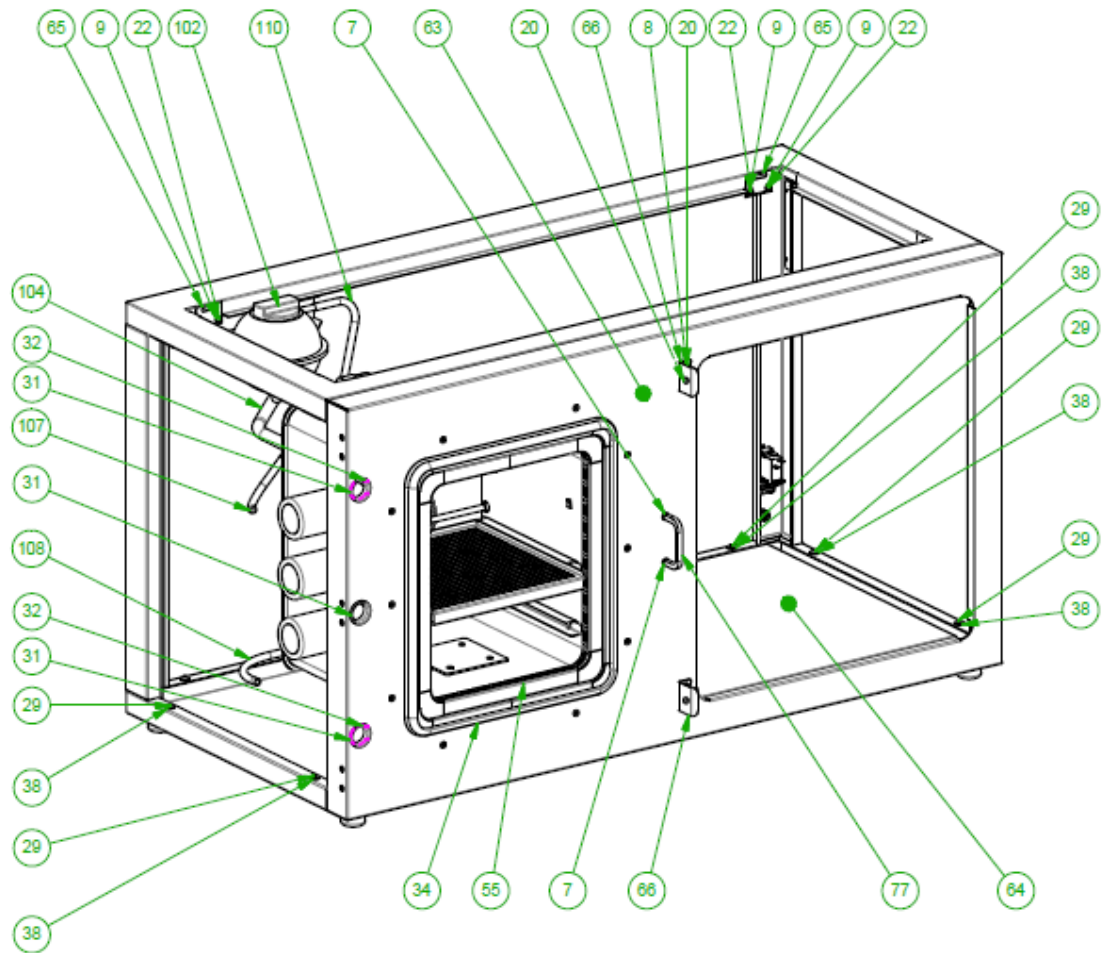


Figure 8.4

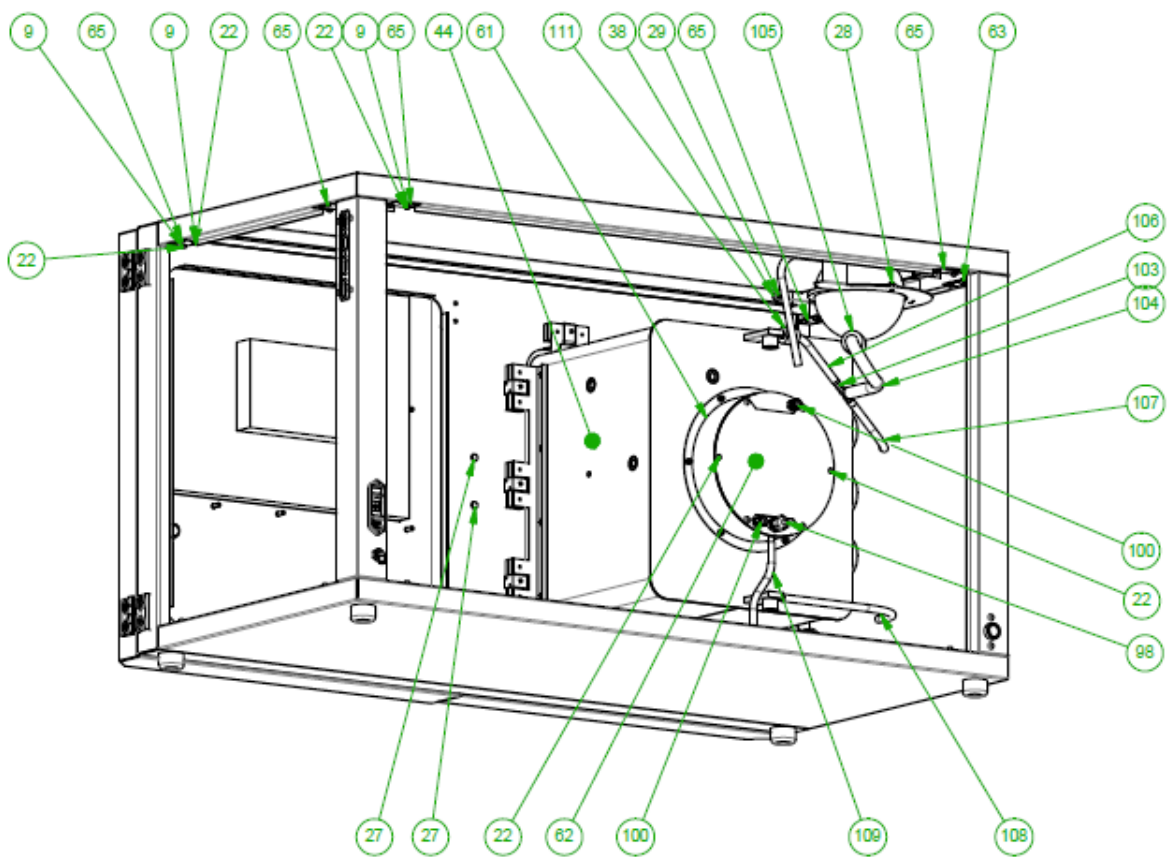


Figure 8.5

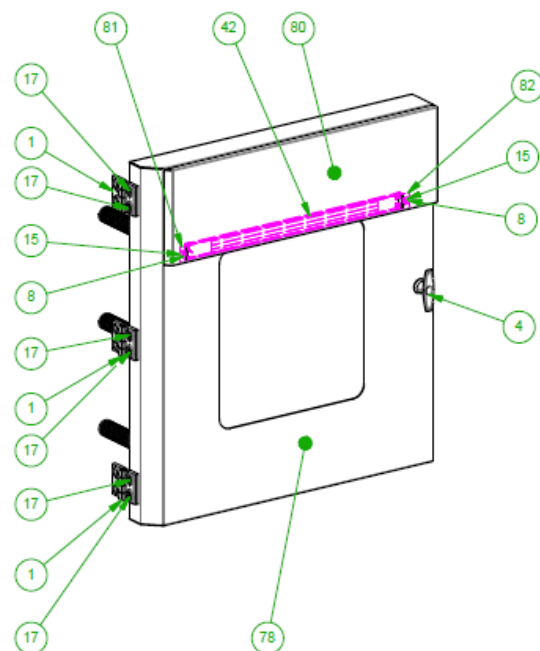
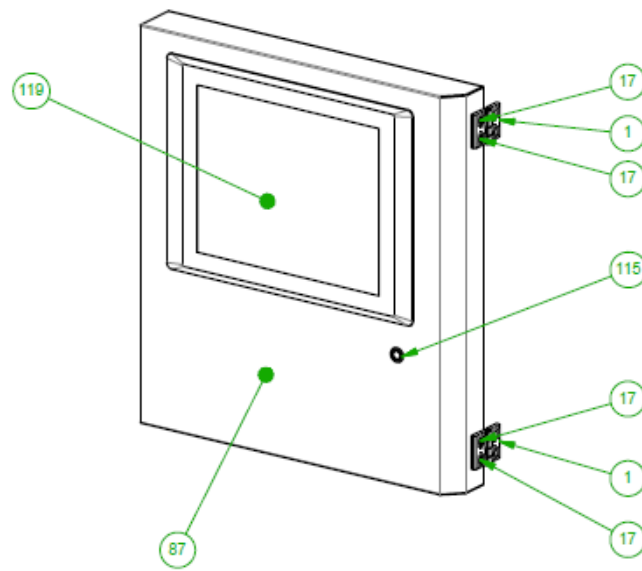
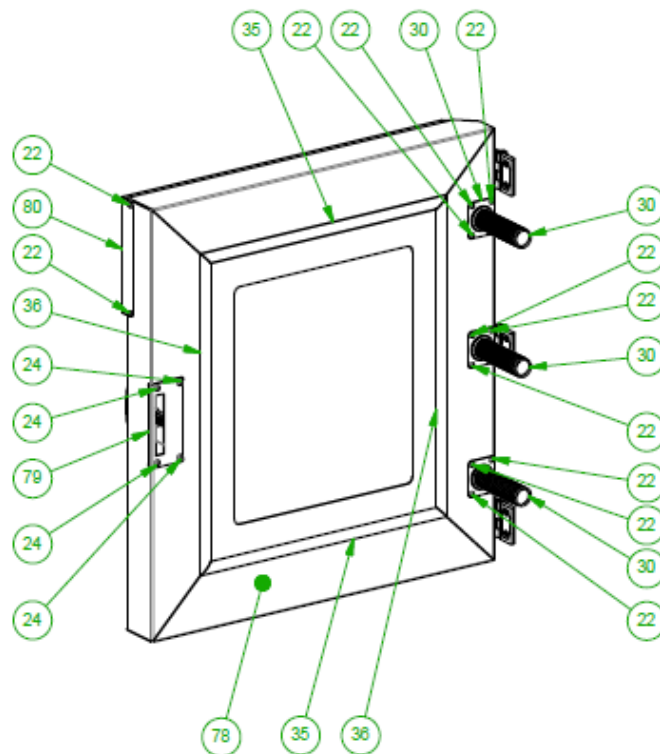


Figure 8.6



**Figure 8.7**



**Figure 8.8**

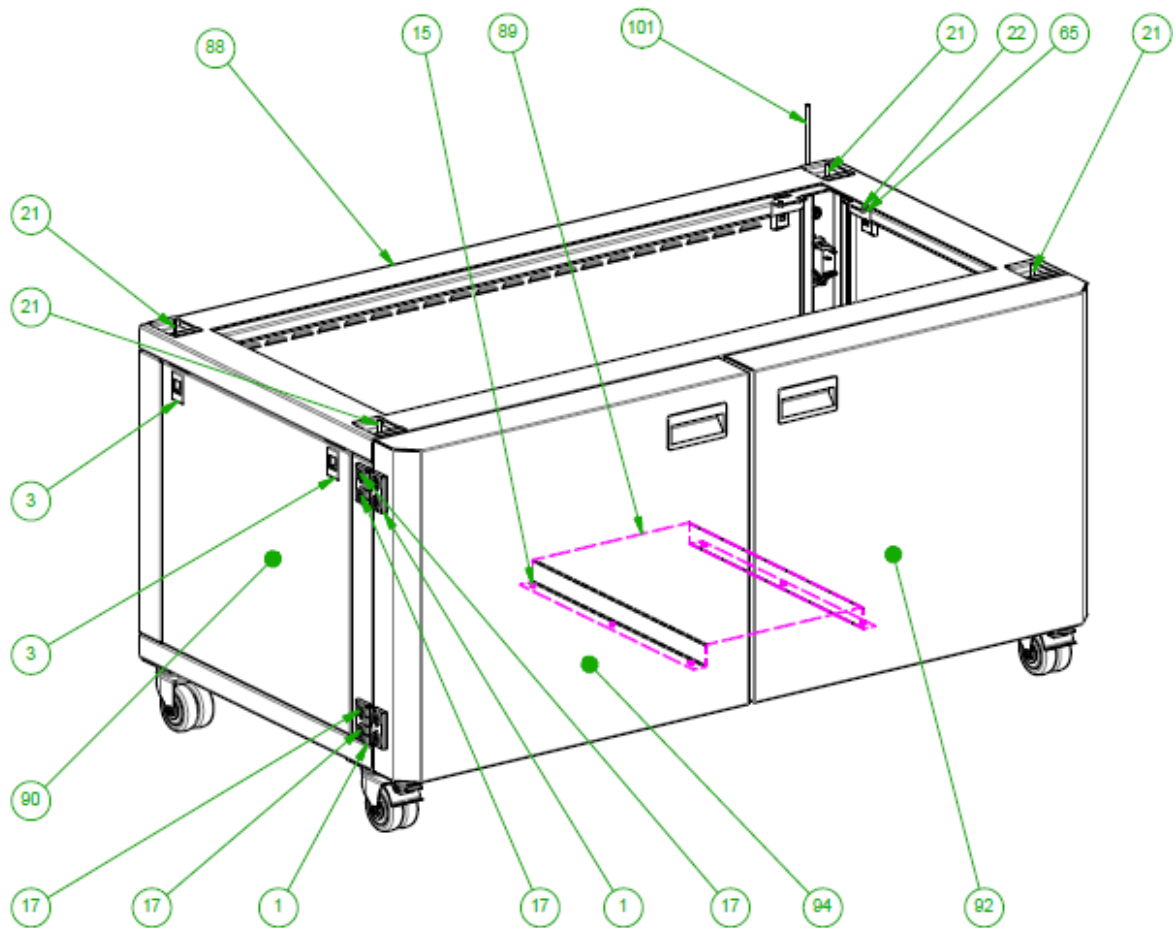


Figure 8.9

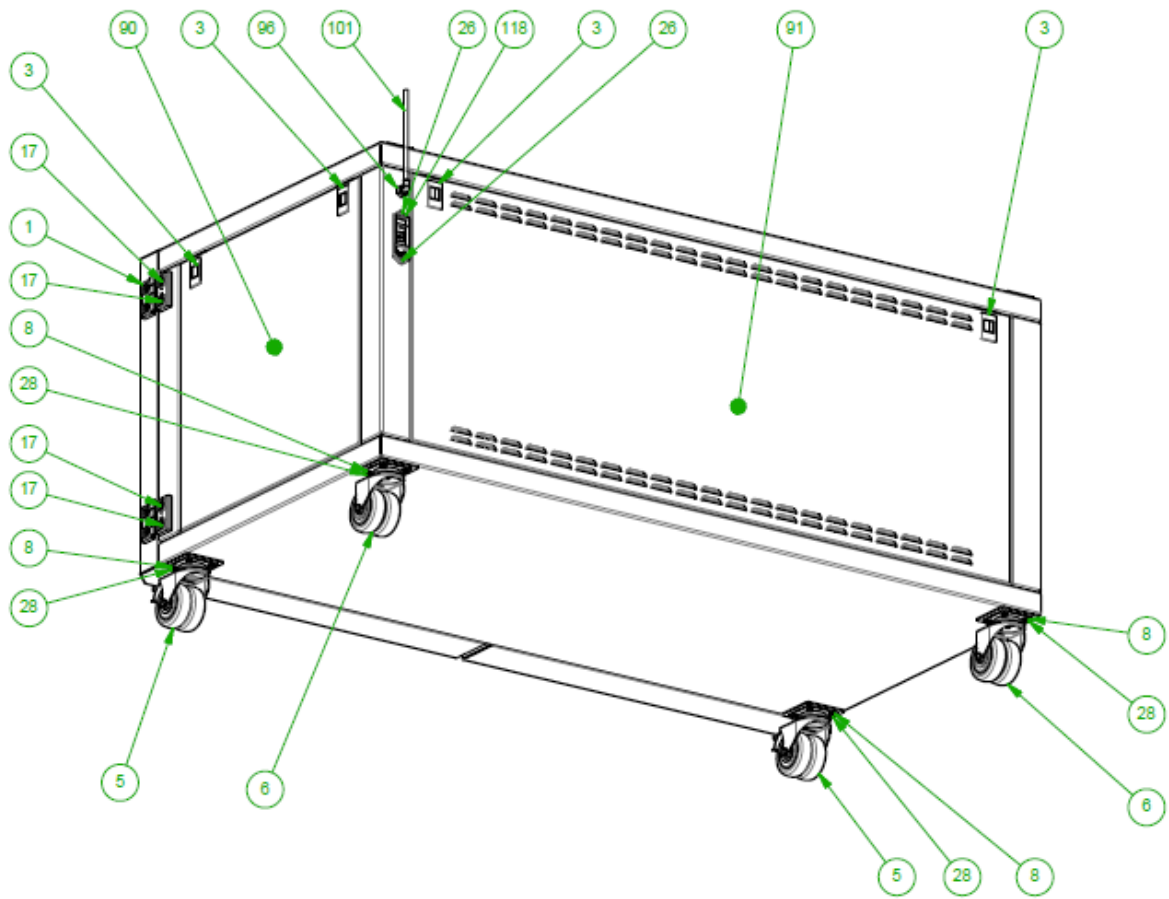


Figure 8.10

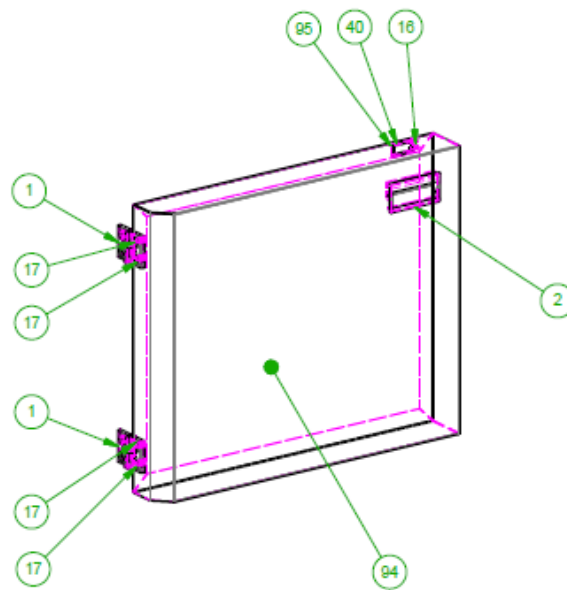


Figure 8.11

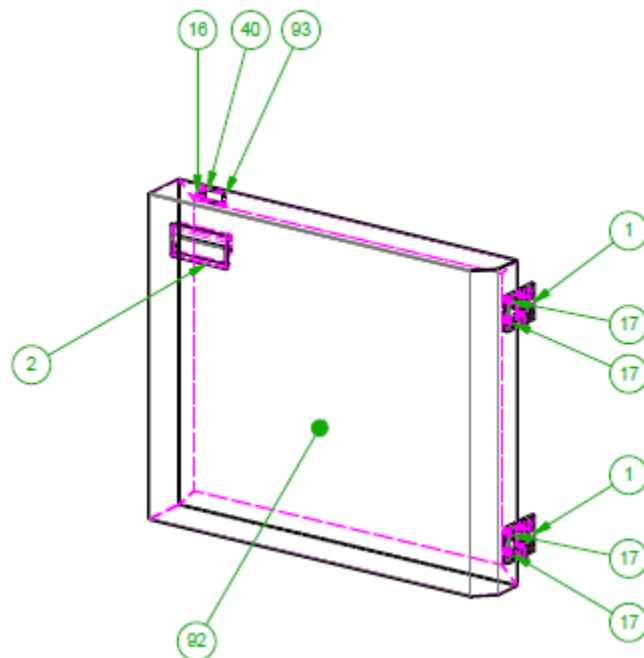


Figure 8.12

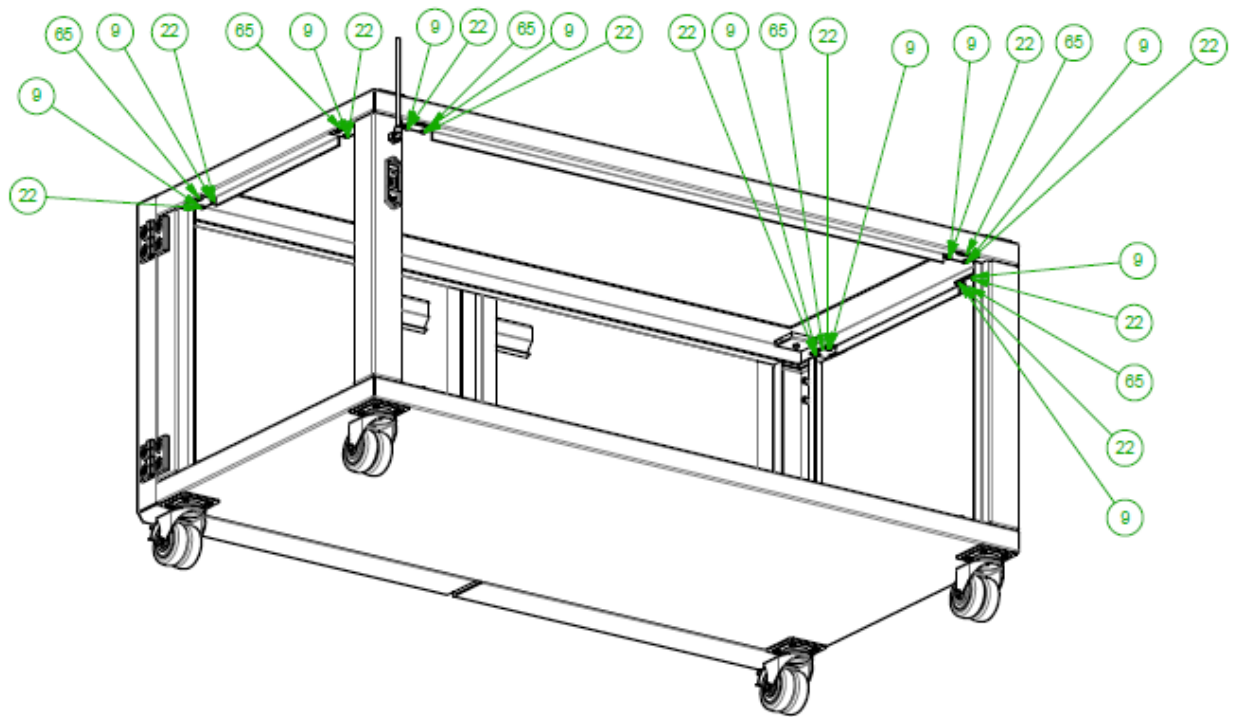


Figure 8.13

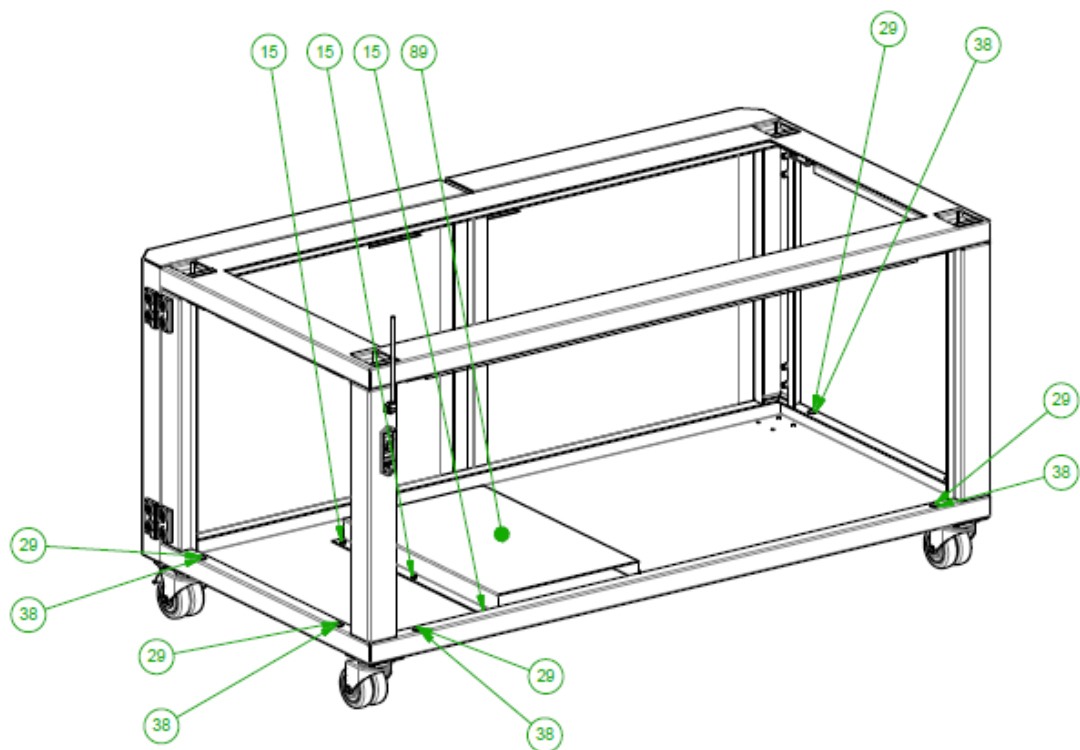


Figure 8.14



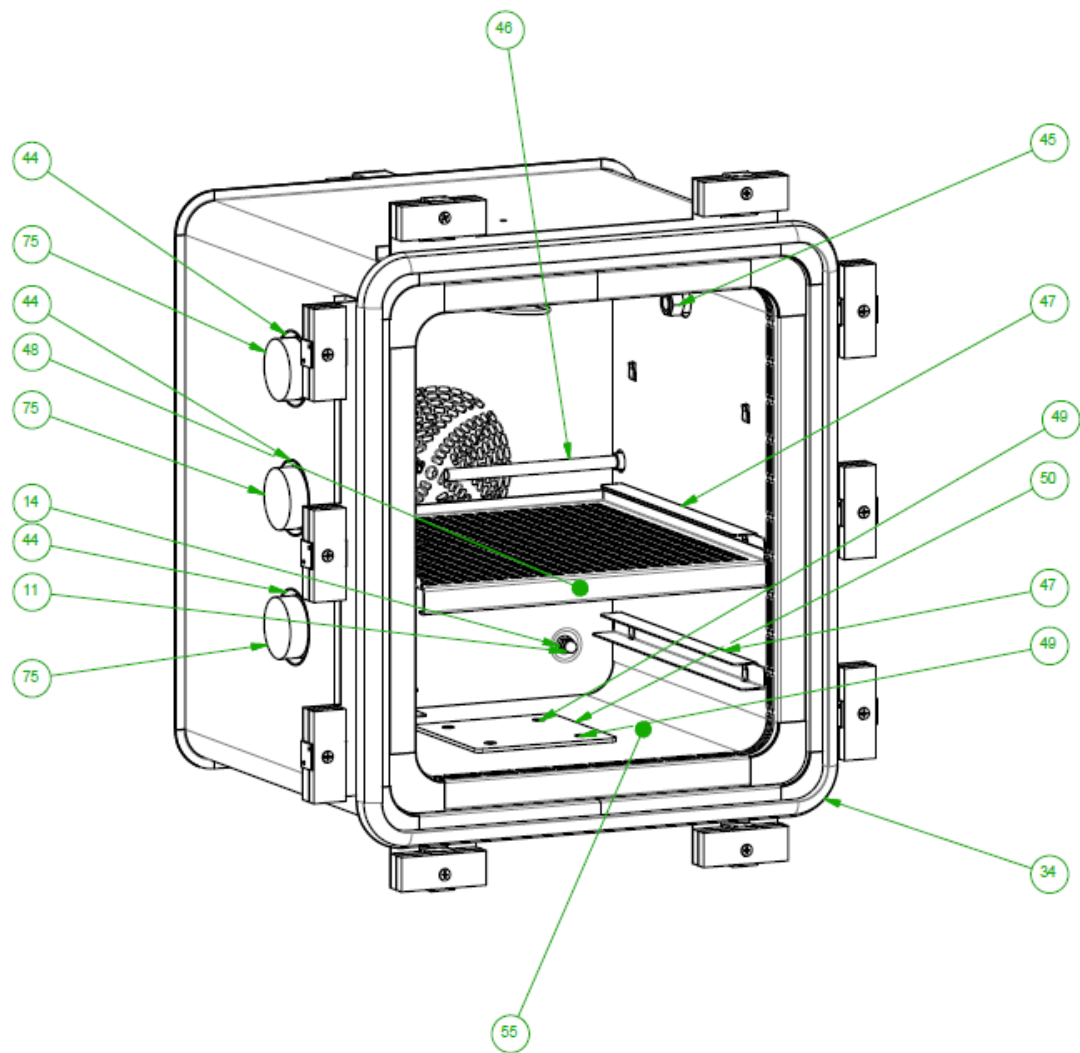


Figure 8.15

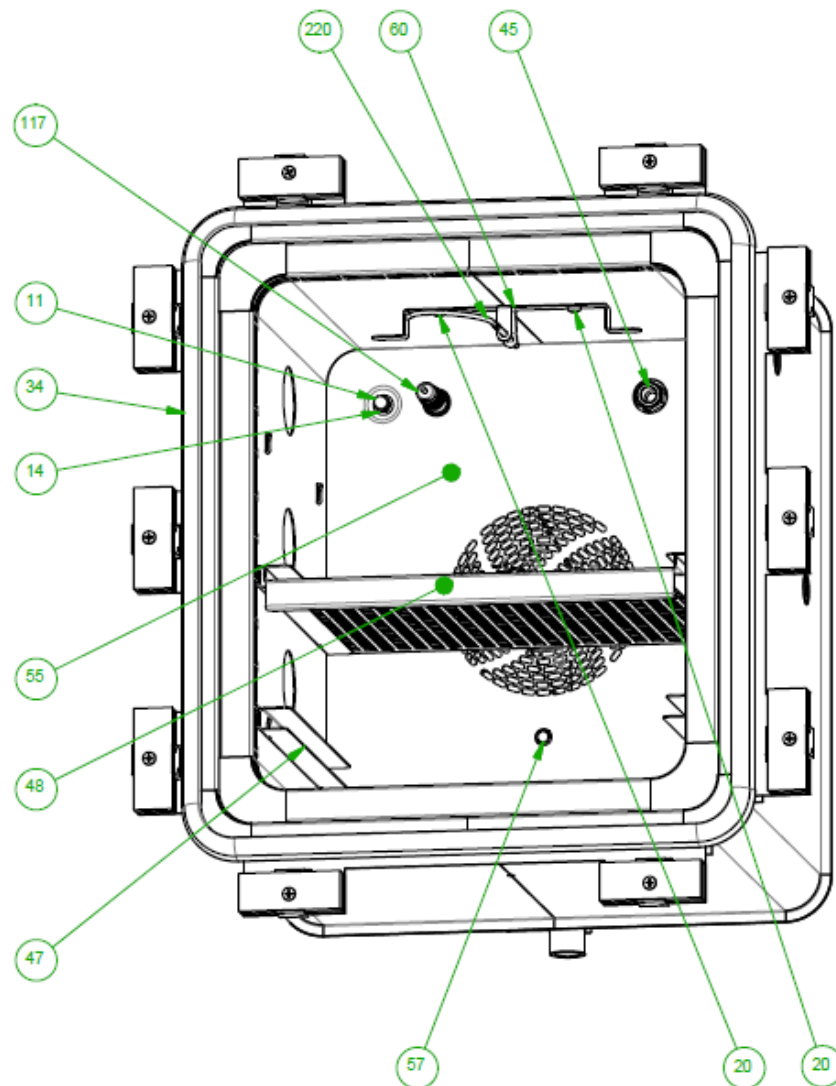


Figure 8.16

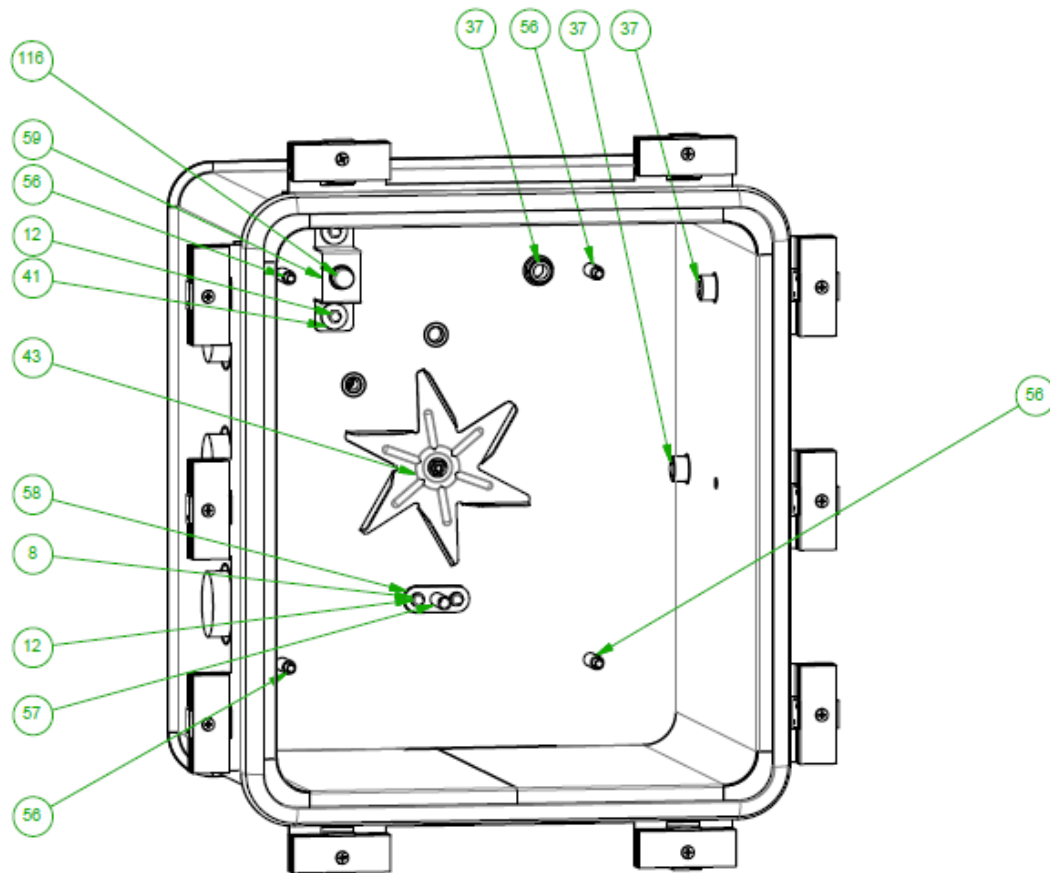


Figure 8.17

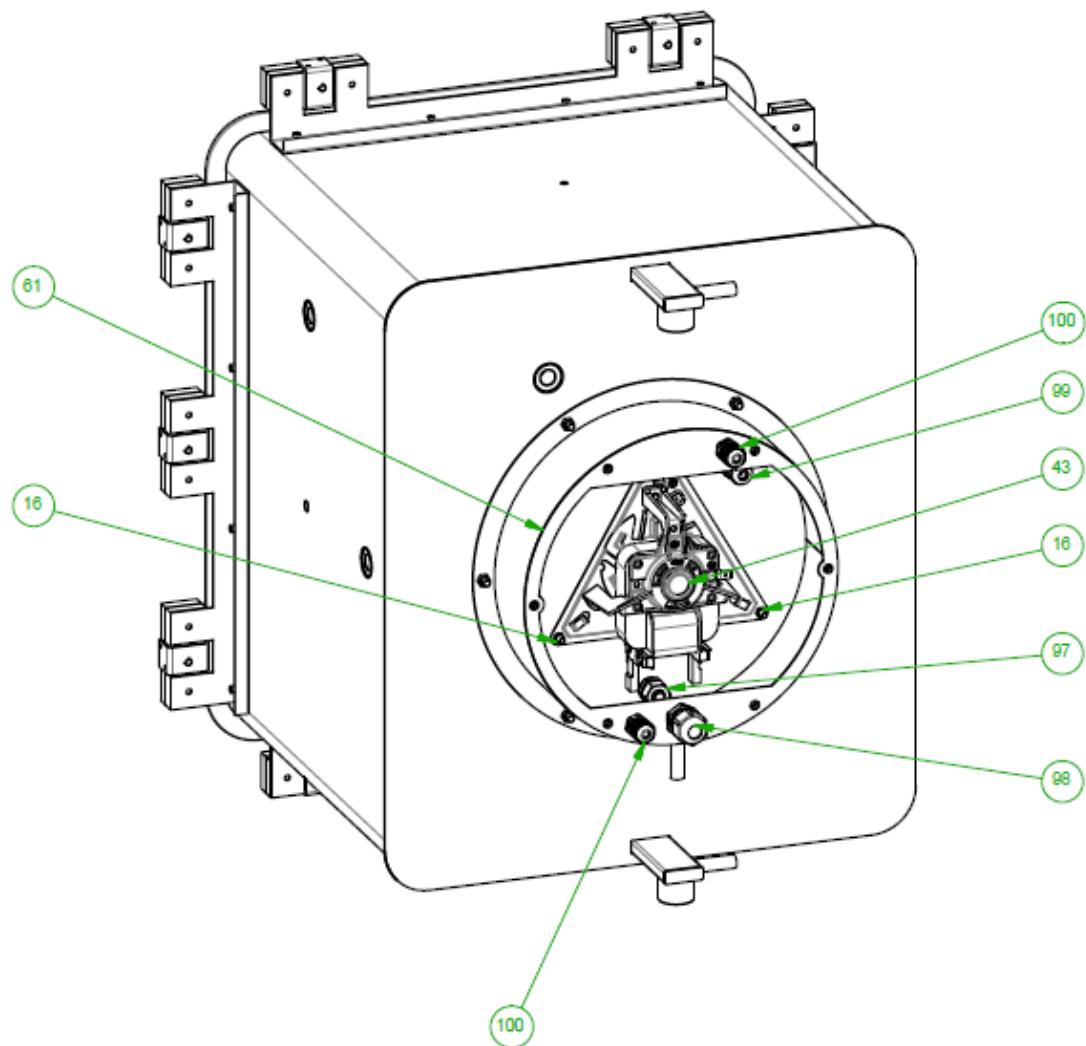


Figure 8.18

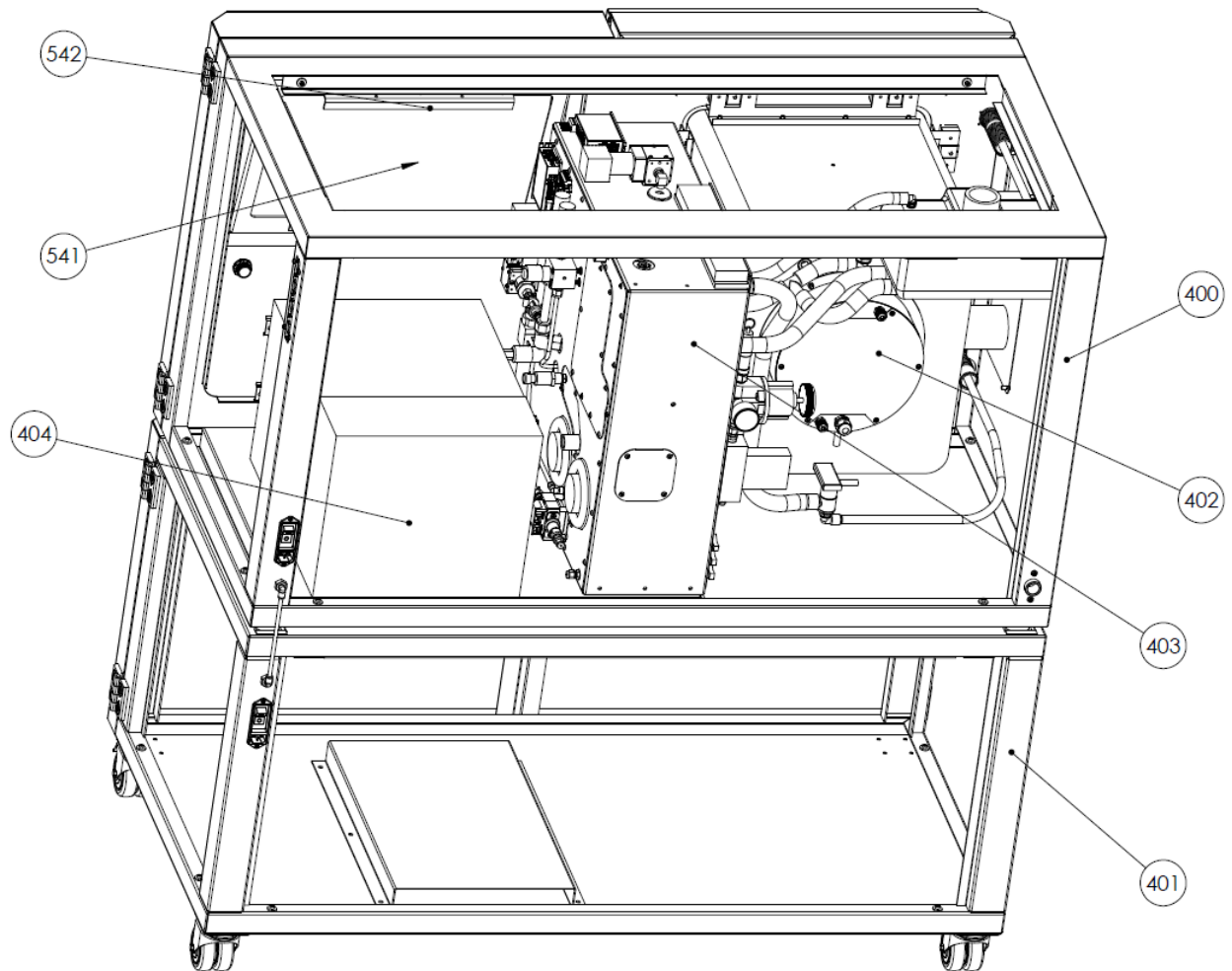


Figure 8.19

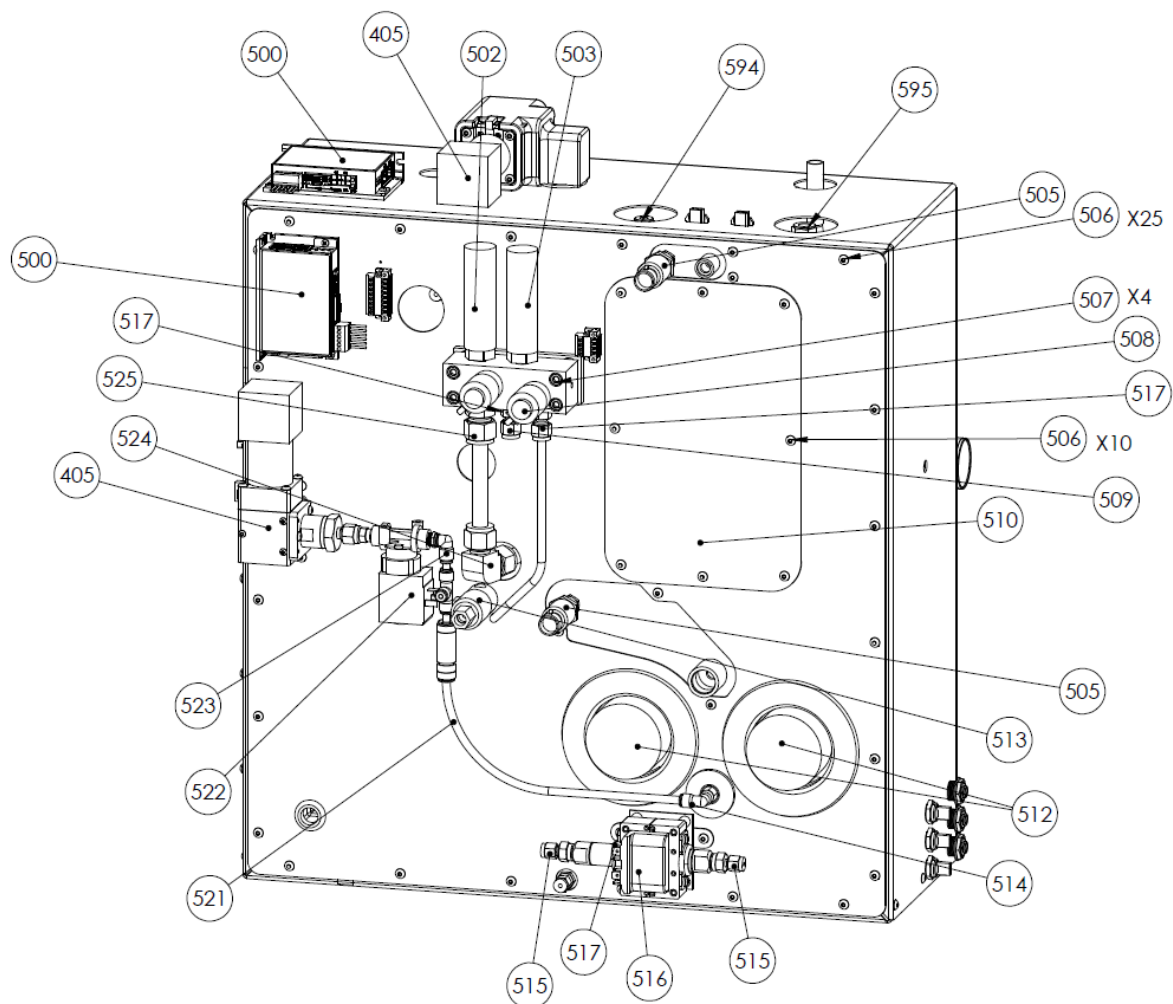


Figure 8.20

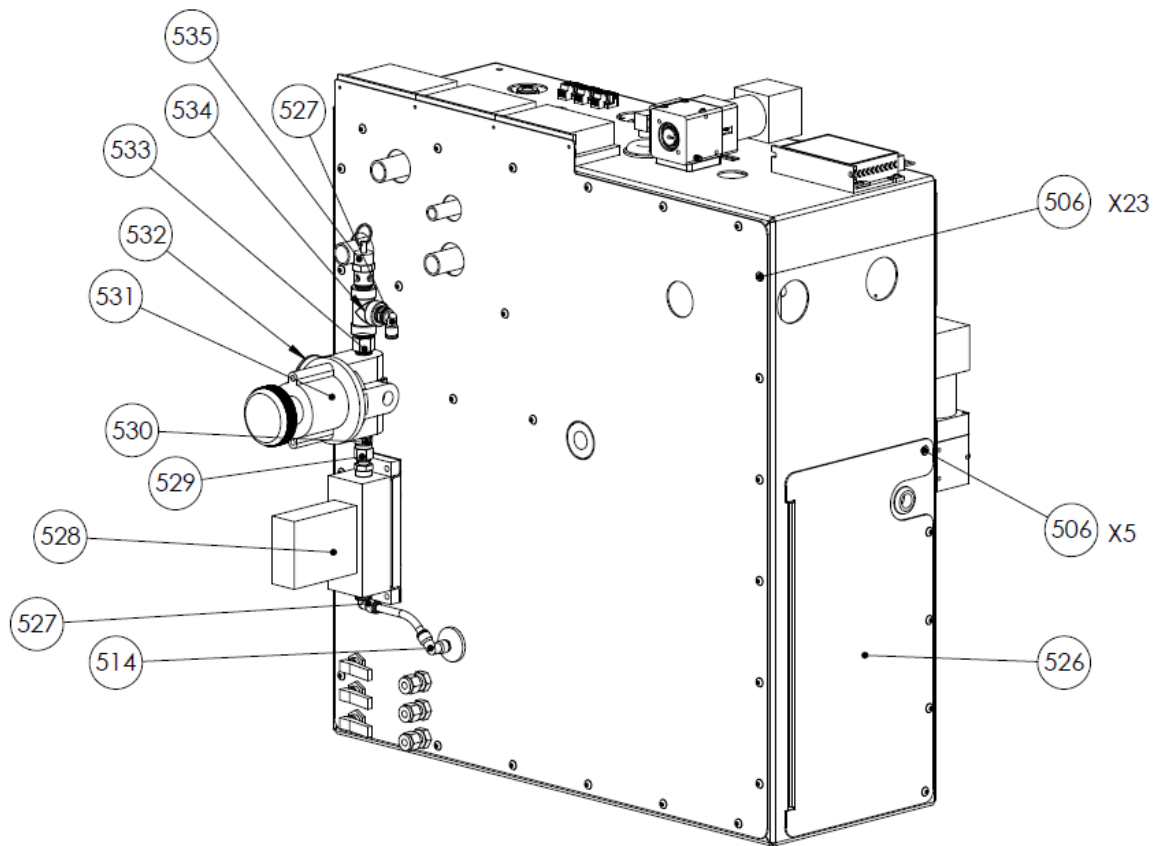


Figure 8.21



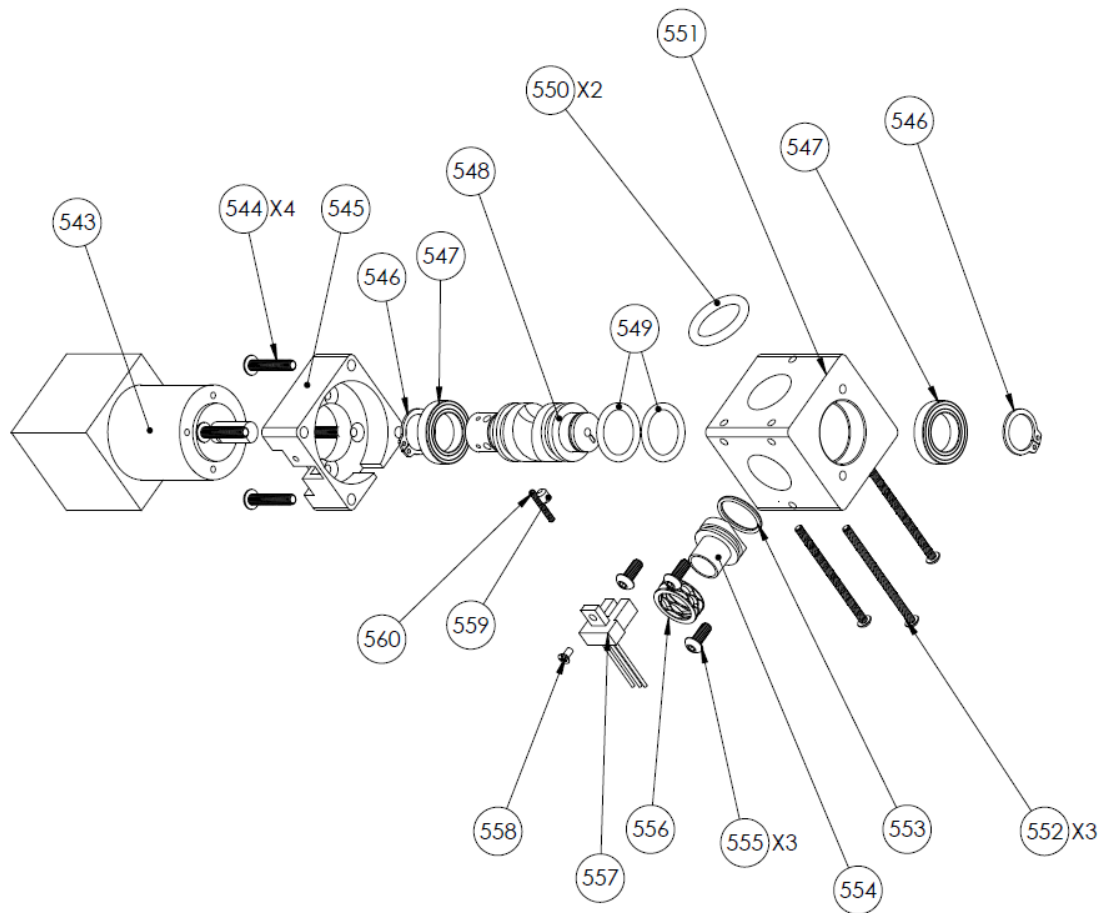


Figure 8.22

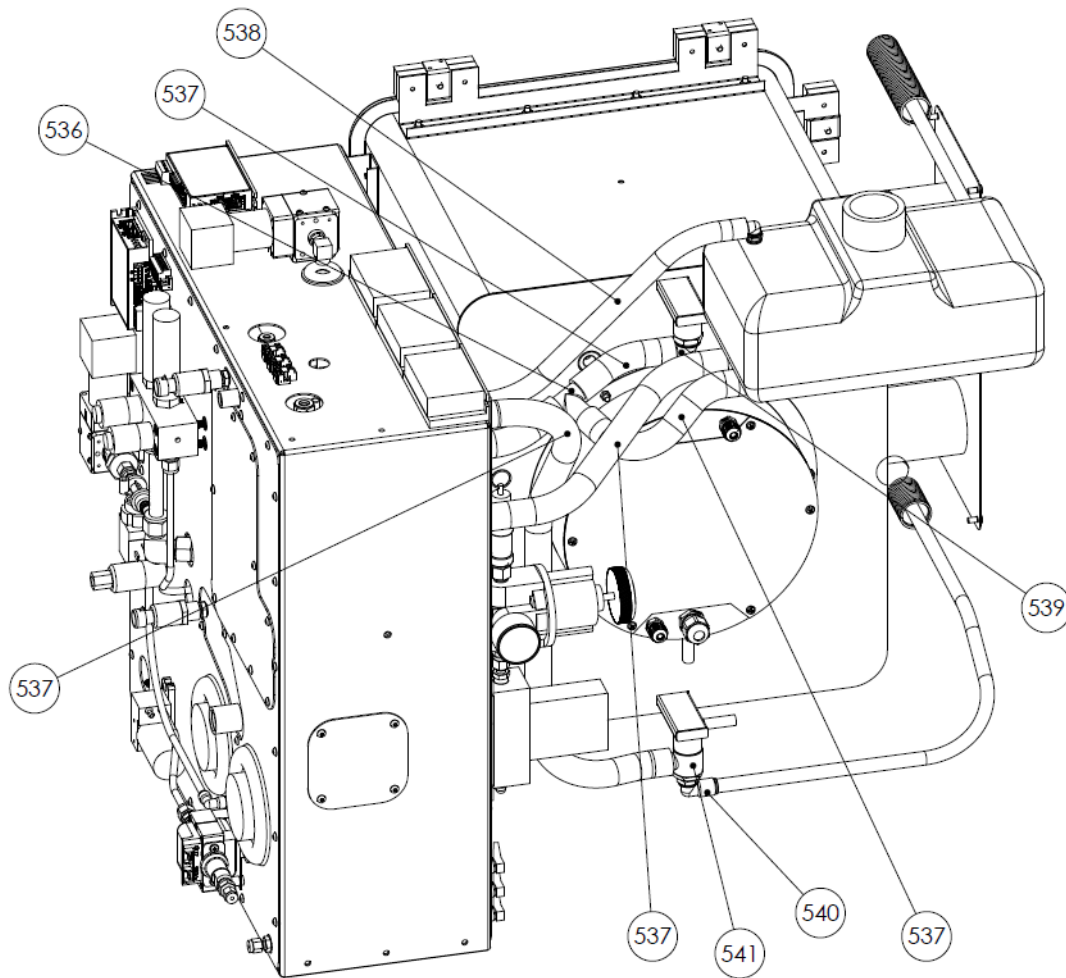


Figure 8.23

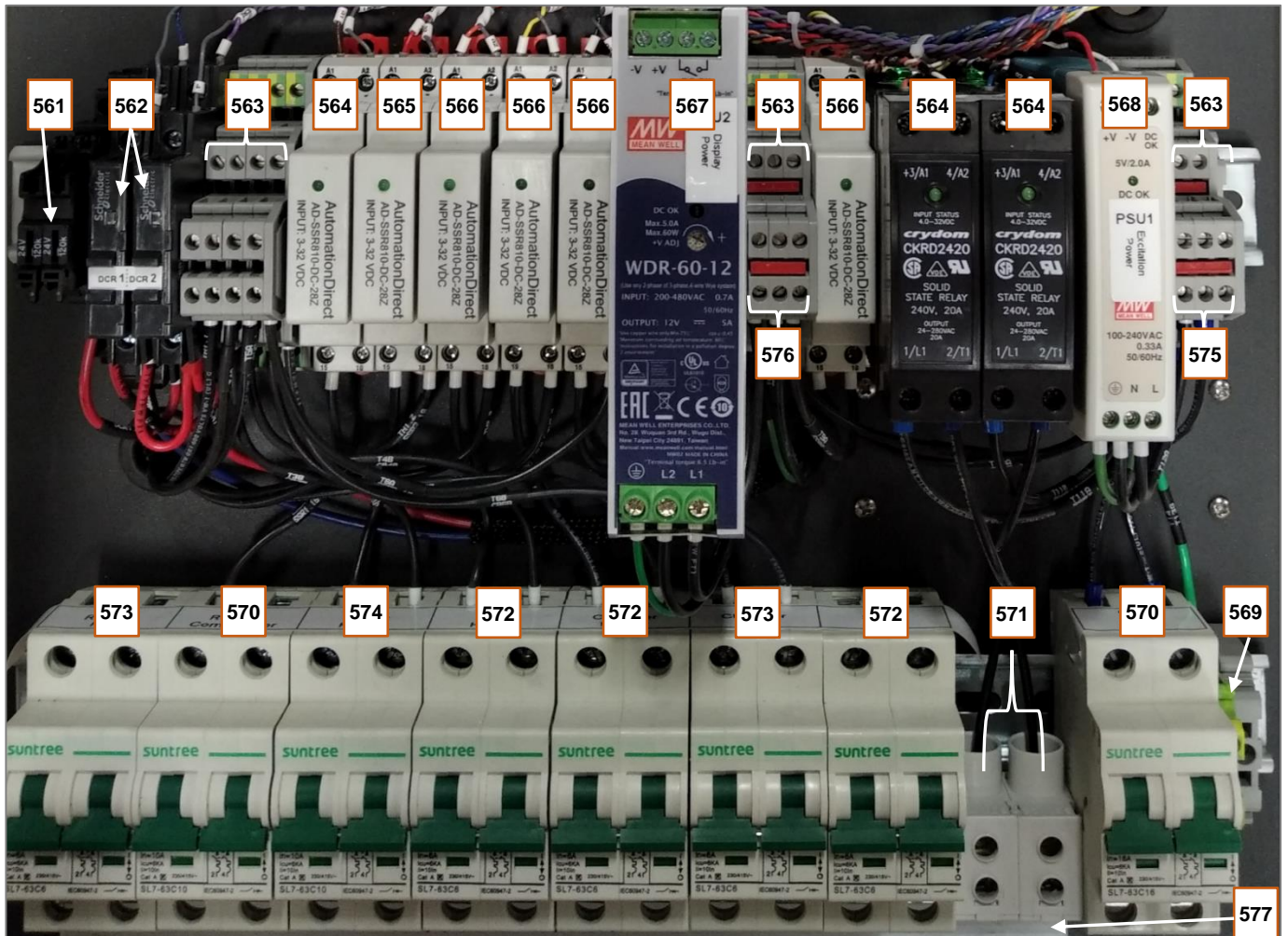


Figure 8.24



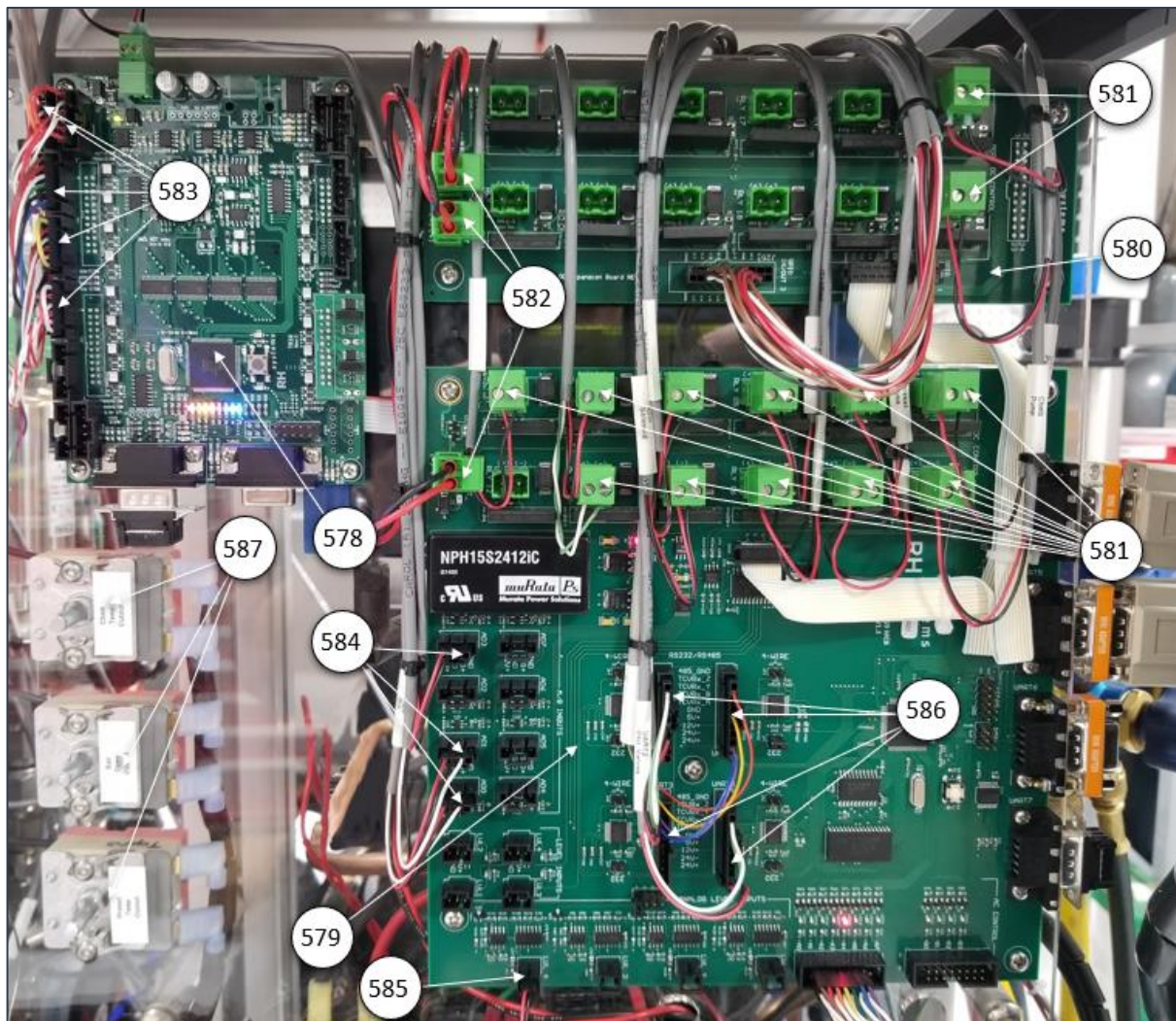


Figure 8.25

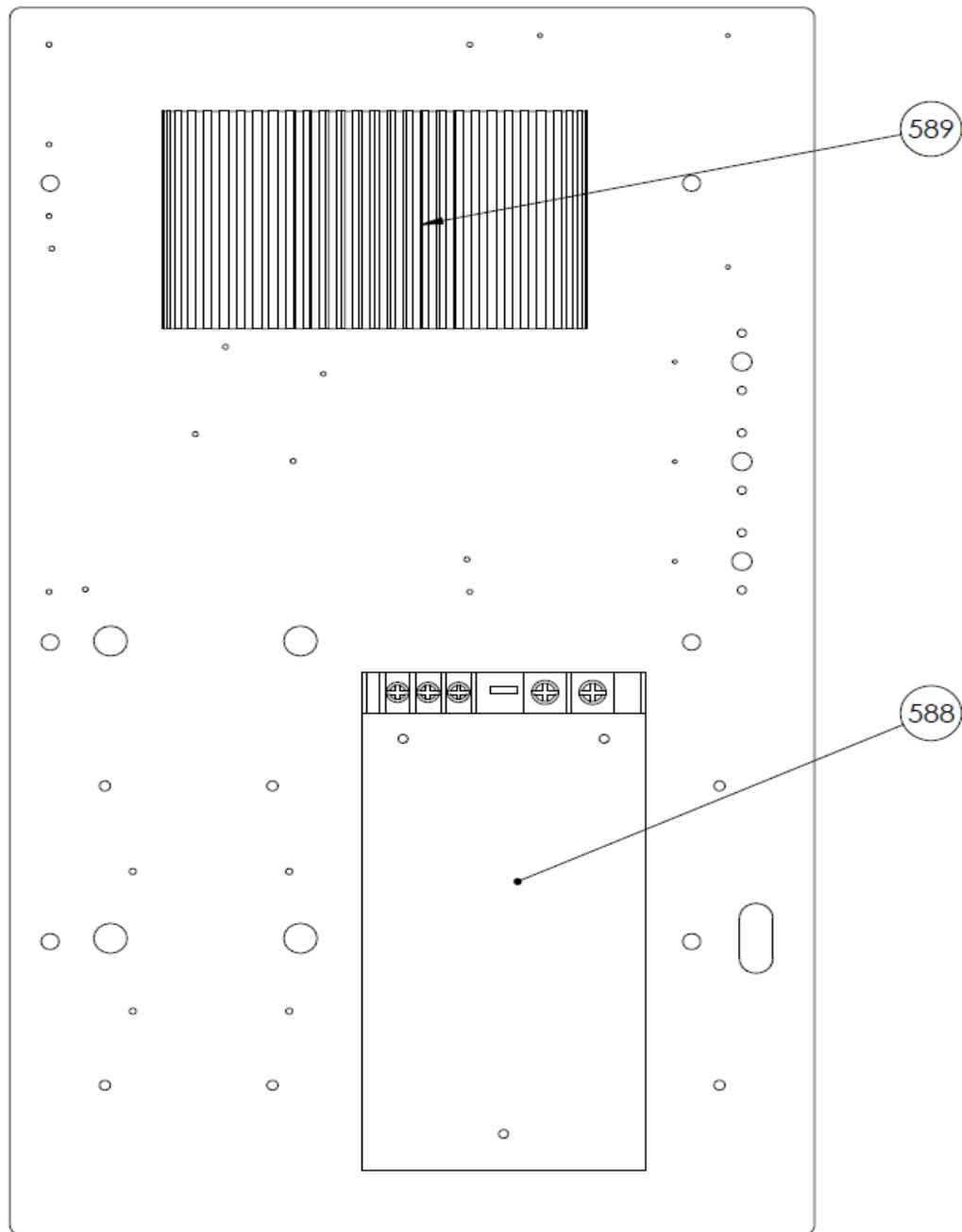

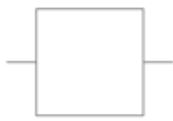

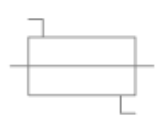
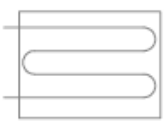







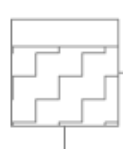

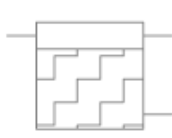
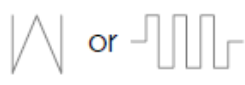
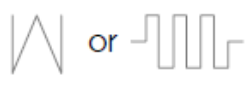
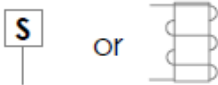










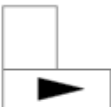




Figure 8.26

## 9 DRAWINGS

The legend is followed by drawings of the refrigeration system, pneumatic system, and fluid system. The electronic board drawings are included in this portion of the manual.

	Air Cooled Condensor		Chamber
	R-134A Compressor		Pre-Saturator
	Fluid Heater		Pump
	Fluid Heat Exchanger		Muffler
	Saturator		Diaphragm Operated Valve
	Receiver Tank		Valve
	Bath		Safety Relief Valve
	Water Reservoir	 or 	Heater

	Solenoid		Pressure Gauge
	Motor		Pressure Sensor
	Check Valve		Sight Glass
	Temp Actuator		Liquid Level Sensor
	Temp Sensor		Diode
	Optical Sensor		
	Flow Transducer		
	Filter Dryer		
	Direction of Flow		



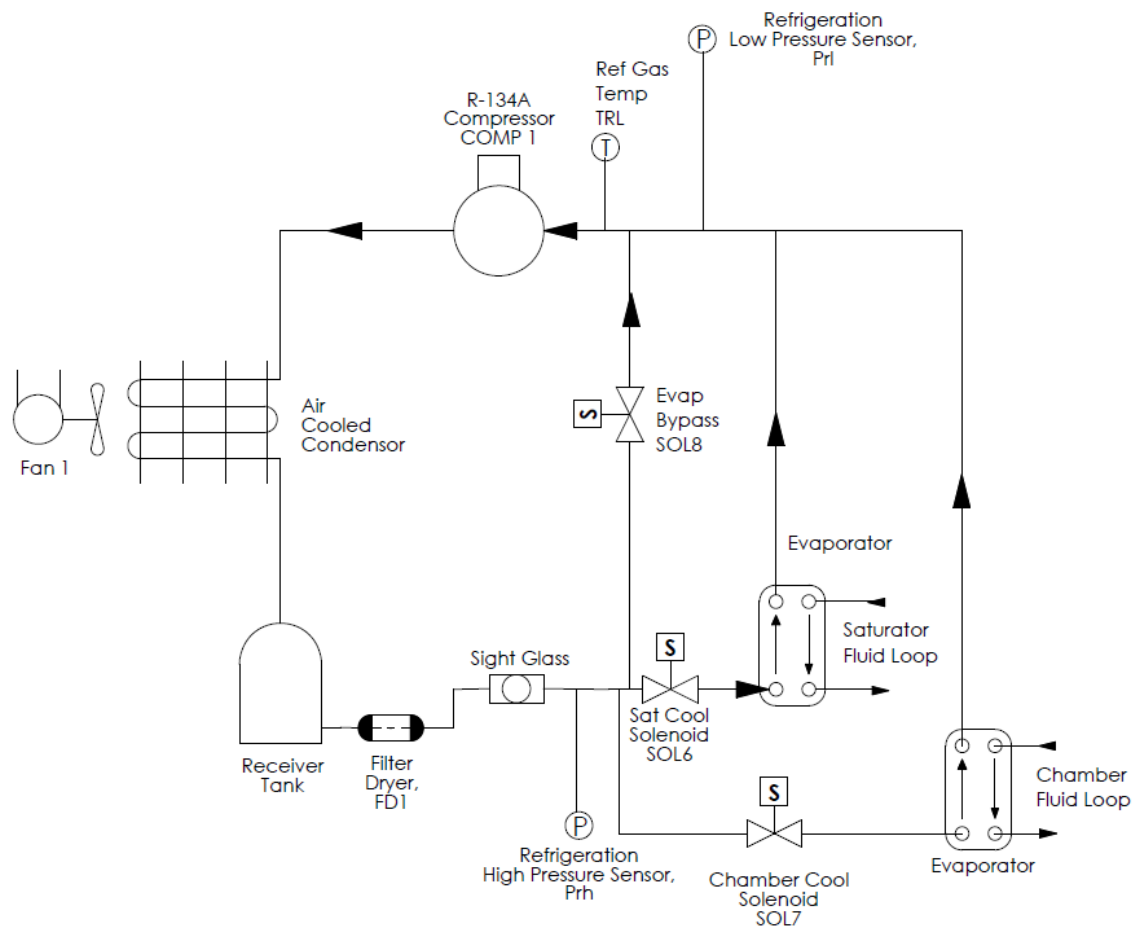


Figure 9.3 Refrigeration System

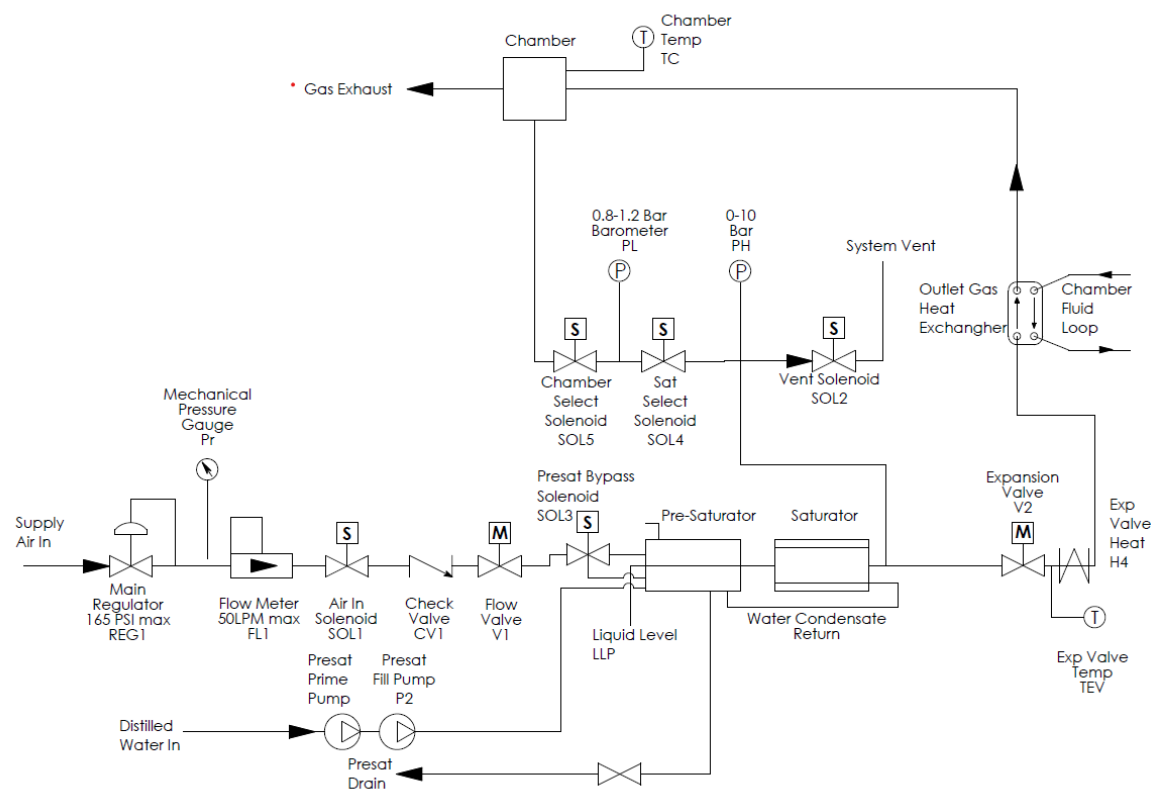


Figure 9.4 Pneumatic System

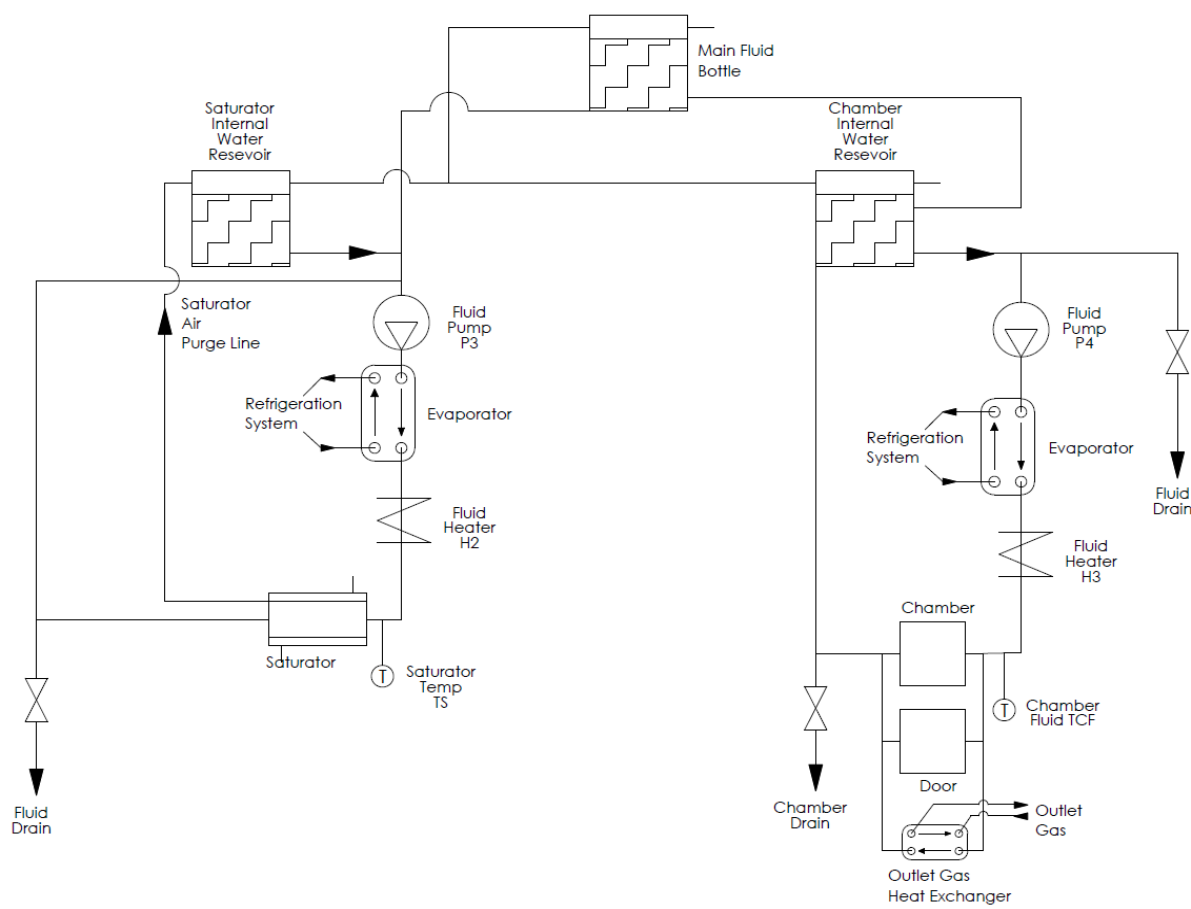


Figure 9.5 Fluid System

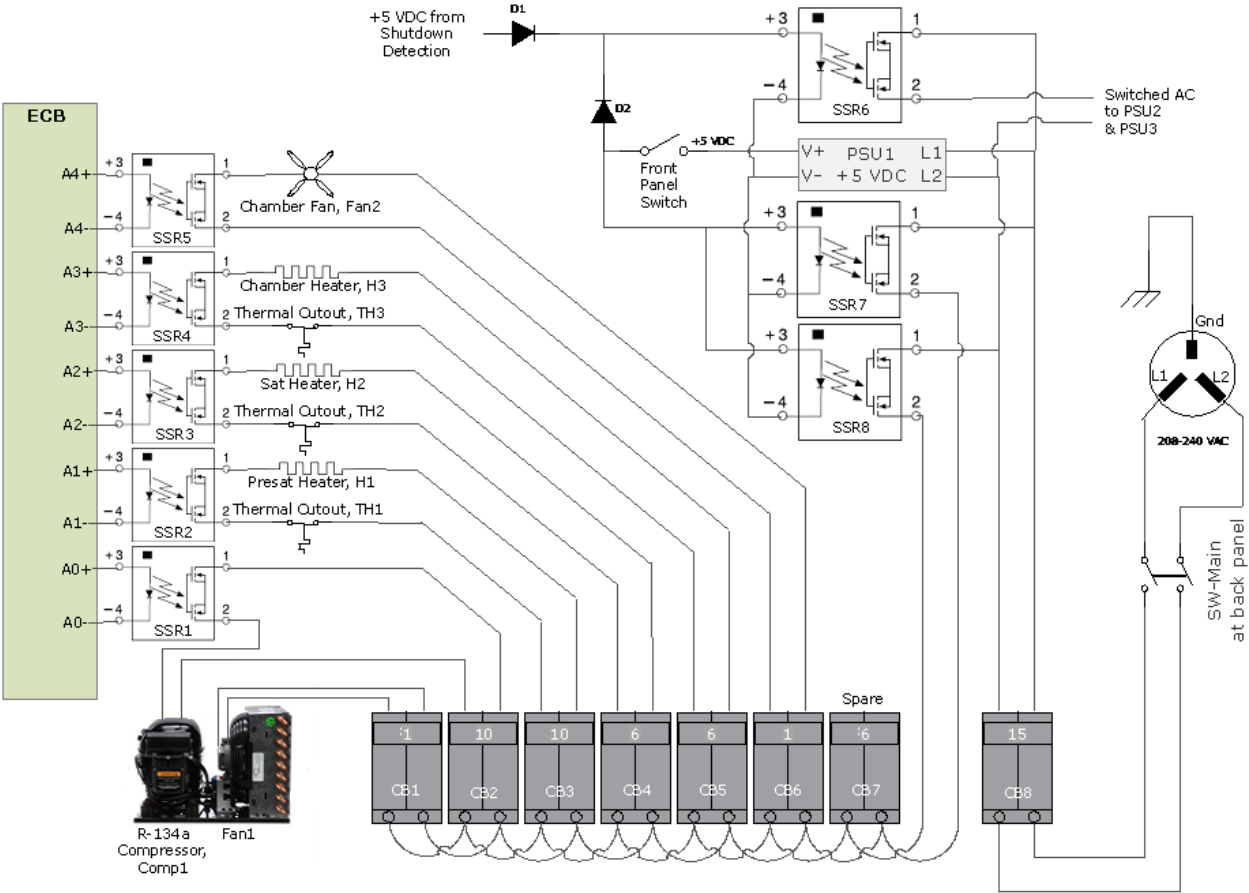


Figure 9.6 AC Distribution

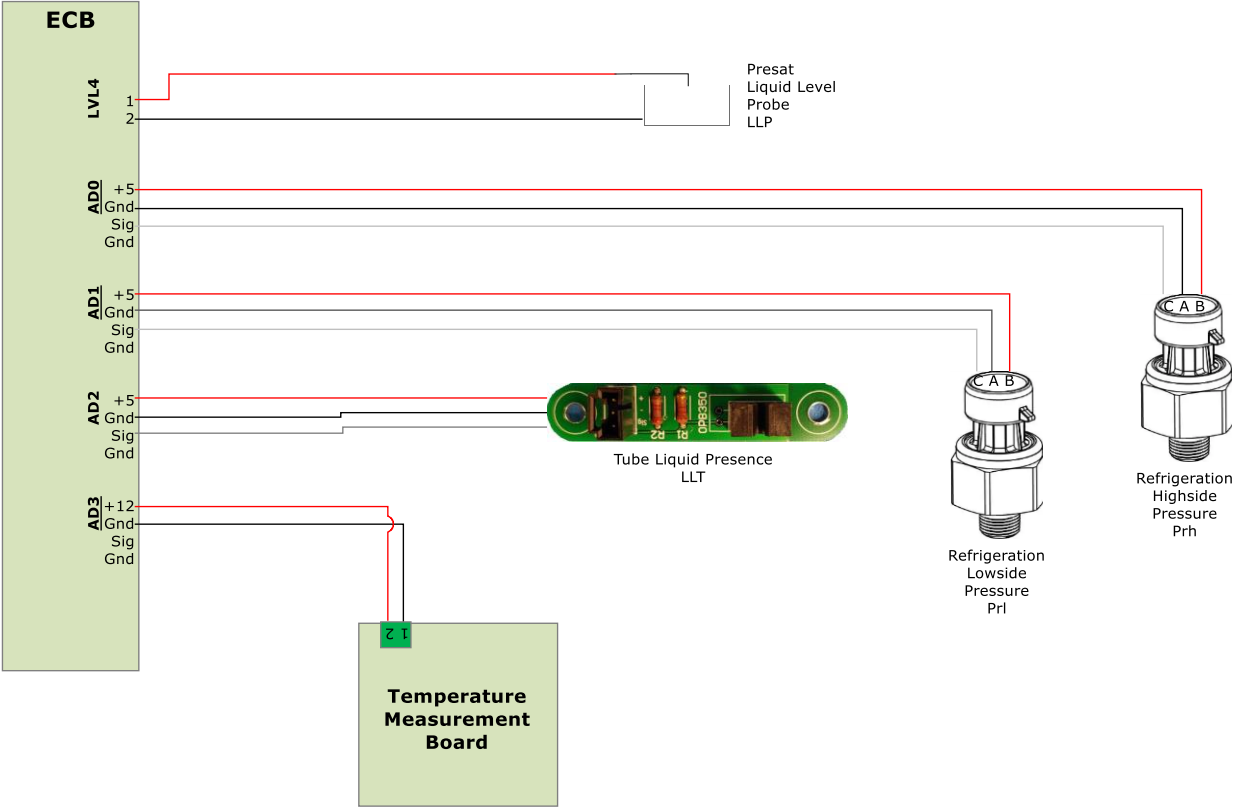


Figure 9.7 AD0-3 & LVL4

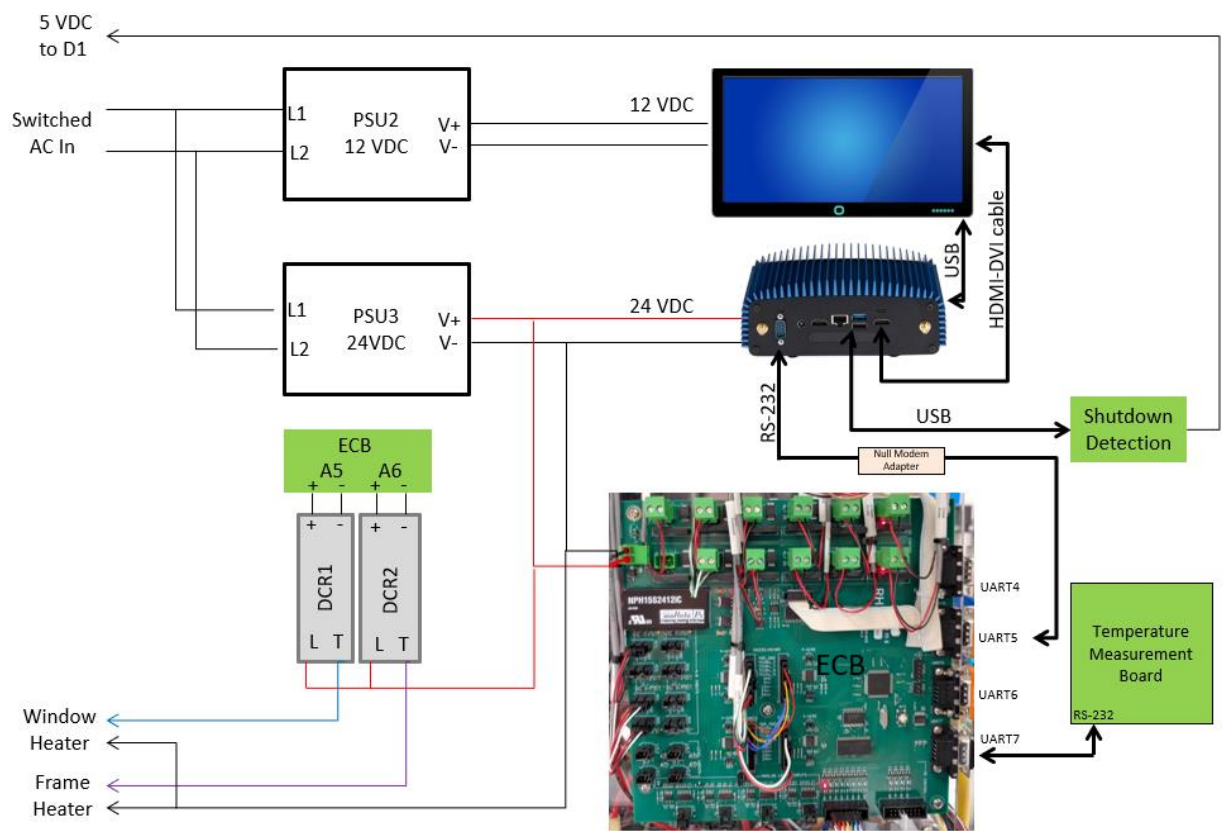


Figure 9.8 Power Distribution

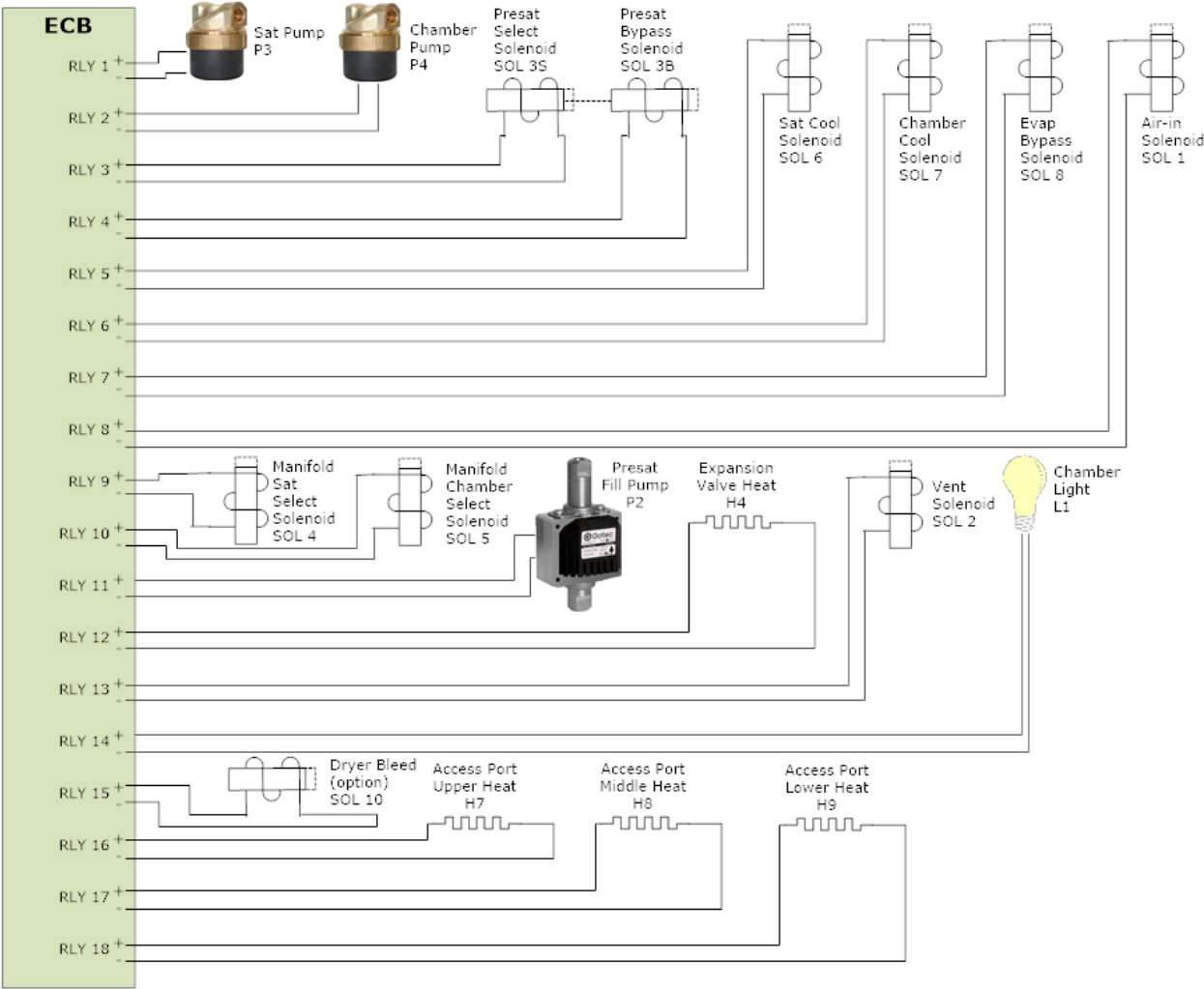


Figure 9.9 RLY 1-14



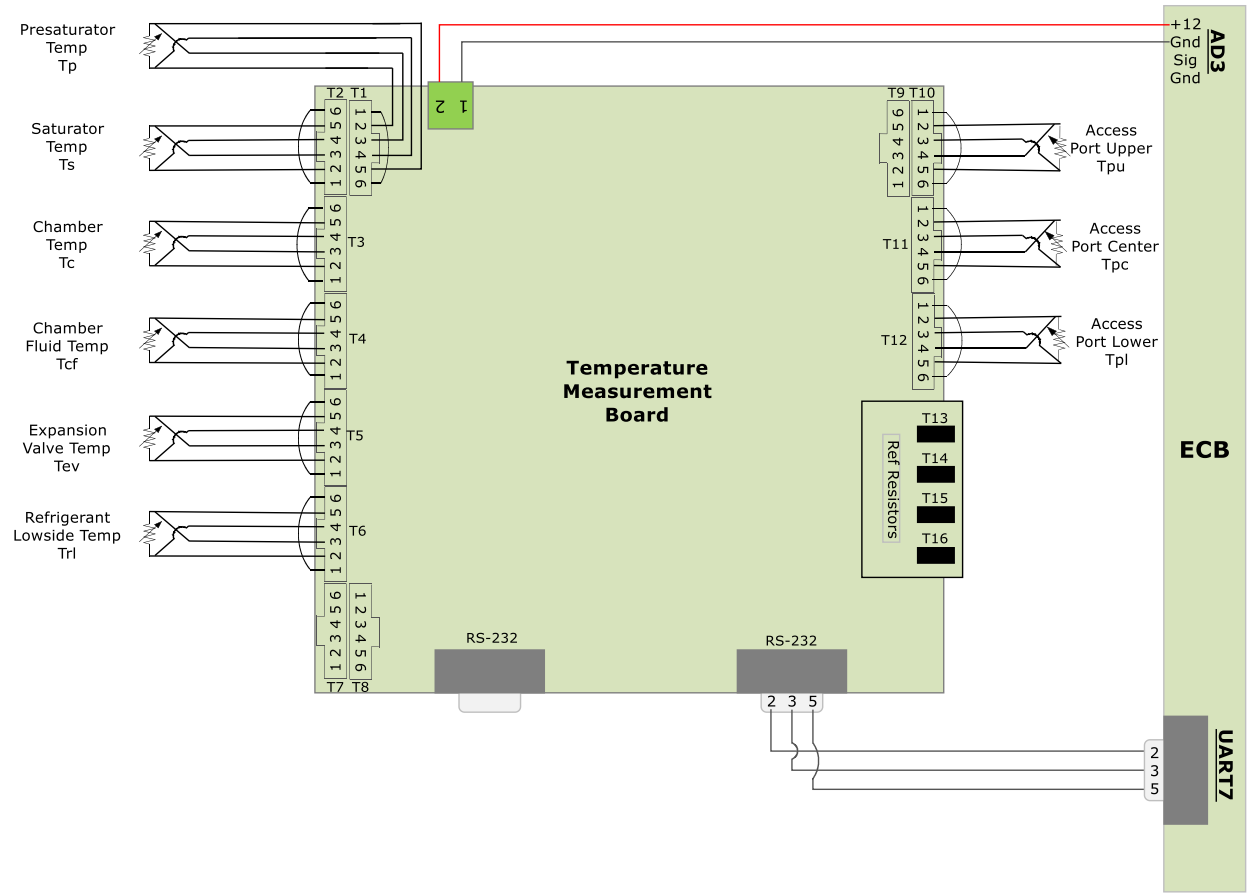


Figure 9.10 PT 12 Temp Board

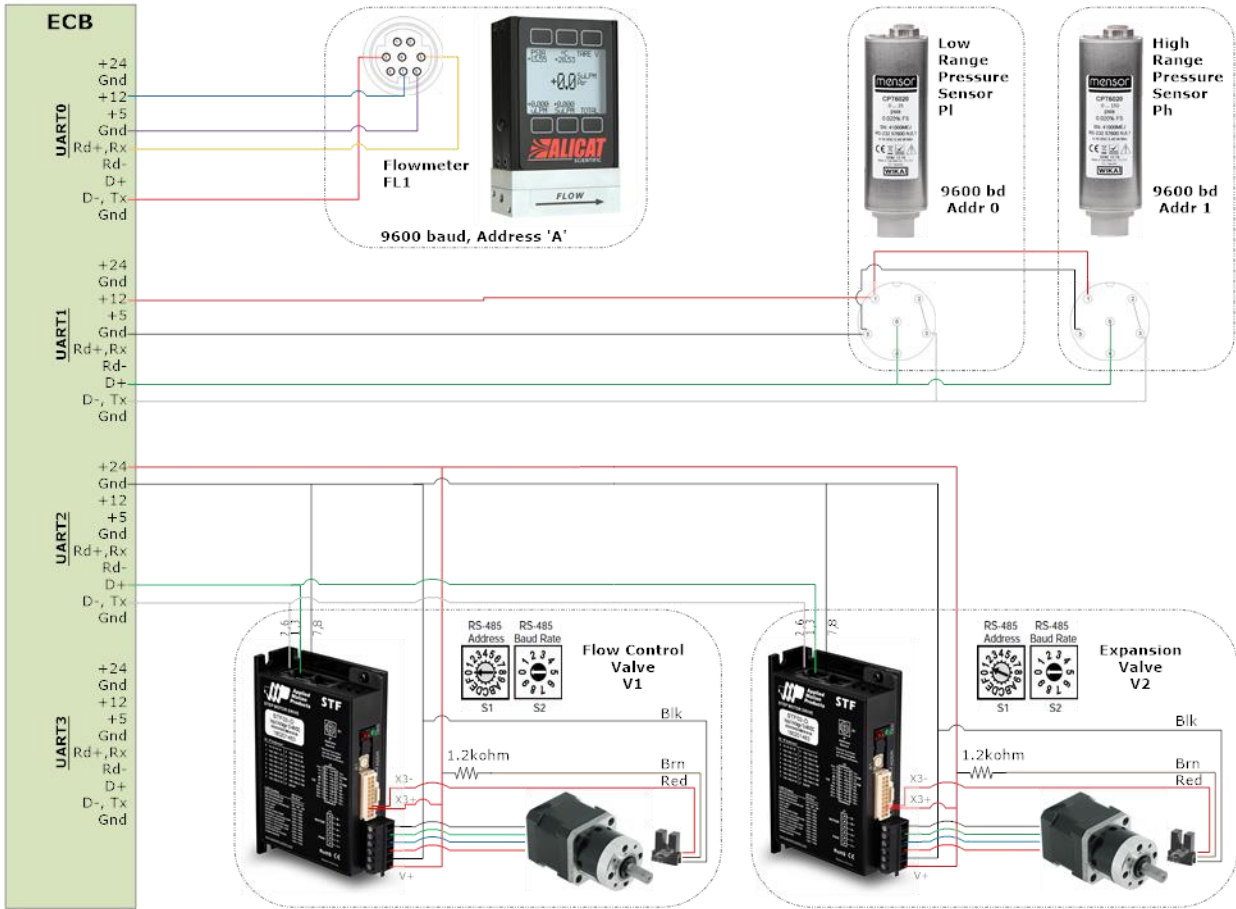


Figure 9.11 UART 0-3

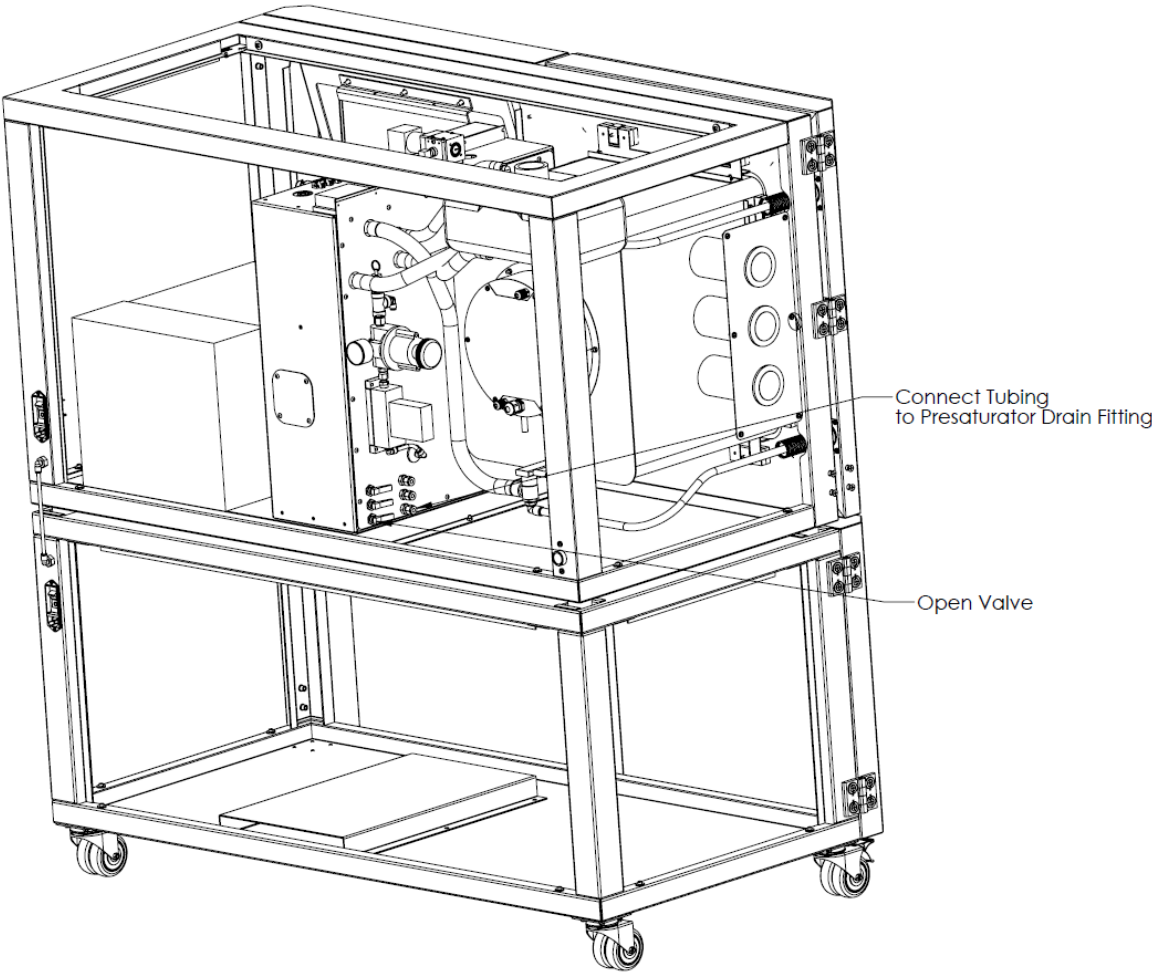


Figure 9.12    Access to Presat Drain Fitting

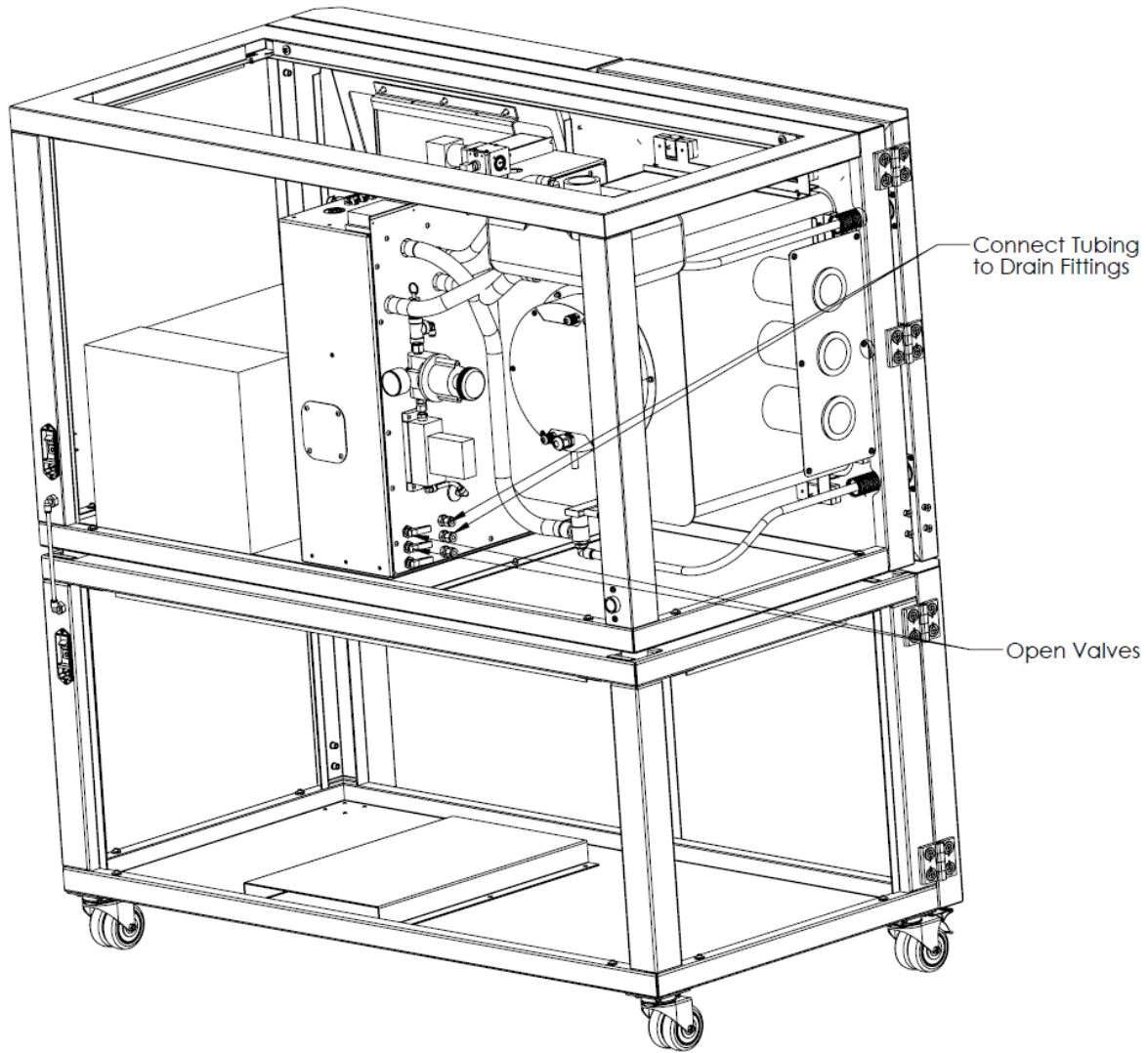


Figure 9.13 Access to Sat Drain Fittings

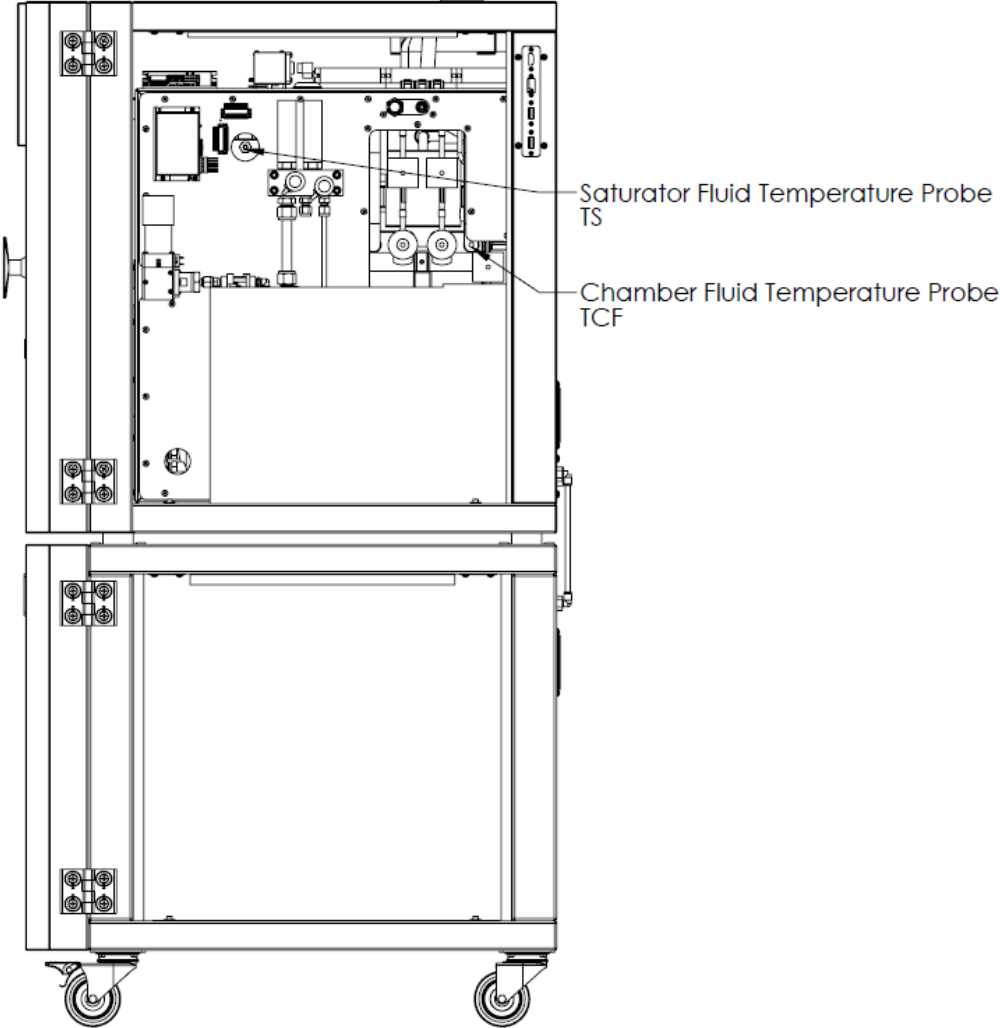


Figure 9.14 Temperature Probes

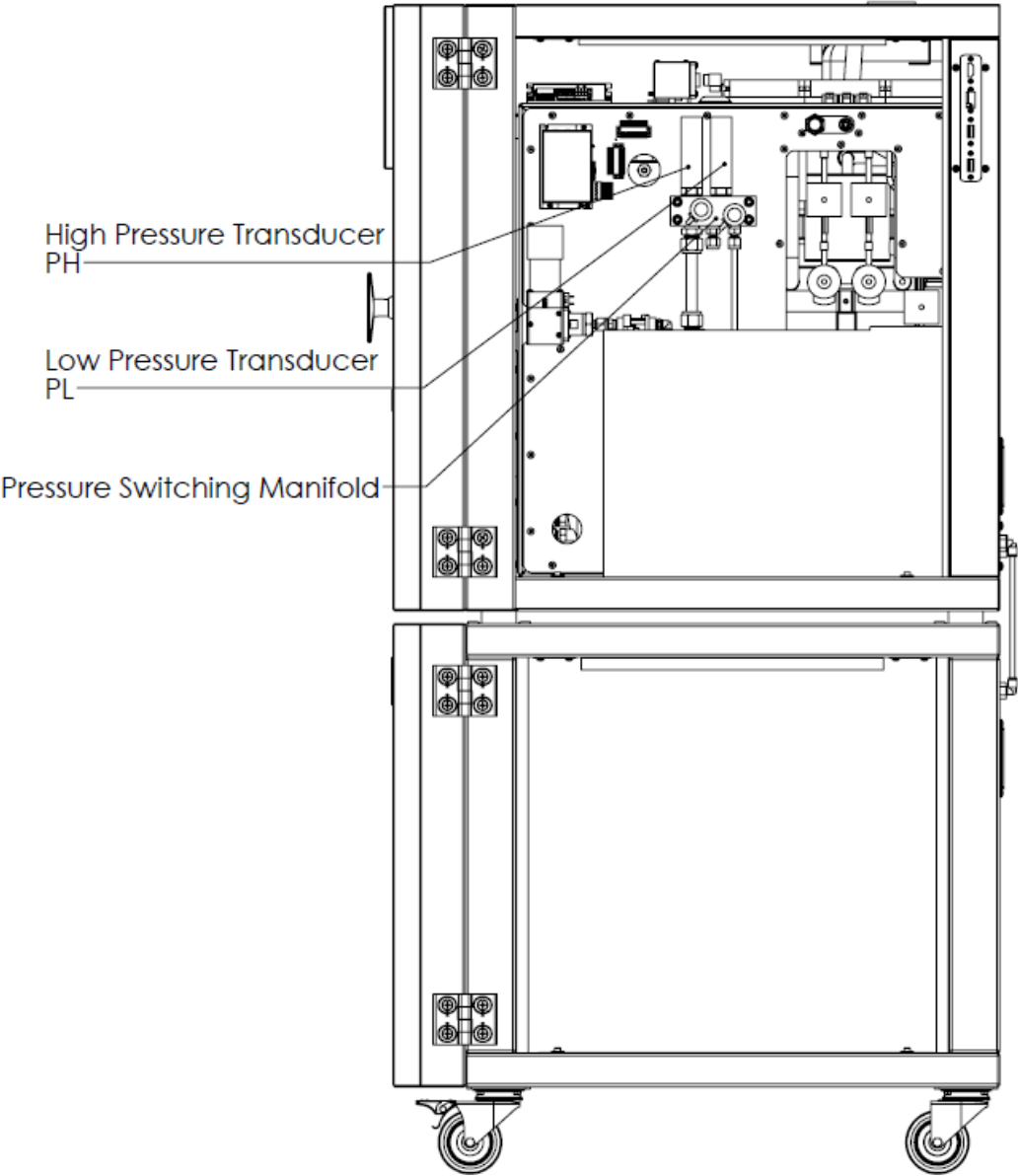


Figure 9.15 Pressure Transducers & Manifold

## 10 RHS PLATEAU SOFTWARE

The CGS-240 RHS Plateau software may be used to calibrate a device given a set of test data (Unit Under Test or UUT) and a set of reference data. It evaluates data, finding plateaus, it then evaluates the plateau for the most stable sections based on standard deviation. Once found, the mean values of the selected stable plateaus are used, along with reference data to calculate new coefficients to fit the data to the reference. The new coefficients and calculated residuals of the curve fit are recorded.

RHS Plateau can be launched from the desktop shortcut.



### 10.1 INTRODUCTION

Figure 5.7 shows the RHS Plateau startup screen, with the **File** menu options shown.

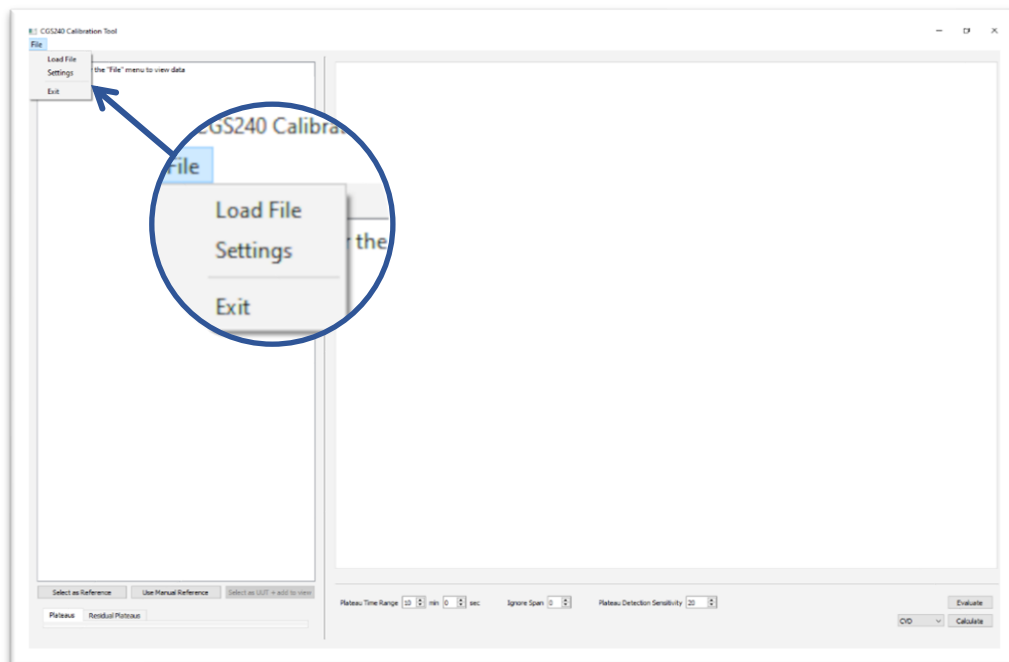


Figure 5.7

Figure 5.8 shows RHS Plateau with a data set loaded and analyzed.

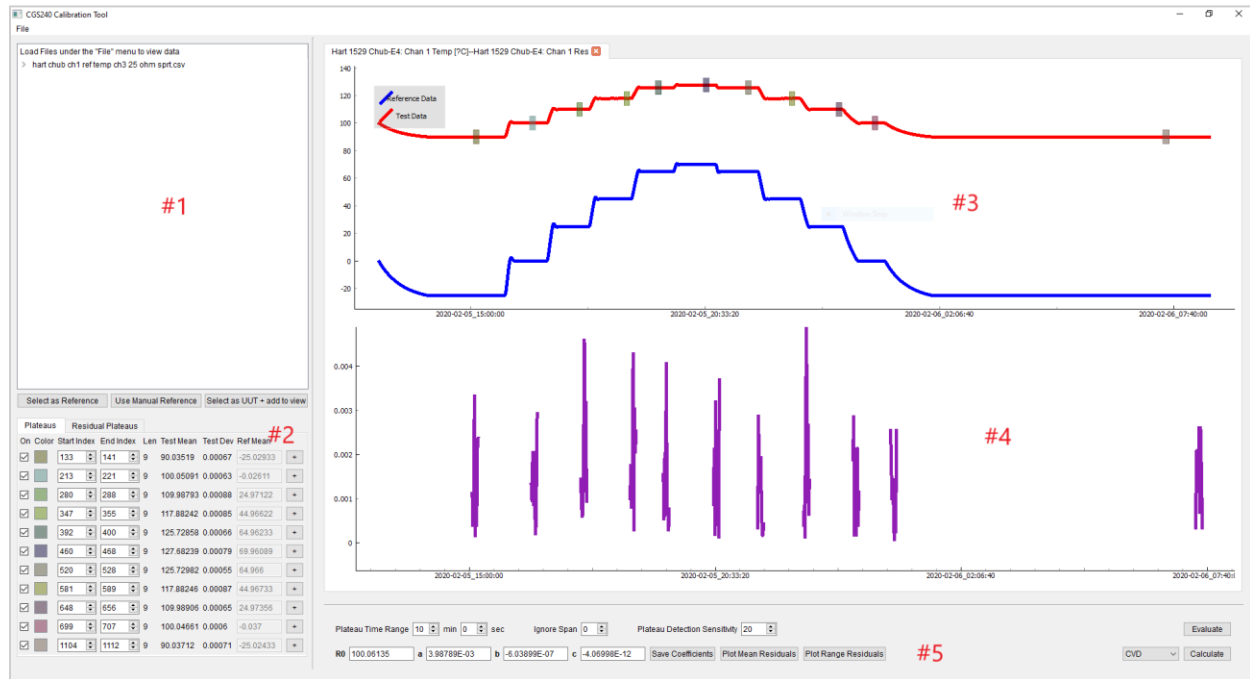


Figure 5.8

### #1 Data File Window

The figure is shown with a data set loaded. A data set may be loaded by selecting **File > Load File** and selecting an existing file from a prestored file location. The data columns within the chosen file may be viewed within the Data File Window by clicking on the drop-down arrow located to the immediate left of the file name. This is shown under the file name 'hart chub ch1 ref temp ch3 25 ohm sprt.csv'. You can use the three buttons below to select a reference data set, use a manual data set, or choose a UUT data set. For example, select the data column name (e.g., T1 under file name 'hart chub ch1 ref temp ch3 25 ohm sprt.csv'), then click **Select as Reference**.

### #2 Plateaus Tab

The UUT data including the indices of which the plateaus begin and end from the original data set, the mean value of the UUT, the standard deviation of the UUT, and the reference mean (mean and standard deviation data displayed is from within the plateau).

### #2 Residual Plateaus Tab

The second tab contains the above-mentioned data corrected by the coefficients calculated by selecting the **Calculate** button which will be explained further within '#5 Utility Settings'. The Plateau(s) windows are shown in Figure 5.9 and 5.10.

Plateaus		Residual Plateaus					
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean
<input checked="" type="checkbox"/>	133	141	9	90.03519	0.00067	-25.02933	+
<input checked="" type="checkbox"/>	213	221	9	100.05091	0.00063	-0.02611	+
<input checked="" type="checkbox"/>	280	288	9	109.98793	0.00088	24.97122	+
<input checked="" type="checkbox"/>	347	355	9	117.88242	0.00085	44.96622	+
<input checked="" type="checkbox"/>	392	400	9	125.72858	0.00066	64.96233	+
<input checked="" type="checkbox"/>	460	468	9	127.68239	0.00079	69.96089	+
<input checked="" type="checkbox"/>	520	528	9	125.72982	0.00055	64.966	+
<input checked="" type="checkbox"/>	581	589	9	117.88246	0.00087	44.96733	+
<input checked="" type="checkbox"/>	648	656	9	109.98906	0.00065	24.97356	+
<input checked="" type="checkbox"/>	699	707	9	100.04661	0.0006	-0.037	+
<input checked="" type="checkbox"/>	1104	1112	9	90.03712	0.00071	-25.02433	+

Figure 5.9

Plateaus		Residual Plateaus					
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean
<input checked="" type="checkbox"/>	133	141	9	0.00131	0.00102	-25.02933	
<input checked="" type="checkbox"/>	213	221	9	0.00136	0.00081	-0.02611	
<input checked="" type="checkbox"/>	280	288	9	0.00184	0.00127	24.97122	
<input checked="" type="checkbox"/>	347	355	9	0.00186	0.00121	44.96622	
<input checked="" type="checkbox"/>	392	400	9	0.00128	0.00112	64.96233	
<input checked="" type="checkbox"/>	460	468	9	0.00164	0.0012	69.96089	
<input checked="" type="checkbox"/>	520	528	9	0.0011	0.0009	64.966	
<input checked="" type="checkbox"/>	581	589	9	0.00168	0.0015	44.96733	
<input checked="" type="checkbox"/>	648	656	9	0.00136	0.00094	24.97356	
<input checked="" type="checkbox"/>	699	707	9	0.00125	0.00085	-0.037	
<input checked="" type="checkbox"/>	1104	1112	9	0.00153	0.00086	-25.02433	

Figure 5.10



### #3 Plot Window

The original test data and the reference data are plotted, with time as the X axis and Y as the common unit of measurement between the UUT and reference data. Evaluated plateaus are shown as boxes of varying colors over the UUT data set.

### #4 Residual Plot Window

After the data set has been evaluated, and the coefficients have been calculated, the user may plot the residual data as means or at individual plot points, and display the residual values in the residual plateau table (Figure 5.8).

### #5 Utility Settings

RHS Plateau settings. In order from left to right they are as follows:

- **Plateau Time Range** - The time over which a subset of data must be stable in order to be considered a plateau. This is defined in Minutes(min) and Seconds(s).
- **Ignore span** - The amount of data rows the user wishes Plateau to ignore during the evaluation.
- **Plateau Detection Sensitivity** - Defines the "acceptable limit of the plateau by evaluation of the standard deviation.
- **Evaluate** - This button causes Plateau to evaluate the UUT data set and find the plateaus given the setting mentioned previously. Plateau will then fill in the plateau table and create the small boxes around the visual representation of the data.
- **Equation Type Drop-Down** – This drop-down menu allows selection of the curve fit equation to evaluate.
- **Calculate** – This button will calculate coefficients using an equation chosen within a drop-down menu.
- **Save Coefficients** – This button will allow the user to save the coefficients to a file name/directory chosen by the user for future access.
- **Plot Residuals** – This will command Plateau to generate a plot of the predicted residuals generated from the calculated coefficients.

## 10.2 SEQUENCE OF EVENTS

The following section dictates the sequence of events that you need to follow in order to utilize RHS Plateau.

### 10.2.1 CONFIGURING SETTINGS

Before loading in data set files, be sure to look over the settings menu (in the File pull down menu) to confirm that your file delimiter and datetime formats are correct.

As shown in Figure 5.11, to display settings, click on **File > Settings**.

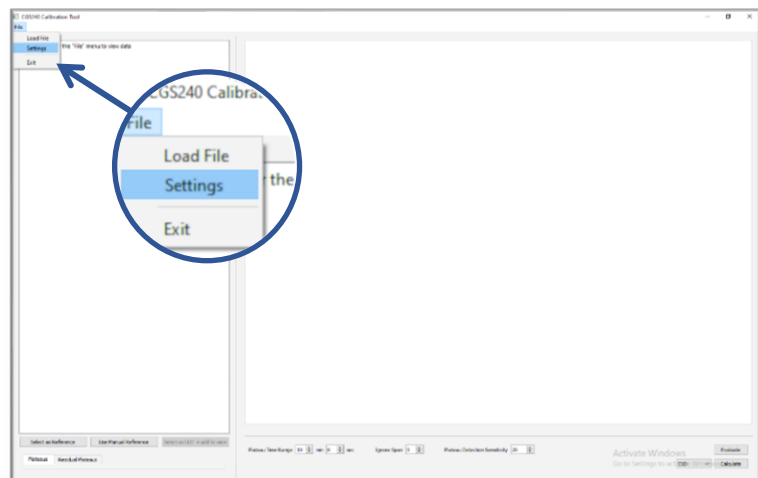


Figure 5.11

The **Settings** will appear as shown in Figure 5.12.

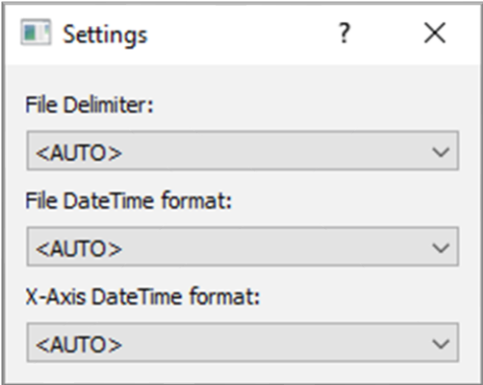


Figure 5.12

Figure 5.13 shows the menu options for **File Delimiter**, which specifies how your data is separated in your data file. For example, if there were a data set that was saved with the .csv (Comma Separated Value) file format, you would select ',' from the drop-down menu to parse the data. If **<AUTO>** is selected RHS Plateau will attempt all.

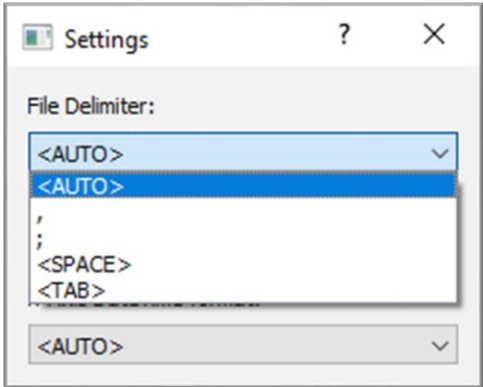


Figure 5.13

Figure 5.14 shows the menu options for **File DateTime Format**, which specifies the format your date data is using in your data file. If **<AUTO>** is selected RHS Plateau will attempt all of the options.

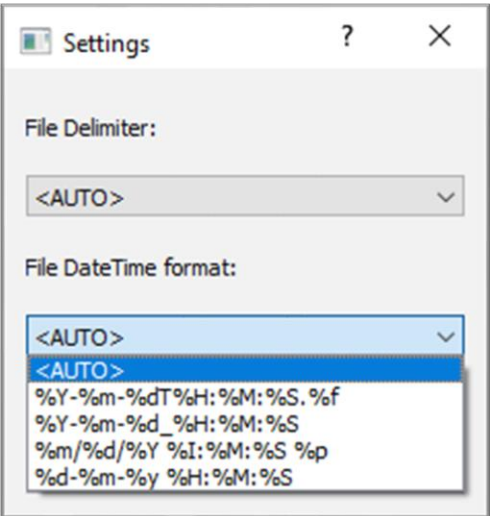


Figure 5.14

Figure 5.15 shows the menu options for **X-Axis DateTime format**, which specifies how the labels for the x axis will be formatted. If **<AUTO>** is selected RHS Plateau defaults to Year-Month-Day\_Hour:Min:Sec.

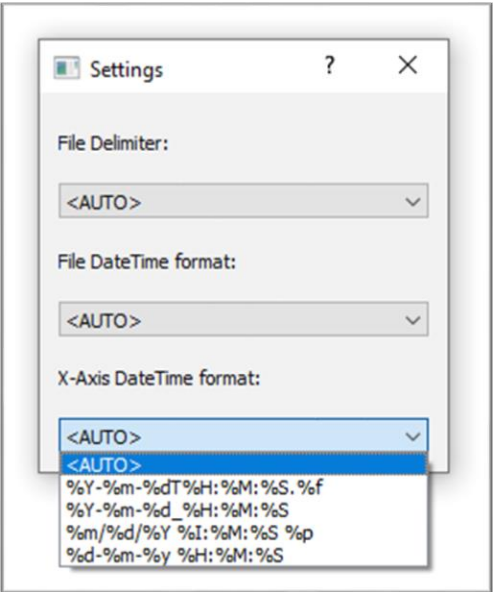


Figure 5.15

Once plotted, the X-Axis will be labeled with the chosen datetime stamp, example shown below in Figure 5.16.

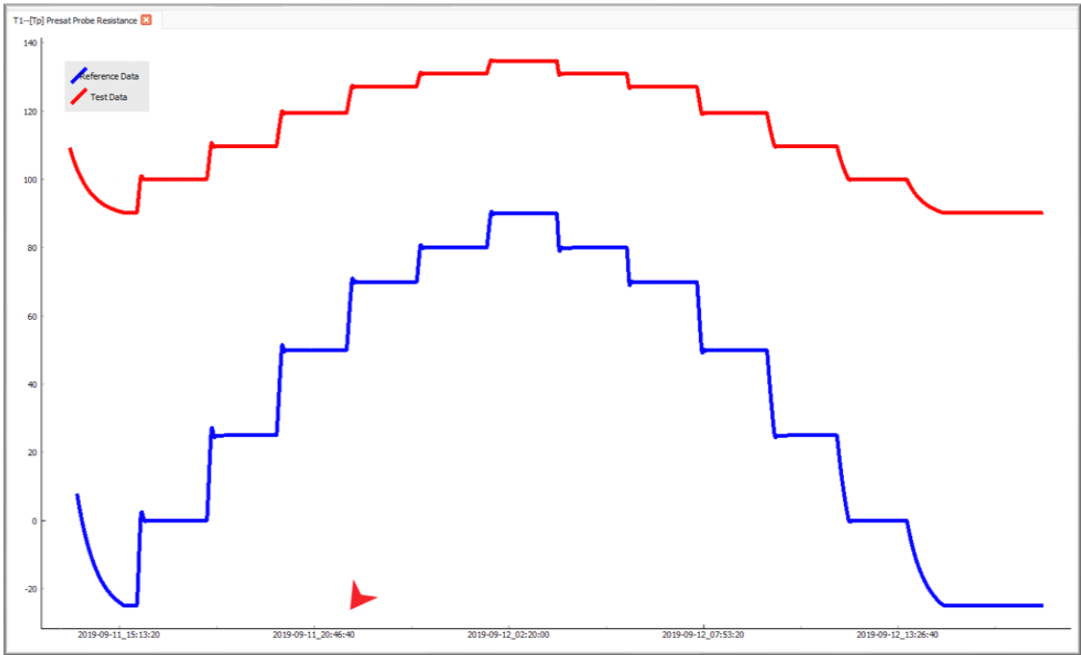


Figure 5.16

### 10.3 DATA FILE SELECTION

The next step is to load in your data files so that RHS Plateau can parse your files into various data sets.

Data files are formatted as shown in Figure 5.17.

The first row contains column headers, such as **DateTime** (1<sup>st</sup> column) and the names of data points (**T1**, **T2**, etc.).

DateTime	T1	T2	T3	T4
2020-12-07T14:30:20.137	24.917	-0.4295	-1.8263	
2020-12-07T14:30:50.132	24.917	-0.4244	-3.9463	-273.150
2020-12-07T14:31:20.129	24.918	-0.5772	-1.9482	

Figure 5.17

To select a file, click **File > Load File** (as shown in Figure 5.18).

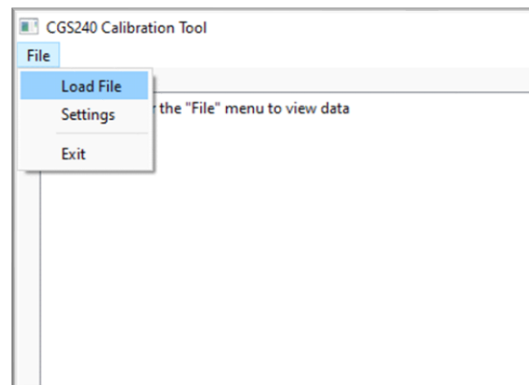


Figure 5.18

A file select window opens (Figure 5.19). Navigate to the desired data file, select the data file, and click **Open**. This can be done as many times as there are data files, but RHS Plateau will not reload the same file. Additionally, if a file is changed you must reload the file into RHS Plateau.

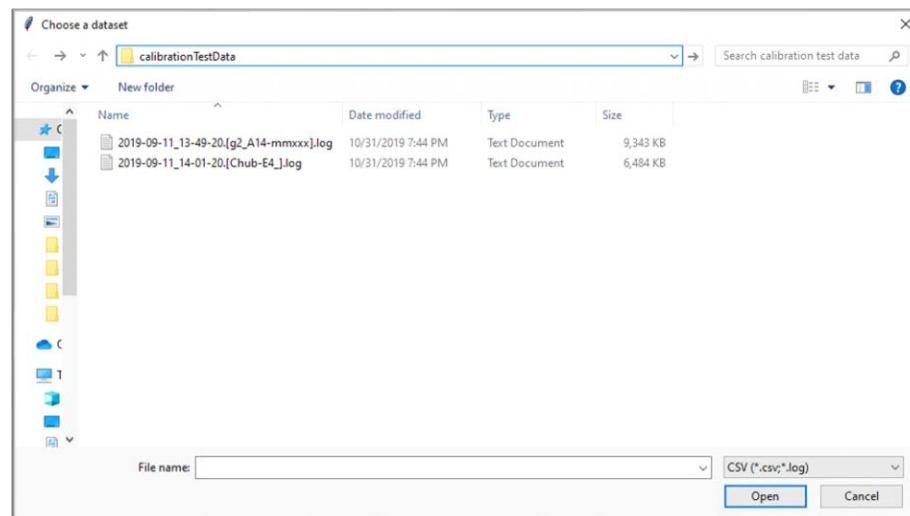


Figure 5.19

Once the data set is loaded, the Data File Window will be populated as shown in Figure 5.20.

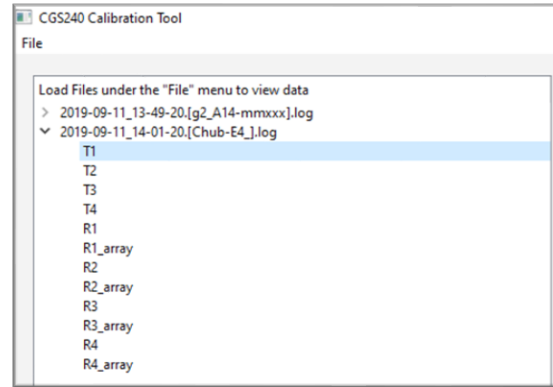


Figure 5.20

Select a reference data set by clicking on a set within the tree and click the button **Select as Reference**.

Alternatively, you may use manual reference values as described in *Selecting a Manual Reference* (section 5.3.3).

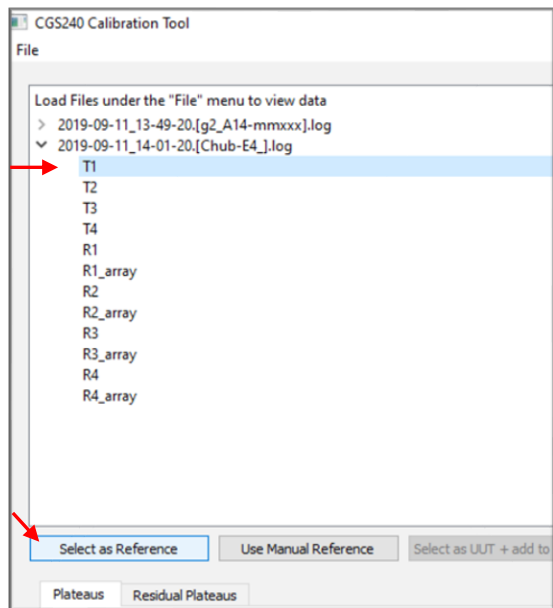


Figure 5.21

You will notice that the “Select as UUT + add to view” button has now also been enabled.

Next, select the desired UUT.

Click the **Select as UUT + add to view** button.

For temperature data, the *reference will be in degrees (°C)*, but the *UUT should be in ohms (Ω)*.

For example, for a UUT of Sat Temperature, select “Sat Probe Resistance,” rather than “Sat Temp.”

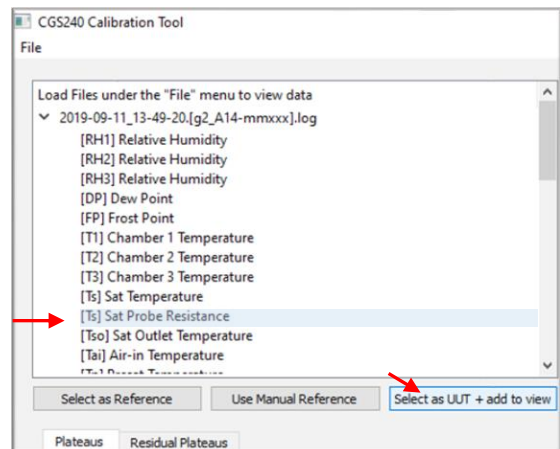


Figure 5.22

After a moment this will display your reference and UUT data on a plot, as shown in Figure 5.23.

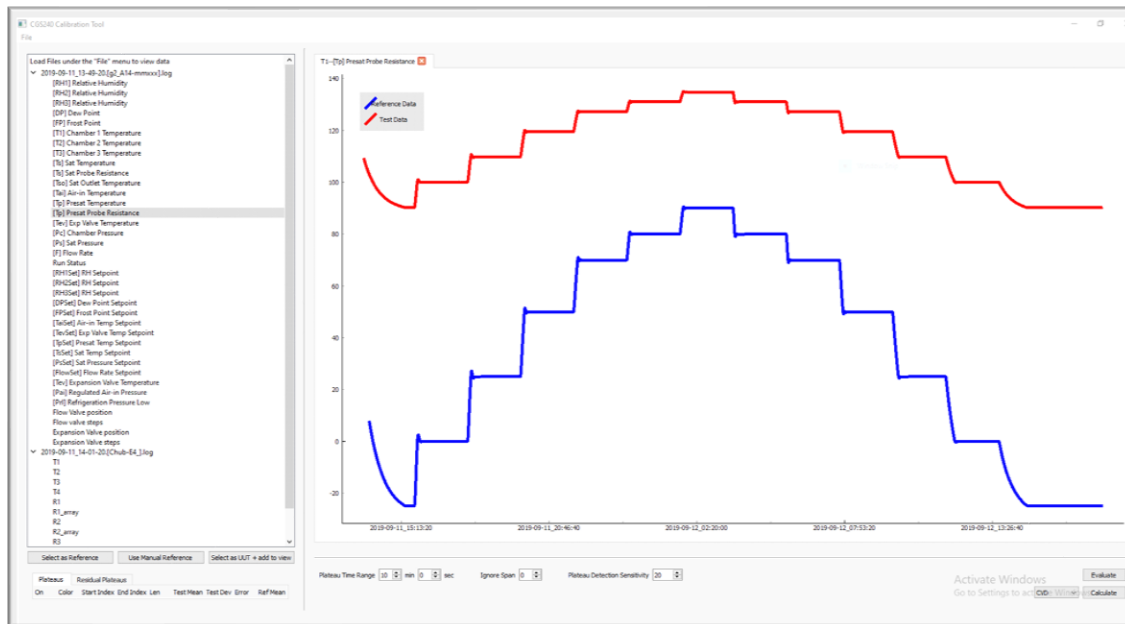


Figure 5.23

## 10.4 EVALUATING FOR PLATEAUS

Once a reference and UUT data set have been selected and plotted, plateaus can be evaluated by pressing the **Evaluate** button. Additionally, there are multiple options with which you can further specify what is considered a plateau with respect to a given data set. To understand these options, refer to the 'Intro' section under reference #5. Upon evaluation, a pop-up window will display the number of plateaus detected.

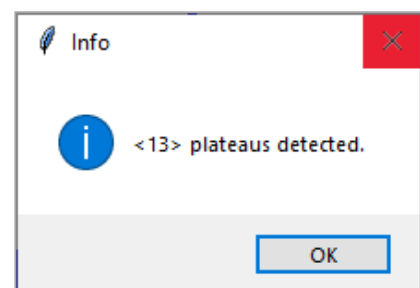


Figure 5.24

On the graph interface a number of colored boxes representing each of the plateaus will appear, as shown in Figure 5.25. To view these more closely it is possible to zoom in on the graph until only the plateau data is shown.

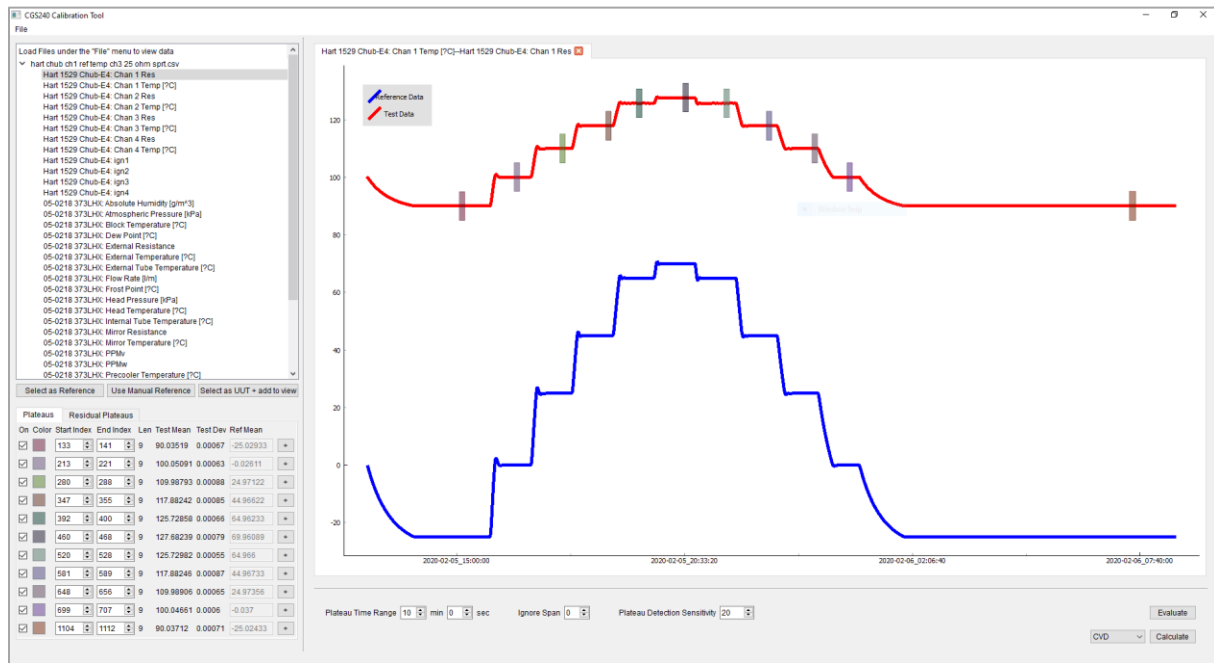


Figure 5.25

A table with all of the plateau data for this set will also display (see Figure 5.26). This data includes the following:

- A checkbox labeled **On** which specifies if the plateau point is used in coefficient calculation. When **Off**, the data is not used in coefficient calculation.
- A colored box labeled **Color** which maps to the color of the plateau box shown on the graph.
- A spinbox labeled **Start Index** which represents the beginning index of the plateau in the original data set, starting from 0. This can also be altered in real time to a different value by clicking in to the spinbox and typing a new value.
- A spinbox labeled **End Index** which represents the end index of the plateau in the original data set, starting from 0. This can also be altered in real time to a different value by clicking in to the spinbox and typing a new value.
- A number labeled **Len** which is the number of data points within a plateau.
- A number labeled **Test Mean** which is the mean of all the values within the plateau data set.
- A number labeled **Test Dev** which is the standard deviation of all the values within the plateau data set.
- An input box labeled **Ref Mean** which contains the mean value of the reference data set over the specified plateau indices.

Plateaus		Residual Plateaus						
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean	
<input checked="" type="checkbox"/>		133	141	9	90.03519	0.00067	-25.02933	+
<input checked="" type="checkbox"/>		213	221	9	100.05091	0.00063	-0.02611	+
<input checked="" type="checkbox"/>		280	288	9	109.98793	0.00088	24.97122	+
<input checked="" type="checkbox"/>		347	355	9	117.88242	0.00085	44.96622	+
<input checked="" type="checkbox"/>		392	400	9	125.72858	0.00066	64.96233	+
<input checked="" type="checkbox"/>		460	468	9	127.68239	0.00079	69.96089	+
<input checked="" type="checkbox"/>		520	528	9	125.72982	0.00055	64.966	+
<input checked="" type="checkbox"/>		581	589	9	117.88246	0.00087	44.96733	+
<input checked="" type="checkbox"/>		648	656	9	109.98906	0.00065	24.97356	+
<input checked="" type="checkbox"/>		699	707	9	100.04661	0.0006	-0.037	+
<input checked="" type="checkbox"/>		1104	1112	9	90.03712	0.00071	-25.02433	+

Figure 5.26

- A button which will display a window where you can specify minimum and maximum values. These values serve as bounds which will exclude any outliers within the plateau range. RHS Plateau will then recalculate the plateau information and display with the newly defined outliers excluded.

Figure 5.27

## 10.5 SELECTING A MANUAL REFERENCE

As an alternative to selecting a reference data set, it is possible to manually input reference values for a given plateau (as shown in Figure 5.28).

**Note:** This section is not mandatory and may be skipped if a reference data set was already selected.

Where you would normally select a reference data set, instead of clicking the 'Select as Reference' button, select the 'Use Manual Reference' button. Then go through the normal steps up through the section 'Evaluating for Plateaus'.

Figure 5.28



When the UUT has been evaluated for plateaus and the Plateau table has been filled you will notice that there are now enabled input boxes where before they were disabled, with a default value of 0.0 (as shown in Figure 5.29).












Plateaus		Residual Plateaus						
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean	
<input checked="" type="checkbox"/>		87	95	9	-25.02111	0.00173	0	+
<input checked="" type="checkbox"/>		229	237	9	-0.03211	0.00185	0	+
<input checked="" type="checkbox"/>		280	288	9	24.97122	0.00235	0	+
<input checked="" type="checkbox"/>		347	355	9	44.96622	0.00235	0	+
<input checked="" type="checkbox"/>		392	400	9	64.96233	0.00149	0	+
<input checked="" type="checkbox"/>		442	450	9	69.96367	0.0017	0	+
<input checked="" type="checkbox"/>		520	528	9	64.966	0.00094	0	+
<input checked="" type="checkbox"/>		581	589	9	44.96733	0.00262	0	+
<input checked="" type="checkbox"/>		648	656	9	24.97356	0.00195	0	+
<input checked="" type="checkbox"/>		699	707	9	-0.037	0.00156	0	+
<input checked="" type="checkbox"/>		1104	1112	9	-25.02433	0.0017	0	+

Figure 5.29

Fill in a manual reference value for each of the plateaus that are going to be used to calibrate the data, shown in Figure 5.30. Once this is done move on as normal to the *Calculating Calibration Coefficients* section.












Plateaus		Residual Plateaus						
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean	
<input checked="" type="checkbox"/>		87	95	9	-25.02111	0.00173	-25	+
<input checked="" type="checkbox"/>		229	237	9	-0.03211	0.00185	0	+
<input checked="" type="checkbox"/>		280	288	9	24.97122	0.00235	24	+
<input checked="" type="checkbox"/>		347	355	9	44.96622	0.00235	44	+
<input checked="" type="checkbox"/>		392	400	9	64.96233	0.00149	64	+
<input checked="" type="checkbox"/>		442	450	9	69.96367	0.0017	69	+
<input checked="" type="checkbox"/>		520	528	9	64.966	0.00094	64	+
<input checked="" type="checkbox"/>		581	589	9	44.96733	0.00262	44	+
<input checked="" type="checkbox"/>		648	656	9	24.97356	0.00195	24	+
<input checked="" type="checkbox"/>		699	707	9	-0.037	0.00156	0	+
<input checked="" type="checkbox"/>		1104	1112	9	-25.02433	0.0017	-25	+

Figure 5.30

## 10.6 CALCULATING CALIBRATION COEFFICIENTS

Once the desired plateaus have been selected, and the manual reference values are filled in if applicable, the coefficients are ready to be calculated.

In order to calculate the coefficients, the equation type must first be selected, as shown in Figure 5.28. There are currently three options:

- **CVD:** Callendar-Van Dusen resistance-temperature equation

$$R = R_0(1 + A * t + B * t^2 + C * (t - 100) * t^3) \quad \blacktriangleleft \text{for temperatures below } 0^\circ\text{C}$$

$$R = R_0(1 + A * t + B * t^2) \quad \blacktriangleleft \text{for temperatures at and above } 0^\circ\text{C}$$

Where  $R$  is the thermometer resistance (in ohms) and  $t$  is the thermometer temperature (in  $^\circ\text{C}$ ).

- **ITS-90**
- **Polynomial:** User option of 1<sup>st</sup>, 2<sup>nd</sup>, or 3<sup>rd</sup> order polynomial

Once the equation type of calibration is selected, click **Calculate**.

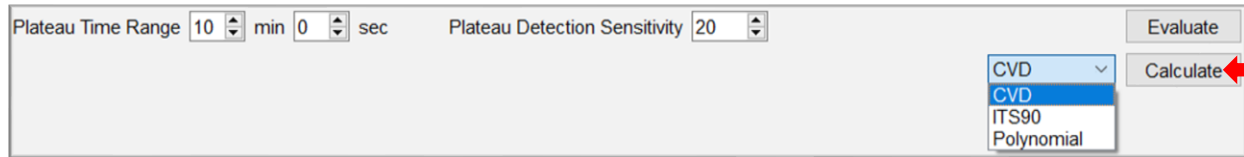


Figure 5.31

A number of labels and input boxes (depending on calibration type) appear, displaying the calibration coefficients (as shown in Figure 5.32).

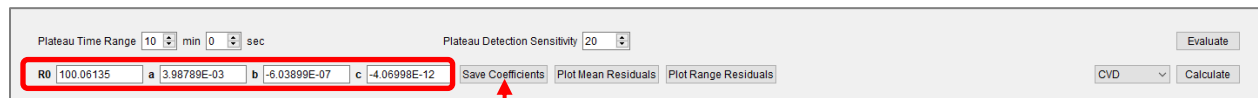


Figure 5.32

To save the newly calculated coefficients to a file on the host computer, click the **Save Coefficients** button.

A pop-up window opens (as shown in Figure 5.33). Enter a **Serial Number** and click **OK**.

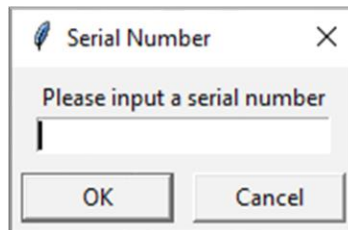


Figure 5.33

Once confirmed, a file browser opens (as shown in Figure 5.34). Choose an appropriate save location for the file.

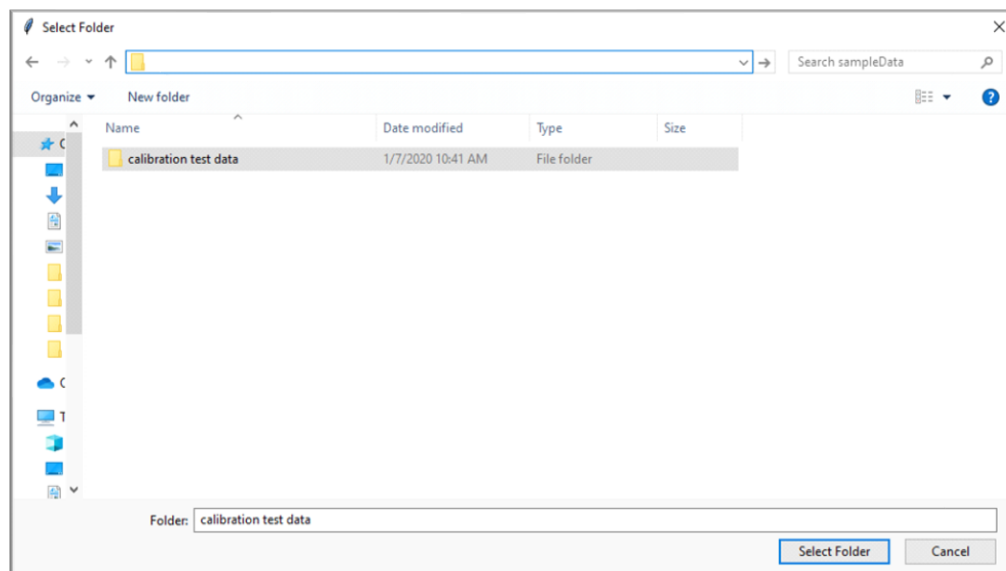


Figure 5.34

A pop-up window (Figure 5.35) will confirm the file was saved with the file name format:  
 'Reference Data Name'--'UUT Data Name'\_'Serial Number'\_'Year\_Month\_Day'.cal.

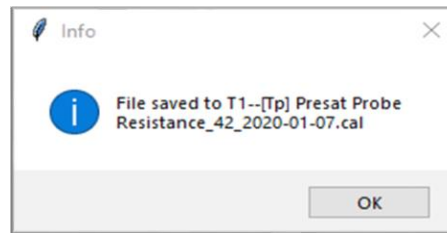


Figure 5.35

A sample of the coefficient file is shown in Figure 5.36.

```
CORTYPE=0
CVDR0=99.99869059297097
CVDA=0.0039138036002286745
CVDB=-6.109649252834681e-07
CVDC=1.6713321967280415e-10
```

Figure 5.36

## 10.7 PLOTTING RESIDUALS

Once the coefficients have been calculated, the UUT data may be evaluated using the new coefficients and the corresponding curve fit residuals determined. A few moments after the 'Plot Residuals' button is clicked a number of changes will occur on RHS Plateau.

A new plot will appear containing the UUT data with the coefficients applied, and the original reference data. Shown in Figure 5.37.

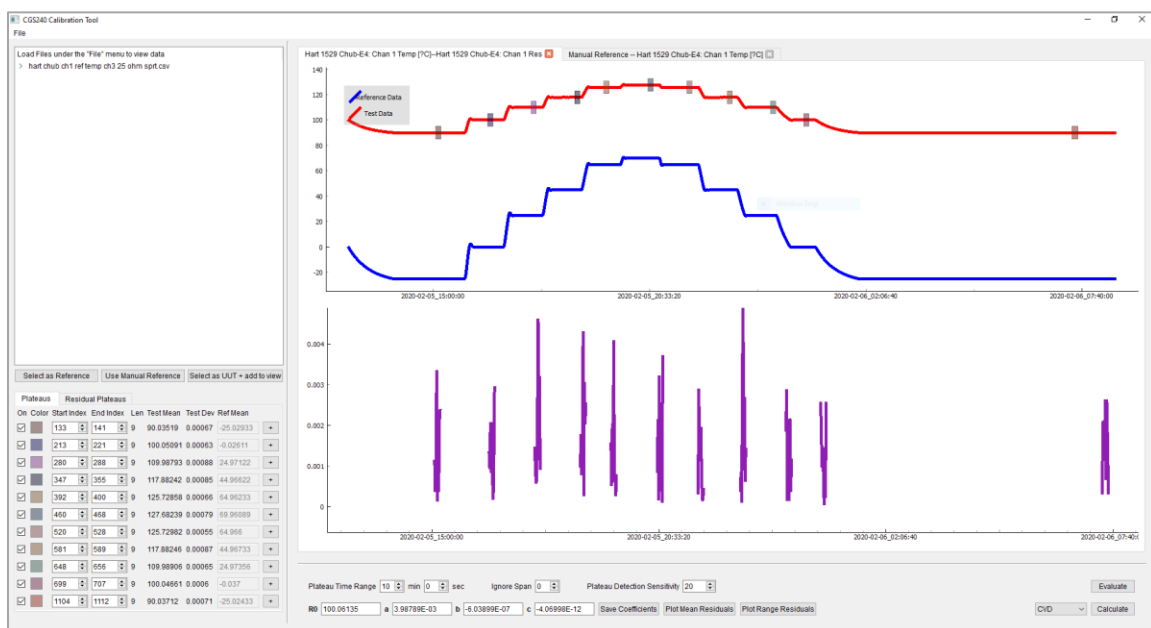


Figure 5.37

The 'Residual Plateaus' tab will also fill with new calculated data relative to the coefficient-applied UUT data, as shown in Figure 5.38. The new Test Mean should be very close to the Ref Mean, and the Test Dev/Error should be much smaller values than they are in the 'Plateaus' tab.

Plateaus		Residual Plateaus					
On	Color	Start Index	End Index	Len	Test Mean	Test Dev	Ref Mean
<input checked="" type="checkbox"/>		133	141	9	0.00131	0.00102	-25.02933
<input checked="" type="checkbox"/>		213	221	9	0.00136	0.00081	-0.02611
<input checked="" type="checkbox"/>		280	288	9	0.00184	0.00127	24.97122
<input checked="" type="checkbox"/>		347	355	9	0.00186	0.00121	44.96622
<input checked="" type="checkbox"/>		392	400	9	0.00128	0.00112	64.96233
<input checked="" type="checkbox"/>		460	468	9	0.00164	0.0012	69.96089
<input checked="" type="checkbox"/>		520	528	9	0.0011	0.0009	64.966
<input checked="" type="checkbox"/>		581	589	9	0.00168	0.0015	44.96733
<input checked="" type="checkbox"/>		648	656	9	0.00136	0.00094	24.97356
<input checked="" type="checkbox"/>		699	707	9	0.00125	0.00085	-0.037
<input checked="" type="checkbox"/>		1104	1112	9	0.00153	0.00086	-25.02433

Figure 5.38

If the coefficients do not correct the UUT values enough, either the plateaus or the coefficients themselves can be changed.

10.8 EXPORT DATA

Once the residual data has been plotted, now export the calculated coefficients and the data from each plateau to a single CSV file. To do so, click the **Export Data** button that has now been enabled under **File->Export Data**. RHS Plateau will ask for a serial number followed by a file dialog where a location and file name can be specified.

This file contains both the calculated coefficients as well as the data that was used in those calculations. This file is a useful resource for auditing purposes where validation of plateau’s curve fit capability is desired.

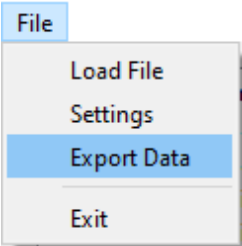


Figure 5.39

## 11 DOCUMENT HISTORY

### REVISION HISTORY

Version	Revision Date	Summary of Changes	Author
A	13 Feb 2020	Parts Lists/Drawing	Bre
B	11 Jun 2020	Operation Figures	Bre
C	25 Jun 2020	Parts Lists/Drawing	Bre
D	16 Nov 2020	Drawings/Pictures	Bob
E	17 Nov 2020	Figures/Drawings	Bre
F	10 Feb 2021	Image Updates / Template Changes	Erik
G	12 Apr 2021	Expanded content in Calibration chapter, Image Updates, Formatting Improvements	Erik
H	05 May 2021	Addition of Cal Mode to Calibration chapter, Relocation of Plateau section, Formatting changes to Illustrated Parts section	Erik