HumiLab

Relative Humidity Generator

Operator's Manual

GE Infrastructure
Sensing

imagination at work

Safety:

This manual as well as safety labels posted on the instrument use the following safety alerts to draw your attention to special safety instructions that should be followed.

CAUTION

CAUTION: Hazards or unsafe practices could result in electrical shock, minor injury, or product damage.

WARNING

WARNING: Refer to accompanying document for additional information.

ALERT

ALERT: Earth ground connection; removal could result in electrical shock, minor injury, or product malfunction.

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Introduction

About GE General Eastern

GE General Eastern is devoted to the design and manufacture of accurate, reliable and rugged humidity measuring equipment. We specialize in providing solutions for applications where humidity measurements are critical.

There are many ways to make humidity measurements, and no single humidity sensor meets all requirements for all applications. Our variety of sensor types — including chilled mirror, lithium chloride, capacitive oxide, capacitive-resistive, resistance polymer, and wet bulb — can precisely determine dew point, parts per million by volume, mixing ratio, absolute humidity, relative humidity, and other parameters.

In keeping with GE General Eastern's philosophy of providing the best solutions to humidity measurement problems, we offer the following products and services:

- high quality state-of-the-art instrumentation to assure excellent performance
- a broad range of humidity instruments capable of covering virtually any humidity measurement application
- full applications assistance to help you choose the sensor that is best for your needs
- worldwide superior service, should it ever be needed

If you have questions about a particular measurement problem, we invite you to call and discuss your application with one of our engineers. Call 800-33HUMID (800-334-8643). If you're calling from Massachusetts or outside the United States, call 978-203-1900. Our fax number is 978-203-1919.

GE General Eastern's website (www.generaleastern.com) has information about our other products as well as technical papers and applications notes on humidity measurements.

Overview of the Humilab

The Humilab Relative Humidity Generator is designed to perform U.S. National Institute of Standards and Technology (N.I.S.T.) traceable calibration of RH instruments and/or several smaller transmitters.

The Humilab design is based on the proven divided flow technology. Divided flow in the time domain excels as a reliable method for accurately controlling relative humidity at a fixed temperature. Temperature stability is ensured by a water jacket surrounding the calibration chamber.

Continuous digital control, using a built-in GE General Eastern N.I.S.T. traceable chilled mirror dew point hygrometer, makes the Humilab a traceable relative humidity transfer standard with which to calibrate other devices. Calibrations meeting the requirements of ANSI Z540-l-1994, MIL-STD 45662A, 10CFR-50, and ISO 9001 may be performed.

The included Prostep software allows you to use your PC to upload a control profile via the RS-232 port, enabling an entire calibration cycle to be run.

About this Owner's Manual

This manual provides the information you will need to set up, use, and maintain the Humilab Relative Humidity Generator. Please read and follow these instructions carefully to ensure that the instrument provides the precise and reliable humidity measurement and control that you have come to expect from GE General Eastern.

Icons

Four categories of information are presented with an accompanying icon for quick identification.

The exclamation mark within a triangle indicates that the accompanying information is important to the correct operation of the equipment. You should take particular care to observe this information because it ensures optimum operation and avoids potential damage to the unit.

The lightning bolt within a triangle indicates that the accompanying information is important to the safety of the operator. Failure to heed this information will place the operator in danger. This symbol must not be ignored.

The ground symbol indicates points that must be connected to earth ground. Failure to connect, or removal, could result in electrical shock, minor injury, or product malfunction.

The pointing hand icon is used to indicate information that is related or simply additional to the surrounding text. This information is not required for proper operation, nor will any harm arise from not applying this information.

Chapter 1 – Installation and Initial Setup

Introduction

This chapter explains site requirements for the Humilab system, what is shipped with the unit, how to install the Humilab, and how to set it up and perform the necessary procedures to ensure efficient and reliable operation to meet your calibration requirements.

Pre-Installation

Before you proceed to install your Humilab, ensure that you have chosen a site suitable for the effective and efficient operation of the instrument.

A location should be found for the Humilab where the ambient temperature is reasonably constant. This is usually the case in a calibration laboratory. Ideally, the room should be stable within ±1°C, between 20°C and 30°C. Ensure that the table or lab bench is level.

The water jacket surrounding the test chamber and the 1/2" thick Lexan cover above it effectively isolate the chamber from short-term temperature fluctuations. However, longer term changes in room ambient temperature may cause a temporary chamber error until the system equilibrates to the new ambient temperature. Therefore, temperature stability of the room is important.

CAUTION:
Two people are required for moving this system.

Components shipped with the Humilab

The following items are packaged with the Humilab:

- cover (removed for shipment)
- Certificate of Conformance

- maintenance kit
  (Additional kits are available through GEI's Service Department)
- mixing/workspace plate
- desiccant cartridges (2)
- rubber stopper
- AC power cord
- RS-232 cable
- mating analog output connector
- transportation case
- CD-ROM containing this manual, HCON Humidity Conversion software, and Prostep software

Optional equipment

- temperature bath/circulator (for maintaining a stable chamber temperature from 20°C to 30°C)

If an item is missing, contact GE General Eastern. Our phone number and address are found on page 1.

System diagram

Interconnection of the HumiLab's components is shown in Figure 1.

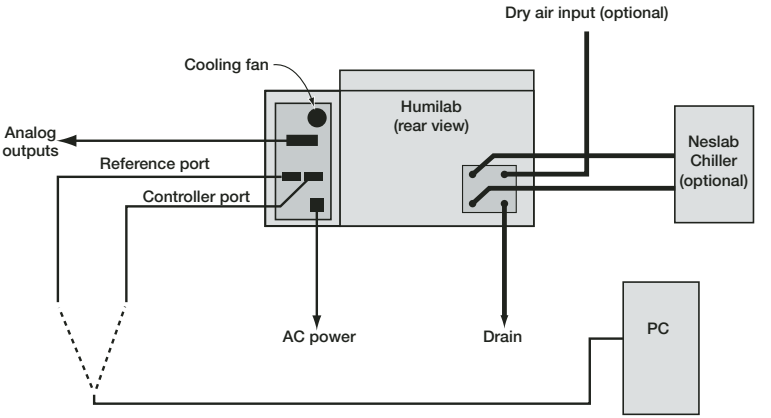


Figure 1 — System interconnection diagram

Installation

Place the Humilab at its operating site

Carefully move the Humilab to its intended site. Leave enough room behind the unit to make the necessary gas, drain, and optional chiller connections on the back panel. The two data cables (an RS-232 cable and an analog output cable) can also be installed at this point.

Connect a dry gas source (optional)

A dry gas source can be utilized to improve the longevity of the desiccant material and provide the user with less frequent desiccant replacement.

The HumiLab does not require an external dry gas source to operate. The unit is equipped with a desiccant cartridge that provides the Humilab with a –40°C dew point dry gas. The unit is designed to operate for approximately 24 hours of continuous usage (at an ambient humidity less than 50%) before having to replace the desiccant.

Gas requirements. If a dry gas source is used, the frost point should be –40°C or lower for operation over the full specified range. **Use**

clean, oil-free gas, regulated at 1 to 2 psig at 5 lpm (minimum). Connect the dry air or dry nitrogen source using the 1/4" "instant-on" **DRY AIR IN** connector on the rear of the unit. See Figure 2, Humilab Rear View.

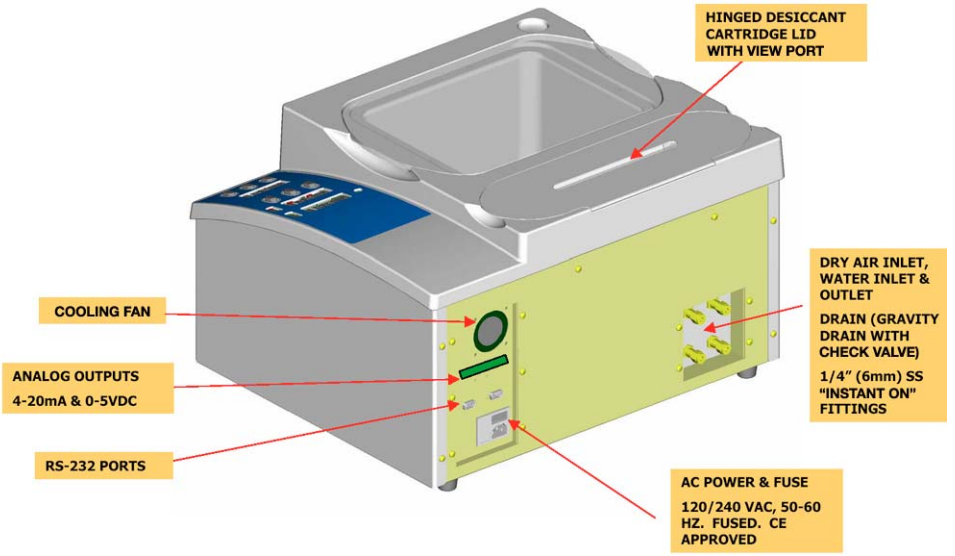


Figure 2 — Humilab rear view (gas, A/C, and signal connections)

Electrical connections

Electrical connections to the Humilab are made on the rear panel as shown in Figure 3.

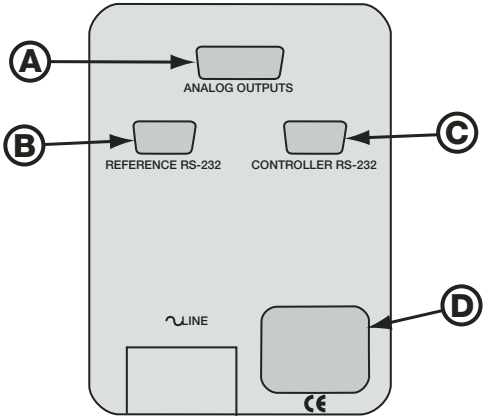


Figure 3 — Humilab electrical connections

A. Analog outputs. Analog outputs are available to the operator via the DB-15 connector located on the rear I/O panel. A cable suitable for connecting to a terminal block is included. The connector pinout is listed below.

DB-15 Pin No.	Function
1	RH 4–20 mA (+)
2	RH 0–5 V (+)
3	Temp 4–20 mA (+)
4	N/C
5	Temp 0–5V (+)
6	Status
7	N/C
8	N/C
9	Service
10	Gnd (Rtn)
11	N/C
12	N/C
13	N/C
14	N/C
15	N/C

B. RS-232 Reference Port. This connector is used for diagnostics when the **LOOP** switch is in the **OPEN LOOP** position. In **CLOSED LOOP** mode, it transmits the digital outputs of the hygrometer: dew point, temperature, and RH.

C. RS-232 Controller Port. This connector is used when downloading humidity profiles from Prostep into the HumiLab.(see Chapter 3).

D. AC receptacle. The AC input power is connected to the power receptacle. The input voltage is noted on the label to the right. The input voltage is configured at the factory and must be determined prior to shipment.

Power Requirements	103–127 VAC 48–66 Hz, 80 VA max	198–264 VAC 48–66 Hz, 80 VA max
Fuse Type	1A Type T	.5A Type T

E. Cooling fan (not visible). The fan is used for cooling the electronics. The fan must stay clean and clear of any obstruction to prevent damage to the internal electronics.

Rear input/output fitting connections

Mechanical connections to the Humilab are made on the rear panel as shown in Figure 4.

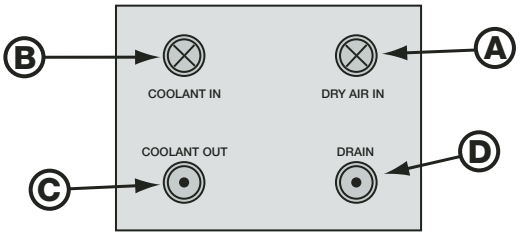


Figure 4 — Humilab mechanical connections

A. Dry air in. A dry air supply can be connected to this port. The dew point of the dry air must be at or below –40°C for proper full-range operation. The flow rate requirement is **1 to 2 psig at 5 liters per minute (minimum)**. If a dry air supply is not available, then this port must be left open to the atmosphere. The internal pump will draw the ambient air through the desiccant cartridge to supply the HumiLab with the proper supply of dry air.

B. Coolant In. For optimum performance, an optional temperature bath/circulator should be connected to provide a stable water and chamber temperature. Connect the chiller's output port to this Coolant In port.

C. Coolant Out. Connect the temperature bath/circulator's input port to the coolant-out port of the HumiLab.

D. Drain. This port allows the operator to easily drain the saturator before transporting or storing the unit. Simply place a 1/4" tube into a bucket and press the other end into the drain fitting until it stops. Water will immediately begin to drain into the bucket. To remove the tube from the fitting, depress the black outer ring and pull out the tubing. A built-in check valve prevents water from running out of the drain port when the tubing is not in place.

Coolant connections

The HumiLab is equipped with 1/4" "instant on" coolant fittings that require no tools for installation. These fittings will accept many types of hard-wall tubing such as Teflon, stainless steel, or Impolene. To insert the tubing, simply press the tubing into the connector as far as it will go. Pull gently on the tubing to ensure the connections are secure.

To remove the tubing from the "Instant On" fittings, simply depress the black outer ring and pull the tubing out. The coolant fittings are equipped with built-in check valves that enable the operator to easily remove the coolant lines with minimal fluid loss.

If the optional chiller is used to accurately control the chamber temperature, connect the chiller output to the "Coolant In" fitting on the HumiLab and connect the chiller inlet to the "Coolant Out" fitting.

Initial setup and water fill

Distilled water is recommended for trouble-free operation. Always add water with the power turned off (the water level may pulse up and down during normal operation). After the water chamber has been filled (or refilled), allow sufficient time (typically one hour) to equilibrate the water temperature.

1. Set up the unit on a flat surface.
2. Pour in one gallon of clean distilled water.
3. Install the drain line in the rear drain port, and drain out enough water (about one cup) to ensure that the drain line is full of water. This procedure is needed for proper water level indication.
4. Remove the drain line and pour in an additional 1¼ gallons of distilled water. Wipe up any spillage.
5. Install the dry line, connecting to a source of dry air, if available (–40°C DP dry air or nitrogen, 15–16 psig, 4–5 l/m flow). If running from a desiccant cartridge, make sure the cartridge is fully seated and the desiccant color is a minimum of 75% blue throughout the length of the tube. Replace the cartridge or desiccant if necessary.
6. Install the unit's cover.
7. Install the power cord and turn the unit on. Set the controller to 80–90% RH.
8. Check the water fill level indicator and make sure the level has not increased above the fill line and that the overflow line does not leak water (front left-hand corner of unit). If the water fill level rises sharply or the overflow tube leaks, check the wet gas tube inlet ports for obstructions.
9. Run the unit for 15–30 minutes and inspect for the absence of water in the bottom of the wet line ports located at the bottom of the tank I/O block (near 1111H sensor). If water is present, soak it up with a cotton swab or absorbent cloth, napkin or towel.
10. Perform mirror cleaning and balance procedure as described in *"Mirror maintenance"* on page 36.

Chilled mirror setup

The GE General Eastern HumiLab is shipped with the chilled mirror sensor (1111H-SR) and temperature probe (T-100) already installed.

Initialize the dew point sensor

Although it was initialized at the factory, the dew point sensor bridge should be initialized again to compensate for any change during shipment. This is accomplished by cleaning and balancing the sensor as described below. Figure 7, shows the location of the switches and LEDs on the front panel. Chapter 2 contains a complete description of the operating procedures.

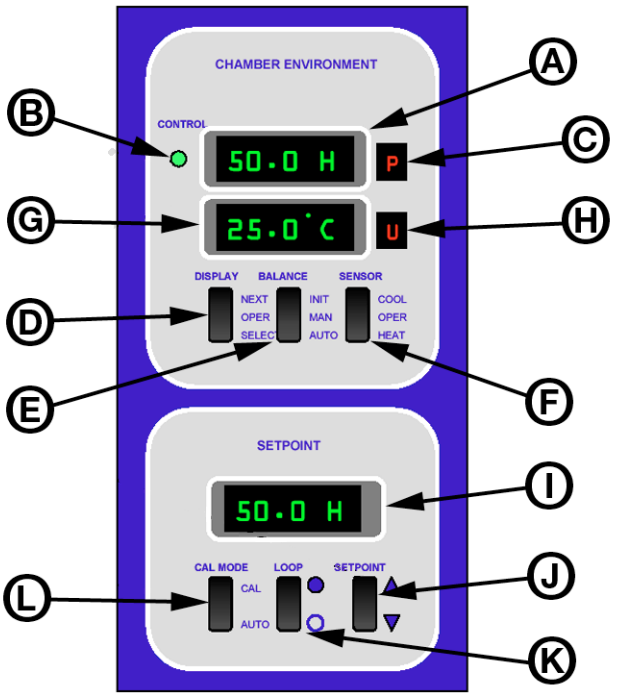


Figure 5 — Front Panel Controls

1. Plug the A/C power cord into a wall socket.

2. Turn **ON** the power switch located on the back right side of the Humilab near the bottom.

   The digital LED displays will light, and the generator will go through a self check cycle. The letter "P" (for Pacer®) will be lit on the front panel (**C** in Figure 5). (See Appendix B, page 45 for information on the Pacer feature.)
3. Wait for the Pacer cycle to complete (approximately three minutes).
4. On the front panel, set the **LOOP** switch (**K**) to the **CLOSED LOOP** position. (Depress the top of the rocker switch, toward the filled circle.)

Clean and balance the dew point sensor

The next steps are required to clean and rebalance the dew point sensor. This normalizes the system, and prepares it for proper operation.

1. Press the **SENSOR** switch (**F**) to the **HEAT** position.
2. Open the test chamber cover and remove the white dust cover.
3. Locate the sensor cleaning solution (in the GE General Eastern Maintenance Kit). Wet a cotton swab with the blue cleaning solution, and rub it lightly over the mirror. Lightly buff the mirror dry with a clean, dry swab. Note: If you don't have the supplied cleaning solution, a solution of two parts rubbing alcohol to one part distilled water may be substituted.
4. Replace the sensor cover. Be sure that the cover is installed so that the sensor balance screw aligns with the hole in the cover.

   Do not attempt to operate the sensor without the cover. It is an optical device and will be offset by overhead light.
5. A vertical LED light bar indicates balance status. Either 3, 2, 1, or zero horizontal bars will be lit. Locate the Balance, or Bias, adjustment screw at the top of the sensor. See Figure 6. Using the small screwdriver supplied in the maintenance kit, slowly rotate the screw until only the bottom bar is illuminated. (The

number of bars is increased when you turn the screw counterclockwise.) The optical bridge has now been balanced.

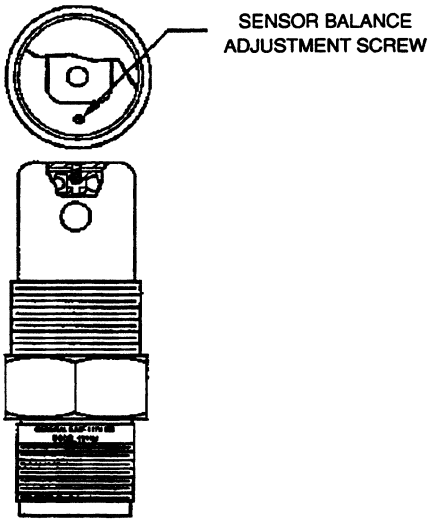


Figure 6 — 1111H Sensor Balance Adjustment Screw Location

6. Place the **HEAT** switch back in the **OPERATE** position.
7. Run the instrument through another Pacer cycle. (Momentarily press the **INIT**iate switch.)

   The letter "**P**" will light, and the displays will be frozen for several minutes as the cycle proceeds. At the end of that time, the "**P**" will go out, and the left-hand displays will read the actual percent R.H. and temperature in the test chamber.
8. Use the **SETPOINT** switch to select 30% RH by pressing on the upper or lower side of the switch as required.

   The display will scroll, one decade at a time, to the desired reading. Release the switch when that point is reached.
9. Run the chamber for at least one hour, until the water surrounding the chamber assumes ambient laboratory temperature and the temperature equilibrates to ±0.2°C or better.
10. Use the **SETPOINT** switch to select 00.0 %RH and allow 30 to 45 minutes for the chamber to dry down.

Shipping the Humilab

This procedure describes the process the customer should follow before shipping the HumiLab to an off site location or shipping the unit back to GE General Eastern.

1. Remove A/C power from the unit and disconnect the dry gas supply.
2. Connect a 1/4" O.D. drain line to the drain port located in the rear of the unit. For customer convenience, an impolene drain line is provided. Otherwise any 1/4" hard wall tubing will do.
3. Visually interrogate the unit through the fill port to determine if all the water has been removed. If water is still visible, then the unit may have to be tilted towards the back and to the left with the drain tube still attached.
4. The temperature bath/circulator lines need to be drained prior to shipment. Insert the drain tube provided into the **COOLANT OUT** port connector. Insert a short 1/4" tube into the **COOLANT IN** port connector. This will allow the coolant to be removed from the temperature coil. This will prevent the temperature coil from freezing during transport and possibly causing damage to the unit. A slightly pressurized air line could be used to help facilitate the draining process.
5. Place the mix tray inside of the chamber and fill the chamber with bubble-pak to prevent any sensor damage and keep the tray from moving during shipment. Place the cover on top. Place the rubber stopper (supplied) into the fill port located at the top front left corner.
6. Place the HumiLab into the transportation case (supplied). The unit is now ready to be transported.

Chapter 2 – Operation

Introduction

The Humilab is very simple to operate. Minimal operator training is required for successful calibration of humidity recorders, transmitters, or hand-held portables. Typically, only the R.H. setpoint selector switch is used in a calibration. All other switches are set as desired and then left in position.

Front panel switch settings are described in this chapter. More detail is available in Appendix B. For quick reference, the following settings are typical for most applications:

- **Power Switch:** ON (mounted on rear of unit)
- **Sensor Switch:** OPERate
- **Display Switch:** OPERate
- **Loop Switch:** Closed Loop (Set to the filled-in circle) for operation; Open Loop (open circle) for uploading profiles
- **Balance Switch:** Center position
- **Auto/Cal Switch:** OPERate
- **Setpoint:** Set to desired chamber humidity

Front panel displays and switches

Refer to Figure 7 as you review the following descriptions of the front panel displays and selector switches.

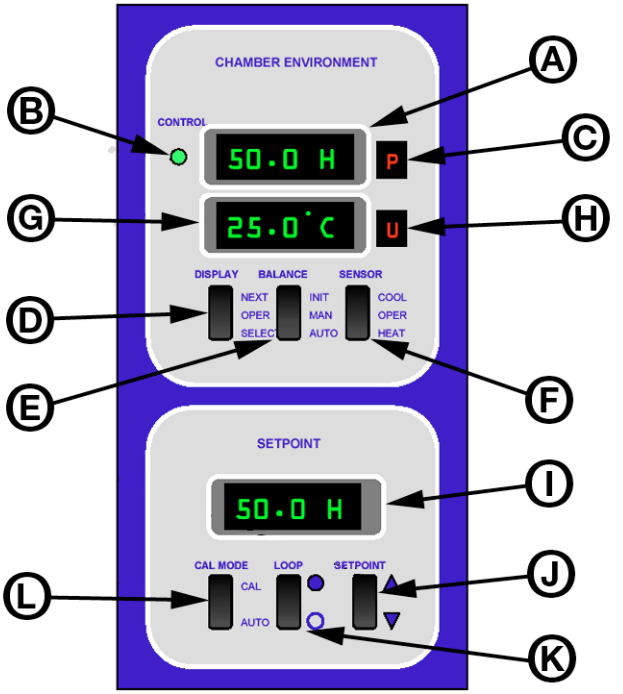


Figure 7 — Front Panel Controls

The Humilab, as shipped, is set up by the factory for normal operation. The two upper digital displays read Percent RH and Temperature in °C. The lower digital display shows the desired chamber set point.With the exception of the setpoint selector switch, the other front panel switches are seldom used in day-to-day operation. However, they are included in case you wish to make changes to normal default operation and for system testing.

Appendix B contains information on changing factory-set defaults.

A. HUMIDITY Display. This display is shipped from the factory set for percent relative humidity. Please refer to Appendix B for more information.

If you wish to perform dew point calibrations in the test chamber, the display may be reprogrammed to read dew point.

B. CONTROL STATUS Indicator. The green control indicator advises you that the control loop that maintains the dew layer on the chilled mirror is operating correctly, and that there is a proper layer. When lit, you may consider it to be an indication that the chilled mirror humidity measurement is valid. Conversely, if the green indicator is not lit, you should wait until it lights before performing calibrations.

C. STATUS Window (humidity). A green letter "**S**" (for Service) in this window advises the operator that the sensor mirror has become contaminated, and requires cleaning.

If you are readjusting the sensor optical balance, a light bar appears in this window. See *"Balancing the sensor optics"* on page 37 for details.

This window will show various indications while reprogramming the display units or analog outputs. See Appendix B.

D. DISPLAY Switch. The **DISPLAY** Switch is normally used in the center **OPER**ate position.

This rocker switch is used to reprogram measurement units and to check the scale factor of analog outputs.

In the standard configuration, the analog output scale factors can only be changed using the RS-232 port, to ensure that they are not changed accidentally. If you wish to reconfigure the system so that these parameters **can** be changed via the front panel, see Appendix B.

E. BALANCE Switch. This switch is normally operated in the lower **AUTO**matic position.

In the **AUTO** position, the instrument will go through a normal Pacer® cycle every 12 hours, rebalancing the dew point sensor bridge and determining whether it requires cleaning.

In the **MAN**ual center position, there will be no automatic Pacer cycles, only those initiated manually (if desired).

*In the manual position, you will never see the "**S**"ervice light displayed, telling you that the sensor mirror needs cleaning.*

The upper (**INIT**iate) momentary position manually triggers a Pacer cycle.

F. SENSOR Switch. The **SENSOR** switch is typically kept in the center **OPER**ate position.

This switch allows you to over-ride the automatic mirror control loop, and force the mirror temperature up or down, causing it to heat or cool. These are test positions used for sensor diagnostics.

G. TEMPERATURE Display. As shipped from the factory, this display reads temperature in °C. It may be factory or field programmed to read °F if desired. See Appendix B.

H. STATUS WINDOW (Temperature). This window provides the operator with programming status for the Temperature display when programming Units or Outputs. See Appendix B.

I. SETPOINT Display. This display window shows the relative humidity setpoint that has been programmed in the chamber.

J. SET (SETPOINT) Switch. This switch allows you to select a humidity setpoint in the display window. Scroll to the desired value by incrementing or decrementing, one decade at a time, until the desired value is reached.

K. LOOP SELECT Switch. This selector is normally kept in the Closed Loop position (up, toward the filled-in circle).

In the Closed Loop position the chilled mirror hygrometer controls the chamber relative humidity. In the Open Loop position, you can download humidity profiles from the Prostep software program, and you can perform diagnostics if necessary (see Chapter 3).

L. CAL/AUTO Switch. This switch is typically kept in the center position.

When this switch is pressed into the momentary **CAL**ibrate setting, the system begins the automatic 9-hour recalibration cycle.

If you ever accidentally switch the Humilab to the "CAL" mode, simply shut the power OFF and then ON using the power switch (on the rear panel) to reset to normal operation.

Performing routine calibrations

The unit has been calibrated at the factory. Field calibration is only required if the measured humidity deviates from the setpoint humidity by more than 1% RH after one hour.

With the selector switches preset to the proper positions for normal operation, calibration may be performed as follows:

1. Insert the item(s) to be calibrated into the Humilab humidity chamber. Run power cables via the top cover to the transmitter.
2. Select the proper RH Setpoint.

   When this switch is held up (for higher humidity) or down (for lower humidity), the digital set point display will scroll toward the desired set point. First the least significant decade will change, and then successively more significant decades will change. Release the switch when the desired humidity is reached. It may be easier to stop a few counts before the desired reading, and allow the least significant unit display to move in 0.1% R.H. steps to the set point.
3. Allow 40 to 60 minutes equilibration time.

   The R.H. in the Humilab cavity will gradually move toward the set point. For the first 20–30 minutes, there will be no closed-loop feedback. After the loop is controlled, a correction will be made every 5 minutes.
4. Calibrate as required.

Relative humidity is a function of temperature as well as moisture content. If you are calibrating a device (such as a humidity transmitter) that generates heat, locate it near the center of the cavity. This will allow the HumiLab's temperature sensor to quickly sense the temperature change and correct for it.

Chamber response time

Due to the large cavity size, typical response time will be approximately 30–40 minutes. At the end of that period, the RH in the test chamber will be within 1% RH of the set point. After that time, the two will track each other within the accuracy specification of the instrument.

Chapter 3 — Using the PROSTEP software

Introduction

This chapter describes the use of GE General Eastern's Prostep software to set up a calibration test profile.

Prostep software generates humidity/temperature profiles to control the Humilab. It is supplied with the Humilab system on a CD-ROM. Using Prostep, a complete automatic test profile (relative humidity vs. time, with ramps and step changes) may be created using an IBM-compatible computer. The profile may then be used for automatic calibration of the devices in the Humilab cavity. See Figure 8 for a sample humidity profile.

In addition to creating humidity profiles for use in the Humilab, the PROSTEP software can be configured to generate temperature control commands/profiles to the recirculating water bath chiller, remotely operate the Humilab, customize the Humilab calibration sequence, and collect humidity and temperature data from the reference hygrometer. This section will detail the creation, uploading, and operation of humidity profiles and datalogging features only. Consult the factory for more advanced operational detail.

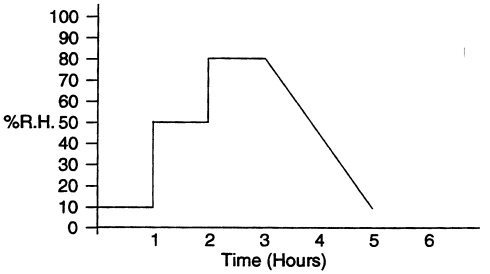


Figure 8 — Sample Humidity Profile

Computer requirements

Prostep requires a computer system with the following characteristics:

- IBM-compatible 286 or higher machine
- RS-232 serial port
- at least 512K of RAM
- at least 1Mb of hard disk space

A DB-9 male to DB-9 female cable is supplied, along with a standard RS-232 cable and null modem adapter.

If your computer has only USB ports in place of serial comm ports, you will need to use a USB-to-serial converter, available from computer supply houses.

Computer communication port settings

Set your IBM compatible computer's serial communications port settings as follows. (In Windows, go to Settings, control panel, system, device manager, ports, communications port, port settings)

Bits per second: 1200

Data Bits: 8

Parity: None

Stop Bits: 1

Flow Control: None

Connecting the host computer

Controlling Humilab. For communication to the Humilab controller (uploading/downloading humidity profiles), connect the host computer COM port connector to the 9-pin RS-232 **CONTROLLER** connector on the rear of the Humilab.

Datalogging. For datalogging with PROSTEP, connect the host computer COM port connector to the 9-pin RS-232 **REFERENCE** connector on the rear of the Humilab. The Humilab must be in closed loop operation.

Installing the Prostep software

Load the supplied CD-ROM and open the folder containing the software. Double click on SETUP.EXE and follow the on-screen directions.

Running Prostep

To start the program, click on start, Programs, Prostep, and Prostep.

Screens shown in this manual represent the appearance of Prostep running under Windows XP, and will differ with other operating systems.

Note: The HumiLab's **LOOP** switch must be in the **OPEN LOOP** position (open circle) when uploading Prostep humidity profiles. It must be in the **CLOSED LOOP** position (filled-in circle) to run a profile in normal operation.

PROSTEP communication settings

Prior to communication with the Humilab, verify the communication settings in PROSTEP. Under Options > Communications Setup, verify the following:

Baud rate: 1200

Flow Control: Off

Stop Bits: 1

Data Bits: 8

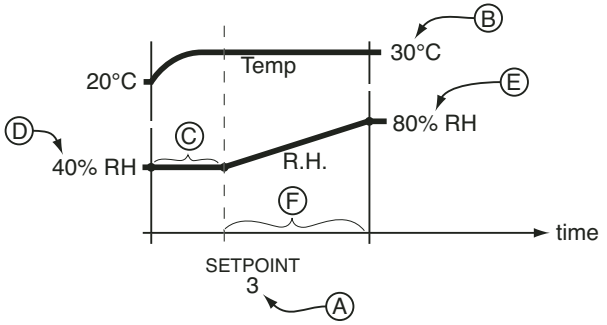
Com Port: 1–4 (matched to host computer)

Parity: none

The profile screen

The main profile screen is used for entering and modifying the Humilab's humidity profile. A profile must be *uploaded* to the Humilab before it can be used, and can be *downloaded* back into the PC for further editing. Use the File menu to manage the loading and storing of multiple profiles. To customize the profile display, see the Options / Scale Graph menu below.

The profile is specified by a number of setpoints. Each setpoint specifies a bath temperature (if configured) and a programmable humidity ramp as shown in Figure *9*. Six items may be specified for each setpoint:



A setpoint sequence number

B bath temperature

C an optional delay before the humidity change is initiated (to allow for temperature stabilization)

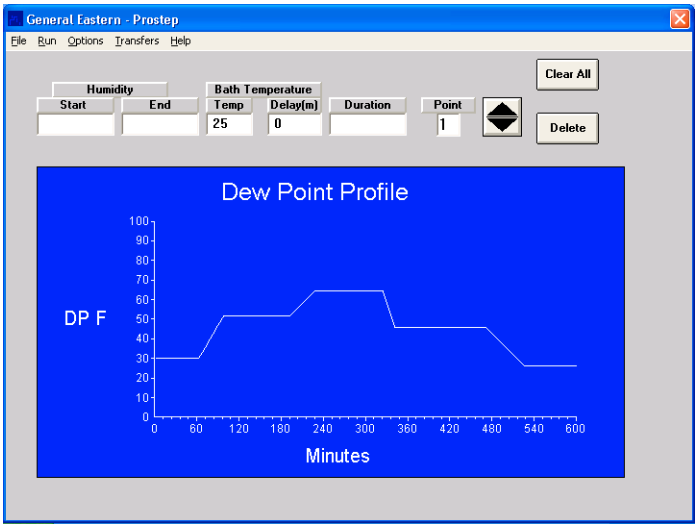
D initial humidity

E final humidity

F duration of the humidity ramp

Figure 9 — A typical setpoint and its values

Click on the large up and down arrows on the screen to step through the list of setpoints, and enter the data for each setpoint.



The File menu

The File menu accesses standard Windows functions for:

- creating a new profile
- loading a existing profile

- saving the current profile
- saving the current profile under a new name or file format
- selecting a folder for holding the profile data or datalog file
- exiting the program

The Run menu

The Run menu contains the following choices:

Run Profile. Runs the profile most recently downloaded to the Humilab.

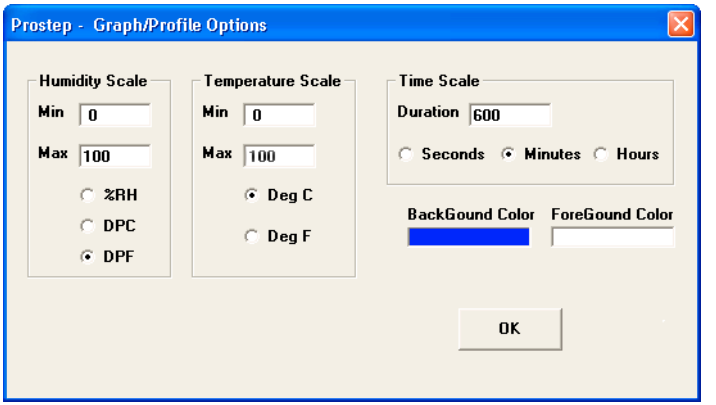
Collect data. Collect RH, temperature, and/or DP data for Humi-Lab operation. (See options > Setup Datalogging Parameters).

Halt Test. Stops running the current profile.

The Options menu

The Options menu accesses all of the setup and configuration items:

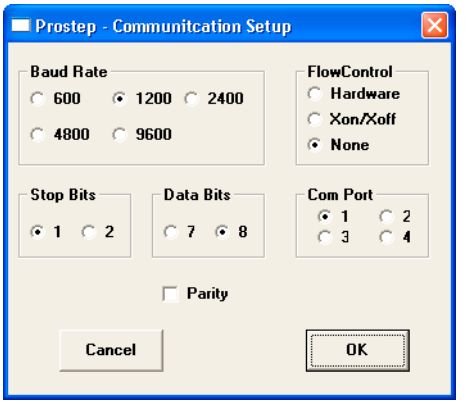
Scale Graph. Sets the parameters for the main screen profile display:



- units and maximum/minimum values for humidity and temperature (units set to %RH for typical Humilab profile)
- time scale

- graph colors.

Set up Communications. Sets the comm port parameters:

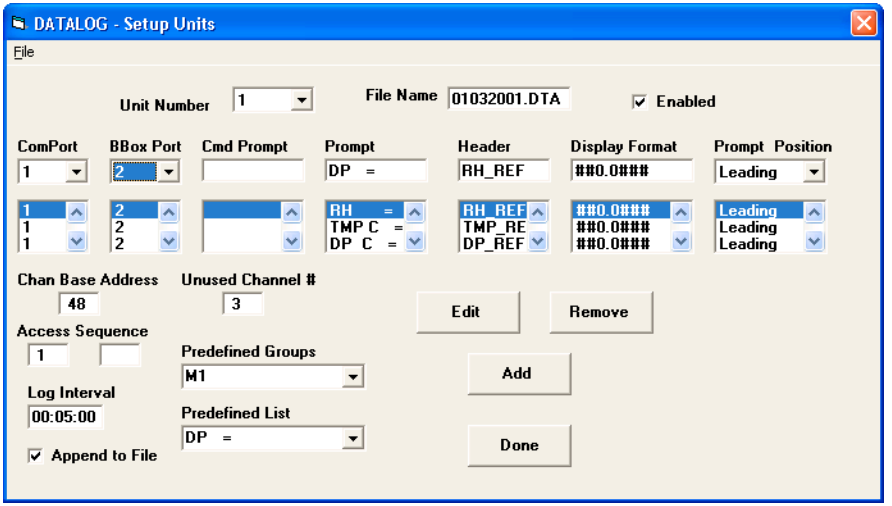


- baud rate: 1200
- flow control: None
- stop bits: 1
- data bits: 8
- parity: not checked
- comm port number: 1

Set up Data Logging Parameters. Sets units and formats for logged data.

Before using this screen, make the following settings:

- set Predefined Groups to **M4**
- set BBox Port to **–1**



A list displays all parameters to be logged, showing all configured data for each. To change one, select the line with the mouse. Data from that line will appear in the edit line, above. Make changes and click on Edit to store the changes. Click on Remove to delete the selected line. To add a new line, enter the data and click on Add.

When finished, click on Done.

- Unit Number: If more than one unit is connected, each can be selected for configuration
- Enabled check box: must be checked to allow datalogging
- the Comm Port that the Humilab or BlackBox is connected to
- Channel base Address: default = 48
- Unused Channel Number: the number of the first Black Box channel that is not in use
- Log Interval: the time between logged items (hh:mm:ss)
- Append to File check box: adds new data to end of existing file if checked

The Transfers menu

The Transfers menu allows moving a profile between the computer and the Humilab.

Upload Profile. Send the current profile from the PC to the Humilab.

Download Profile. Transfer a profile from the Humilab to the PC

The Help menu

The Help menu supplies on-line instructions for using the Prostep software.

Chapter 4 — Theory of Operation

Overview

The Humilab Relative Humidity Generator uses a divided flow method to accurately generate a selected relative humidity in a large test chamber. The selected humidity is controlled using a GE General Eastern Chilled Mirror Hygrometer System. This chapter describes divided flow and the chilled mirror controller.

Divided flow

The Humilab's chamber RH is controlled by time proportioning a fraction of an air stream through a saturator and a desiccant. The saturated air mixes with the dry air to produce the desired RH value in the chamber. Figure 10 shows the basic block diagram of the Humilab's operation.

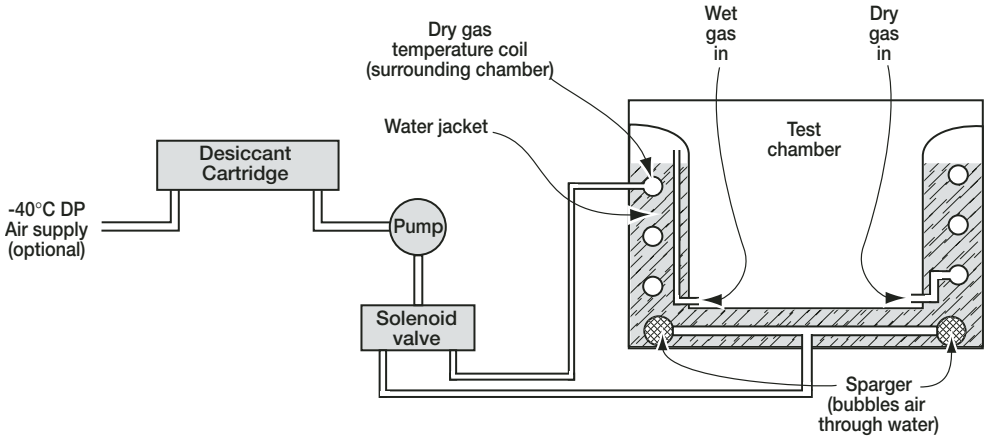


Figure 10 — Basic Block Diagram

The operator selects the desired relative humidity on the front panel, using the increment/decrement switch to scroll to the value. The selected RH determines the duty cycle of a solenoid operated wet air/dry air valve.

The time required for one complete cycle of operation is 1 second. During that period, the on-off duty cycle determines the ratio of wet air to dry air, which, in turn, determines the percent relative humidity in the test chamber. When the valve is ON, wet air is generated and flows into the chamber. When the valve is OFF, dry air flows into the chamber. Figure 11 shows how the wet/dry air ratio is proportional to the relative humidity.

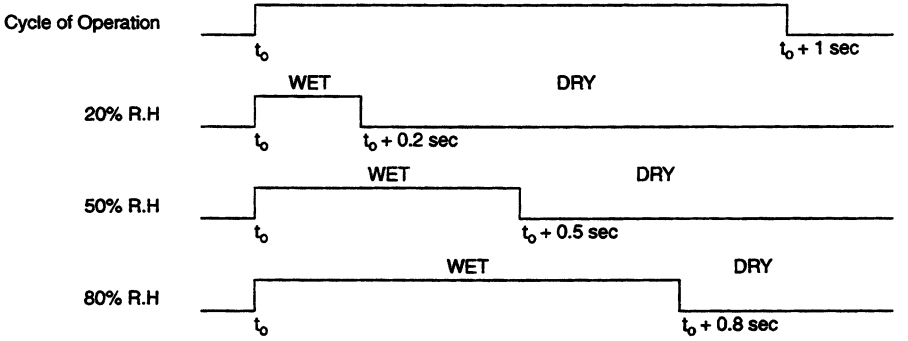


Figure 11 — Wet/Dry Air Selection

During the wet air portion of the cycle, the air is thoroughly saturated by an efficient diffuser. It then passes into the test chamber. During the remainder of the cycle, the dry air enters the chamber, after having first been completely temperature stabilized so that it is virtually the same temperature as the water in the jacket surrounding the chamber. This stabilization ensures that there is very little temperature gradient between the incoming air and the chamber itself.

The Humilab chilled mirror controller

A GE General Eastern chilled mirror dew point hygrometer is built into the Humilab, providing continuous closed loop feedback to control the relative humidity of the test chamber. This device provides a fundamental, N.I.S.T. traceable measurement of the chamber dew point. See Appendix B for more detailed information on the operation of the chilled mirror hygrometer.

Mounted inside the test chamber is a chilled mirror dew point sensor, bringing chamber dew point information to the hygrometer.

Also mounted within the test chamber is a platinum RTD air temperature sensor, providing air temperature information (dry bulb) to the chilled mirror hygrometer. A microprocessor calculation converts the chamber dew point and air temperature data to percent relative humidity.

A microprocessor-based relative humidity controller receives the RH information. It also looks at the RH setpoint which has been selected on the front panel by the operator. If there is a difference between the two readings, the controller adjusts the ratio of wet to dry air entering the test chamber, at 5-minute intervals. This closed loop operation ensures that the resulting relative humidity in the chamber remains within ±0.2% R.H. of the chilled mirror hygrometer reading.

A multi-point calibration of the test chamber against the built in chilled mirror has been performed at the factory, at 10% R.H. increments. At each point, a correction factor, determined by the actual dew point and temperature measurement, has been stored in non-volatile memory. Thus, the test chamber has acquired the accuracy and N.I.S.T. traceability of the fundamental chilled mirror hygrometer. If desired, this automatic calibration of the test chamber against the chilled mirror hygrometer may be repeated at any time in the field.

What is optical condensation hygrometry?

Optical condensation hygrometry is a precise technique for determining the water vapor content in gases by measuring dew or frost temperatures. Because these hygrometers are so accurate, they are widely used as a standard in many of the world's metrology laboratories.

Optical condensation hygrometry works on the chilled-mirror principle and provides a fundamental measurement of dew/frost point temperature. A metallic mirror surface is cooled until it reaches a temperature at which condensation begins to form on it. The dew layer is optically detected and the mirror is held at that temperature. The mirror temperature, measured with a platinum resistance thermometer, is an accurate indicator of the dew or frost point.

General description of the chilled mirror hygrometer system

The Humilab includes a general purpose chilled mirror dew point system that utilizes advanced microprocessor control. It is supplied with GE General Eastern's patented PACER® (Programmable Automatic Contaminant Error Reduction). See Appendix B, page 62, for information on the Pacer feature. The Chilled Mirror Hygrometer System also provides 4-20mA and 0-5 VDC analog outputs and RS232C communications. For detailed Chilled Mirror Hygrometer System Specifications, refer to Appendix A.

The Humilab Chilled Mirror System measures humidity in dew/frost point or relative humidity (RH). It also measures temperature in °C or °F. It accepts inputs from the Model 1111H chilled mirror dew point sensor and the Model T-100E temperature sensor. These are located within the test chamber.

Chilled mirror hygrometer system theory of operation

The Humilab Chilled Mirror System operation is illustrated in Figure 12 on page 34, which shows the way in which the chilled mirror hygrometer detects and measures dew point. The condensate detection mirror is illuminated with a high intensity, solid state, light emitting diode (LED). A photodetector monitors the LED light reflected from the mirror. A separate LED and photodetector combination are used to compensate for any thermally induced changes in the optical components.

For detailed information on the chilled mirror hygrometer, refer to Appendix B.

The photodetectors are arranged in an electrical bridge circuit, and the photo-detector is fully illuminated when the mirror is clear of dew. As dew forms on the mirror, the photodetector receives less light due to scattering losses. Since the bridge output current is proportional to the light received, a large bridge current develops whenever the mirror is dry. The bridge output is amplified and used to control the direct current to the thermoelectric cooler, causing the mirror to cool toward the dew point.

As dew begins to form on the mirror, the optical bridge output is reduced due to a reduction in detected light. This in turn, causes a decrease in cooling current. A rate feedback loop within the amplifier ensures critical response, and the system quickly stabilizes at a condition where a thin dew or frost layer is maintained on the mirror surface (i.e., the dew or frost point). Thus, the mirror temper-

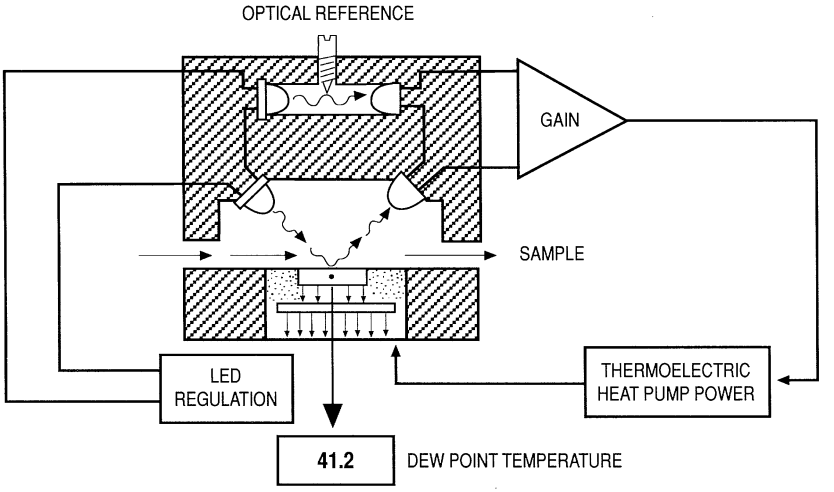


Figure 12 — Chilled Mirror Sensor Block Diagram

ature is always at the dew point of the gas being measured, and it follows the dew point if it changes. A precision thermometer element embedded within the mirror directly monitors this dew point temperature and provides a continuous readout to the user.

Chapter 5 — Maintenance and Troubleshooting

Introduction

There are two levels of maintenance on the Humilab: basic system maintenance and reference measurement maintenance.

Basic maintenance

The following should be checked (every few hours, until the requirements for your particular application determine a different schedule):

- check the water level surrounding the calibration chamber
- check the desiccant condition and replace if it has turned pink

Verifying water level. Water should be added to maintain the level in the green area of the water level indicator. Be sure to use only distilled water, and be careful not to accidentally spill water in the test chamber. If you do spill any water, wipe it up completely.

The water level may pulse up and down while the Humilab system is operating.

Verifying desiccant condition. Prior to each use of the HumiLab, verify that the desiccant cartridge contains active desiccant material. The desiccant contains an indicating material which turns from blue to pink as the desiccant is exhausted. Replace or regenerate the desiccant granules before the cartridge is completely exhausted.

To regenerate the desiccant, the granules may be spread in layers one granule deep and heated for 1 hour at 210° C or 425° F. The regenerated material should be placed in the original glass or metal container and sealed while hot. **Do not overheat the desiccant.**

Replacement desiccant can be obtained from GE General Eastern.

Reference measurement maintenance

The following should be performed as required to maintain the accuracy needed for your particular application:

- periodic mirror cleaning
- balancing the sensor optics

Details for these procedures are given below.

Problems not resolved by these procedures require the attention of a person with more in-depth knowledge. The chilled mirror hygrometer sensor (Model 1111H) generally requires the most attention because it is the most intricate component of the Humilab. Information addressing these problems is contained in Appendix B.

Mirror maintenance

Some Humilab owners routinely perform a mirror cleaning before each calibration run for best possible system operation. While this is truly optimum, it is theoretically possible (and generally most practical) to operate until the system tells you that the mirror needs cleaning by lighting the letter **"S"** (for Service) in the Status window.

In normal operation, the green "**CONTROL STATUS**" indicator on the left hand side of the front panel will be lit. The Control Status light tells you that everything is normal with regard to the control loop that determines the mirror dew layer.

If the Service indicator adjacent to it does light, momentarily activate the Pacer® switch. A letter "**P**" will appear in a window on the front panel. If the Service light goes out after several minutes (at the end of the Pacer cycle), continue normal operation. If the Service light remains on after the end of the Pacer cycle, it is an indication that the sensor mirror requires cleaning. A fine layer of dust or other contaminant has gradually built up on the surface, and it must be removed.

Cleaning the sensor mirror

Periodically inspect and maintain the chilled mirror hygrometer sensor (1111H) optics as described in the following paragraphs. These procedures can be done at any time but are only necessary

when an **"S"** appears on the status display, indicating that service is required.

Under normal conditions, the chilled mirror hygrometer is self-checking and self-balancing. However, there are occasions when particulate matter and water-soluble contaminants reduce sensor mirror reflectance and system accuracy. Clean the sensor mirror according to the procedure below.

1. Deactivate the sensor cooler by setting the Electronics front panel Sensor switch to the **HEAT** position.
2. Open the sensor by removing the sensor cover.
3. Moisten a cotton swab with a cleaning solution suitable for mirrors, such as the blue cleaning solution in the GE General Eastern maintenance kit, or dilute methanol or rubbing alcohol.

   Do not use Q-tips or other swabs that contain oils.
4. Clean the mirror with a few light wipes. If the sensor has been exposed to significant contamination, clean the other optical surfaces in the sensor and the sensor cavity itself.
5. Replace the sensor cover. Leave it in the Open position, with the large holes allowing maximum air into the sensor cavity for fastest response time.
6. Return switches to normal, initiate a Pacer cycle, and continue operation.

Balancing the sensor optics

If the service (**"S"**) flag reappears after a Pacer cycle, even after performing the mirror cleaning procedure above, check the sensor optics balance adjustment. Improper adjustment of the optical balance is the most common cause of instrument malfunction. Also, new systems may require an optical balance adjustment after one or two months of operation.

Never perform the Optical Balance Adjustment without first cleaning the mirror.

Place the sensor switch on **HEAT**, wait one minute, then observe the segment display. If only the bottom segment bar is lit, the sensor is properly balanced. Otherwise, balance the sensor according to the procedure below.

1. Clean the mirror as described earlier in this chapter. Make sure you replace the sensor cover when checking the balance. If no bars are lit or more than one bar is lit, go to Step 2. If one bar is lit, go to Step 3.
2. **If no bars are lit**, turn the balance screw on the sensor **COUNTERCLOCKWISE** until only the bottom bar is lit.

   If more than one bar is lit, turn the balance screw **CLOCKWISE** until only the bottom bar is lit. (For the adjustment screw, see Figure *6* on page 14.)

   Be sure to cover the mirror cavity while adjusting the balance screw, since ambient light can cause an offset.
3. The sensor is balanced when one bar is lit. Replace the sensor cover, if necessary, and make sure one bar is still lit. If not, repeat Step 2, since you were allowing some light to enter the cavity. Place the Sensor switch back to **OPERATE** to stop heating the mirror.
4. Initiate a Pacer cycle by switching the Balance switch to **INIT**. At the completion of the cycle, the Humilab Chilled Mirror Hygrometer System is properly balanced. Figure 13 on the next page diagrams the complete balancing procedure.

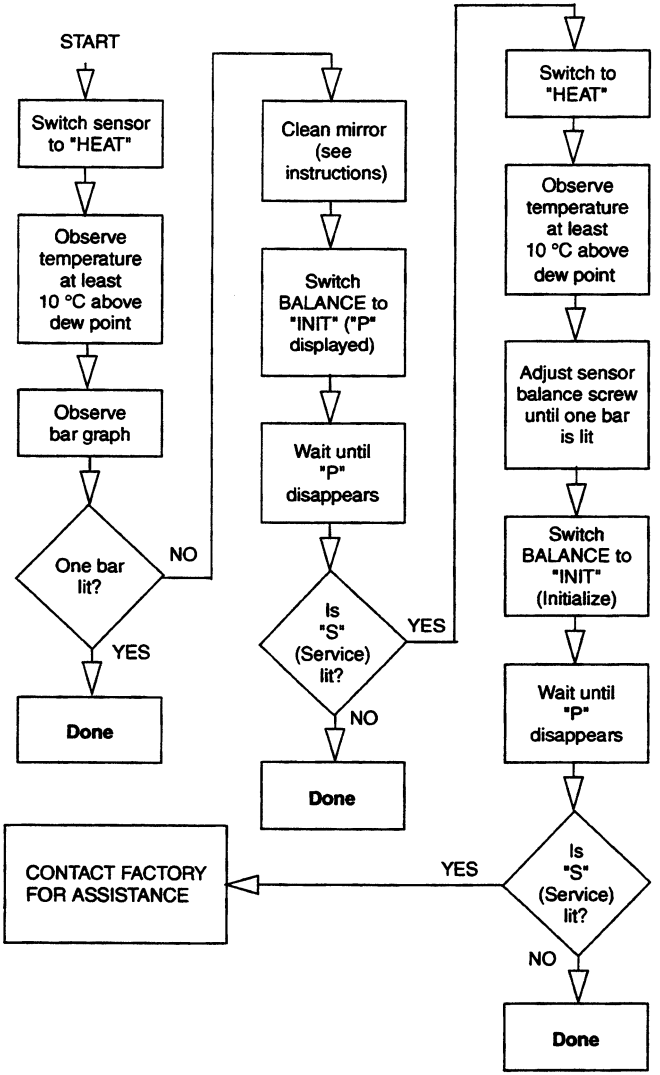


Figure 13 — Mirror Check and Mirror Sensor Balancing Procedure

Field replacement of the sensor mirror

One advantage of using a GE General Eastern chilled mirror dew point sensor is you can replace the mirror yourself. A sensor does not have to go back to the factory for replacement of the reflective surface, but of course you can return it for factory service if desired. A mirror may require replacement for these reasons:

- The reflective surface may be gradually abraded by sharp particles.
- The mirror surface may be accidentally scratched or gouged during use or cleaning.

Replacing the sensor mirror. Required equipment: Torque driver, set to 20-30 inch-ounces of torque. You can order a GE General Eastern type TW-1 torque driver if needed.

1. Open the sensor by removing the sensor cover.
2. Unscrew the old mirror, using a 3/16-inch (0.187) hex socket. Discard the old mirror.
3. The kit supplied by the factory contains the replacement mirror and a container of white thermal compound for proper heat transfer. Complete instructions are also included in the kit.
4. Use a toothpick or similar tool to place a small amount of thermal compound in the hole into which the mirror is tightened. (Do not apply the compound to the mirror stem.) Do not use an amount large enough to leak out when the mirror is tightened. Do not allow any compound on the mirror surface, as it is very difficult to remove completely.
5. Carefully screw in the new mirror and tighten to the proper torque.

   The mirror protrudes only about 1/16-inch above the surface. Ensure that the hex socket does not slip off while tightening, as this may mar the new mirror or mar the vapor barrier.
6. Carefully clean the mirror surface, using a cotton swab and the cleaning solution supplied in the maintenance kit. Alternatively, you can use distilled water or diluted rubbing alcohol.
7. Replace the cover and return the sensor to normal operation. Under some circumstances, a new mirror may operate in a somewhat unstable manner for the first one to two hours.

Annual recertification

A dated Certificate of Conformance has been supplied with the Humilab system from the factory. This document indicates traceability to the National Institute of Standards and Technology (N.I.S.T.), in Gaithersburg, MD, USA. Under most regulatory standards, this certification is good for one year from date of issue. If your regulations require that the Humilab be re-certified annually, there are two methods you should consider.

- Return the unit to GE General Eastern for re-certification
- Have it re-certified in your standards laboratory if adequate traceable standards are available.

Troubleshooting the Humilab, system diagnostics

Is the system operating correctly?

The Setpoint display (lower right) shows the R.H. that you have set the test chamber to. The Humidity display (upper left) shows the **actual** R.H. in the chamber, as read by the chilled mirror hygrometer. Do they agree within the instrument specifications?

Set Point RH and Actual RH do not Agree within Specifications.

Actuate the setpoint select switch. You will instantaneously get a reading in the Setpoint display window that is the **actual** value needed to generate the previously displayed setpoint. That is, it is the R.H. value selected by the **SETPOINT** switch (plus or minus a correction value).

Set Point RH and the Corrected Reading Differ by more than 5%.

Check the following to determine the source of the problem.

- Is a green letter **"S"** illuminated in the window to the right of the Control Status light?

  If so, the mirror needs cleaning due to buildup of dust on the surface. See mirror cleaning instructions earlier in this chapter.
- Did you fill the reservoir with water and run a calibrate cycle without an adequate waiting period for the water temperature to completely equilibrate to ambient?

If that is possible, run it again with a stable water supply.

- Relative humidity is a function of temperature. Are you calibrating devices in the chamber that generate heat?

  If you are, try to locate the heat producer adjacent to the temperature sensor in the center of the chamber. This way, the system will correct for it automatically.

- Is the green Control Status indicator off?

  If so, the chilled mirror is not tracking the chamber. See the section on page 59 in Appendix B on chilled mirror hygrometer system troubleshooting.

Appendix A — Specifications

% RH range	10 to 90% RH at 77°F (25°C)
Temperature range	68 to 86°F (20 to 30 °C) May be used with Temperature-Controlled Water Bath/Circulator. Humidity limited by surface temperature of internal walls and cover (dew point in chamber must be less than interior surface temperature to avoid condensation).
Response time	10 minutes for 63% step change. 30–40 minutes to full stability
Accuracy	±1% RH from 10% to 70% RH ±1.5% RH from 70 to 90% RH ±0.3°F (0.15°C) dew point at 77°F (25°C) ±0.3°F (0.15°C) dry bulb at 77°F (25°C)
Analog outputs	Two (humidity and temperature), each user-scalable, 4–20mA/0–5VDC
Power	115 or 230 VAC ±10%, 50/60Hz single phase
Digital interface	Two RS-232 ports for reference and generator interface
Prostep software	Windows 95/98 or above required. Supplied on CD ROM with Operator's Manual (PDF) and HCON Humidity Conversion Software.
Approvals	CE approved. Certifications supplied: Certificate of NIST traceability and functional test data
Display	Three LEDs, 0.5" (1.3cm) high, 7-segment Shows Set Point (%RH), Actual % RH, and Temperature 0.1% RH/°C/°F resolution
Workspace dimensions	11" by 9" by 6.5" (28 by 23 by 16.5 cm) Approx. 644 in^3 (10.6 liters)
Overall dimensions	23"L by 19"W by 13"H (58 by 48 by 33 cm)

Materials	Chamber: stainless steel I/O block: aluminum Water jacket: stainless steel
Water capacity	2.2 gallons (8.3 liters)
Mechanical I/O	Fill port Fittings: 1/4" OD tubing, instant-on fittings for: water circulation (inlet and outlet); water drain (for gravity draining); and dry air inlet (compressed dry air to be regulated to < 5 PSI)
Weight	66 lbs (30 kg) dry weight
Electrical I/O	Power: IEC receptacle Analog outputs: DB-15 RS-232: DB-9
Water capacity indicator	Liquid sight glass – color keyed indicator
Desiccant	Indicating type (bright blue when dry; pink when saturated). Chamber runs 24 hours at 50% RH and 77°F (25°C) on a new charge of desiccant. Dry compressed air (–40°F / –40°C Dew Point or drier) extends life indefinitely.

Appendix B — Humilab chilled mirror hygrometer details

Introduction

A general description of the Humilab chilled mirror is presented in Chapter 4. In most installations this general description is completely adequate. However, some applications may require system modification to meet specialized needs. This appendix describes how to make these changes. It also provides more detailed information on the Humilab mirror system, its maintenance, and troubleshooting.

Because of the delicate and critical nature of the chilled mirror components, this information is intended for trained electronics technicians. If you are not comfortable performing procedures in this appendix, contact GE General Eastern for assistance.

Chapter organization

This is a large appendix consisting of the following sections:

- A list of the Humilab Chilled Mirror System Components
- Front Panel Operation
- Using the **DISPLAY** Switch to Set Defaults (Select Options)
- RS-232 Communications (Windows Terminal Program)
- Using RS-232 Communications to modify Humilab Operations
- Output Terminal Connections
- Service and Troubleshooting Procedures
- Helpful Hints

System components

The Humilab chilled mirror system consists of the following items:

- Electronics Module (as part of the Humilab)

- A dew point sensor (GE General Eastern Model 1111H)
- A Temperature Sensor (GE General Eastern Model T-100E)
- Interconnecting cables (part of the Humilab)

Front panel operation and displays

The front panel was discussed in Chapter 2 from a daily operations standpoint. This section repeats some of this information (for quick reference), but also supplies additional information.

Figure 7 on page 17 shows the front panel layout. The panel contains digital dew point and control status displays and three operating switches: **SENSOR**, **BALANCE** and **DISPLAY**. The lettered sections below correspond to the labels in page 17.

A **DEW POINT** display — The **DEW POINT** display shows the dew or frost point in Celsius or Fahrenheit units.

B,C **CONTROL/STATUS** display — The **CONTROL/STATUS** display includes a green control light and a seven-segment display. The control lights comes on when the system detects both a stable dew or frost layer and a stable dew point temperature. The seven-segment display indicates as follows:

P	Programmable Automatic Contaminant Error Reduction (PACER®) mode or Automatic Balance (**AUTO**) mode is in operation.
S	Service — The system optics require service, cleaning, or adjustment.
(bars)	Indicates the approximate amount of condensation on the sensor mirror. (Only seen in **HEAT** or **COOL** mode.)

D **DISPLAY** Switch — This is a three-way switch that selects:

NEXT	A momentary position used when viewing or changing
OPERATION	Normal operation.
SELECT	A momentary position used when viewing or changing displayed unit, output unit and scaling or alarm units and limits.

E **BALANCE** switch — This is a three-way switch that selects:

AUTO	The Pacer/Auto cycle occurs at a pre-selected interval.

	MANUAL	No PACER cycle unless manually initiated.
	INIT	No PACER cycle unless manually initiated.

F **SENSOR** Switch — This is a three-way position switch that selects:

HEAT	Allows the mirror to be cleared of condensation in order to check for proper control loop operation.
OPERATION	Normal operation.
COOL	A momentary position that forces maximum cooling in order to check depression capability.

Displays

Main display. The upper display can show R.H. or Dew Point °C or °F. The front panel **DISPLAY** switch is used to determine which parameter is displayed. The factory default for the Humilab is %R.H. The lower display shows temperature in °C or °F. The factory default is °C.

Control status display. The CONTROL STATUS display includes a green control light and a green, seven segment LED display. The control light comes on when the system detects both a stable dew or frost layer and a stable dew/frost point temperature. The green LED can read as follows:

P - Programmable Automatic Contaminant Error Reduction (PACER®) mode or Automatic Balance (AUTO) mode is in operation.

S - Service. The system optics require service, cleaning, or adjustment.

U - In Units Select mode when using the **DISPLAY** switch

O - In Output Select mode when using the **DISPLAY** switch

Horizontal bars indicate the approximate amount of condensation on the sensor mirror when the **SENSOR** switch is in **HEAT** or **COOL**. It is an indication of dew layer thickness on the mirror.

See the information starting on page 49 in this appendix for information on using the **DISPLAY** switch for re-programming Units, Outputs, or Alarms.

Switches

Display switch. The **DISPLAY** switch is a three-way switch that selects:

NEXT - A momentary position used when viewing or changing displayed units, output units and scaling.

OPER - Normal operation.

SELECT - A momentary position used when viewing or changing displayed units, output units and scaling.

Display switch operation. The **DISPLAY** switch is used to change the units displayed in the main display, view or change units for the analog output(s). In the Default mode, as shipped from the factory, the actual analog output scaling can only be modified via the RS-232 port, to avoid accidentally changing them when changing displayed units at the front panel. (See *"RS-232c re-programming mode"* on page 52 of this appendix.)

Balance switch. The **BALANCE** switch is a three-way switch that selects:

INIT - A momentary position that initiates a balance cycle, either **PACER** or **AUTO**.

MAN - No balance cycle unless manually initiated, using **INIT**.

AUTO - The **PACER/AUTO** cycle occurs automatically at a pre-selected interval.

See *"Set balance type"* on page 54 for details on resetting the balance interval via RS-232 communication.

Sensor switch. The **SENSOR** switch is a three-way switch that selects:

COOL - A momentary position that initiates maximum cooling of the chilled mirror sensor in order to verify its depression capability.

OPER - Normal operation.

HEAT - An on position that initiates heating of the chilled mirror sensor in order to clear it of dew or frost and verify proper control loop operation.

Option selections using the display switch

The **DISPLAY** switch is used in conjunction with the three green **LED** displays (the Units portion of the main display, the parameter annunciator, and the Control Status display). It has a central rest position, **OPER**(ate), and two momentary positions, **NEXT** and **SELECT**. In general, **NEXT** allows you to get into Option Selection mode, scroll through various portions of the menu, and scroll through digits and characters to set values. **SELECT** allows you to select which area to access and to set values and characters.

A simplified explanation of the option selection system

The **DISPLAY** switch provides you with several main menus. In sequence, these are:

UNITS on the top display

UNITS on the bottom display

OUTPUTS on the top display

OUTPUTS on the bottom display

Menu navigation.

It's easier than it might first appear to move about and select options. Follow the three-step process below.

1. Press **NEXT** until you see one of the above main menus that you want. When you get to the one you wish to see, press Select. This action puts you **IN** that main menu, and you can proceed to scroll through it until you see the submenu you want.
2. When you see it, press **SELECT**. You are now **IN** that submenu. By pressing **NEXT**, you can scroll through it and find the parameter you wish to select.
3. When you find the one you want, save it by pressing **SELECT**. Indications on the front panel will guide you. It may sound complicated, but once you have done it a few times, it will seem very logical.

It is suggested that you now proceed to try it intuitively. The indicators will help you, and you may not need to use the manual. If you do run into trouble, consult the following sections.

- To begin programming the Electronics Module, press the **DISPLAY** switch to **NEXT**. (You may have to keep the switch pressed for 1-2 seconds in order to see a change.)
- The Electronics Module will leave Operate mode, enter Program mode and display the first of the three main functions. *While you are programming the Electronics Module, it will not display or output measurement data.*
- Press **NEXT** to display the next menu or option.
- Hold the switch in the **NEXT** position to scroll through all the options available. When you get to the end, the Electronics Module will return to Operate mode.
- Press **SELECT** to access the displayed function or accept a setting displayed on the main display.

The following two sections map out the functions available in Program mode along with the state of the three green LED's at each step.

- **N** will display the next function or scroll through alphanumeric values. Depress **NEXT** for 1-2 seconds
- **S** will access a function or accept a new value. Depress **NEXT** for 1-2 seconds

A more rigorous explanation of the option selection system

The following description describes the **DEFAULT** programming sequence for a unit as shipped from the factory. If the behavior of the **DISPLAY** switch has been modified, using the RS-232C port, the description may not be accurate.

Default operation.

- From **OPERATE** mode, Press **N**.
- The main display and parameter annunciator blank, and the **CONTROL STATUS** display shows "**U**" in the upper display. If you press **S**, you can scroll through all the parameters available for display and select one. For now, press **N**. You can now do the same for the bottom display.
- The **CONTROL STATUS** display shows "**O**", and the parameter annunciator shows "Humidity." If you press **S**, you can view

the parameter for the Humidity output and the scaling. For now, press **N**. You can now do the same for the bottom display.

The units that you can select in the Units mode are shown in Table 7:

Display Units	Parameter Flag	Explanation
°C	Humidity	Dew Point, °C
°F	Humidity	Dew Point, °F
H	Humidity	Relative Humidity,%
°C	Temperature	Temperature, °C
°F	Temperature	Temperature, °F

Table 7: Electronics Module Unit Selection

When you see the parameter you want to display, press **S** to select it. You can have the Electronics Module display a subset of its default parameters. See the RS-232C communications information in Appendix C for details.

- The **CONTROL STATUS** display now shows "**O**." Press **S** to view the output(s). The **CONTROL STATUS** display shows "Humidity." The current high value for the humidity output is shown. Press **N** to view the low value. Press **N** again. You will then be able to view the high and low values for the Temperature output. When you are done, press **N** to move on.

Changing output(s). You can modify the behavior of the **DISPLAY** switch so that the output units and scaling **ON/OFF** limits are hidden from view or are viewable and changeable. See the RS-232C Communications information in Appendix C for details. The following section describes how to change the analog output(s) units and scaling using the **DISPLAY** switch. Once again, you can do this only after you have changed the default behavior of the **DISPLAY** switch.

- From Operate mode, press and hold **N** until "**O**" is displayed in the **CONTROL STATUS** display. In addition, the parameter annunciator will show "Humidity."

  Press **S** to View and/or Change the humidity output. The **CONTROL STATUS** display will show "**H**." Press **S** to change the humidity output units.

  The **CONTROL STATUS** display will show "**O**." The units portion of the main display will show the units available for the output you are changing. Press and hold **N** to scroll through the units, and press **S** to select one.

  The **CONTROL STATUS** display will now show "**H**," and the current high value will now appear on the main display. Press **S** to change this value. The right-most digit will blink.

  Press **N** and hold to scroll through the digits and press **S** to select one. The second digit from the right will blink.

  Continue as before. Finally the sign for the value will blink. The choices here are –, –1, 1, or "blank." Note that the 1 is a half-digit and that + is not shown.

  Once the sign is set, press **S** to continue through the output changing sequence.
- You will now be given the opportunity to view and/or change the low humidity output value. Note that you cannot change the output units by accessing the low output value. This can be done only by accessing the high output, as described above. If you want to change the low output value, press **S** and proceed as above.
- You will then have an opportunity to view and/or change the Temperature. Proceed as above.

RS-232c re-programming mode

See Appendix C for information on establishing RS-232 communications. Once you have established communications, follow the menu descriptions here.

RS-232C re-programming is done via a series of menus and operates on firmware in the Humilab chilled mirror system. To access

the main menu, press **ESC** twice. Note that the menu is not available when **BALANCE** mode is active. Also, when menu functions are active, the Electronics Module deactivates the sensor cooler control circuit and allows the sensor mirror to rise to ambient temperature. The front panel display of the Humilab will also blank. Press **E** from the main menu to return to Operate mode.

The Main Menu

```
1) SCALE OUTPUTS     2) SET BALANCE TYPE 3) SET RS232 UNITS
4) DISPLAY OPTION    5) SET AVERAGING    6) CALIBRATE OUTPUT1
7) CALIBRATE OUTPUT2 8) SET ALARM        9) SET INPUT 2 PARM
A) MOLECULAR WEIGHT  E) EXIT
```

Scale outputs

From the main menu, press **1** to assign and scale the analog outputs. The current state of the output(s) is echoed, followed by a sub-menu:.

```
OUTPUT1:
DP C:
HIGH =60            LOW = -40
OUTPUT2:
TMPC:
HIGH=60             LOW=-40
1) OUTPUT1      2) OUTPUT2       E) EXIT
```

Press 1 to access Output1, the Humidity output. One of the following menus will appear:

```
OUTPUT1:
0) DPC      1) DPF       2) RH        E) EXIT
```

Make a parameter selection, or press **E** to exit.

If you make a parameter selection, the following then appears:

```
HIGH =
```

Enter a value and press **RETURN**. The following appears:

```
LOW =
```

Enter a value and press **RETURN**. The values entered will be echoed and you will be returned to the Scale Outputs sub-menu.

You can now press **2** to set Output2 in the same manner. The only difference is the parameters which are available:

```
OUTPUT2
O)TMPC     1)TMPF       E)EXIT
```

Make a selection and continue as with Output 1, or press **E** to return to the Scale Outputs sub-menu. Press **E** again to return to the Main menu.

Set balance type

From the main menu, press 2 to change the type of balance used by the Electronics Module, adjust the balance interval, or remotely initiate a balance cycle. The current state will be echoed followed by a sub-menu:

```
BALANCE TYPE = PACER
DAY =0
HOUR =12
1) PACER BAL  2) AUTO BAL  3) SET INTERVAL
4) INITIATE BALANCE  E) EXIT
```

Press **1** to set the type of balance to **PACER** (the default) or **2** to set the type of balance to **AUTO**. Press **3** to set the balance interval. The following will appear:

```
DAY=
```

Type a value for the number of complete days between balance cycles and press **RETURN**. The following will appear:

```
HOUR =
```

Type a value (in 24-hour format – e.g. 2 p.m. = 14) for the number of fractional days between balance cycles and press **RETURN**. The interval time will be echoed, and you will be returned to the Set Balance Type sub-menu.

EXAMPLE:

Day =0 **Hour = 12**	Balance every 12 hours
Day = 1 **Hour =0**	Balance every 24 hours
Day =5 **Hour = 12**	Balance every 5 1/2 days

At the Set Balance Type sub-menu, press **4** to initiate a balance cycle. If you do this, the Electronics Module will be returned to

Operate mode at the completion of the balance cycle. Alternatively, press **E** to return to the main menu.

Set RS-232 units

From the main menu press **3** to customize your RS-232C data output. The units selected for output and the handshake status will be echoed followed by a sub-menu:

```
SELECTED UNITS = 1,2
HANDSHAKE = DISABLED
1) DATA   2) HANDSHAKE (TOGGLE)    3) EXIT
```

Press **1** to set the RS-232C data display. The following sub-menu will appear:

```
1) SELECT UNITS    2) USER PROMPT    E) EXIT
```

Press **1** to select the parameters to be displayed. One of the following sub-menus will appear:

```
1) DPC     2) DPF     3) RH     4)TMPC
5) TMPF    6) NONE    E) EXIT
```

Press numbers individually to add the associated parameter to the RS-232C data output. Press **3** (or **6** or **8**, depending on Model) for no data output or to clear before adding parameters. Press **E** when you are done.

At the Data sub-menu, press **2** to output data at the prompt of the user. The following will appear:

```
STATUS = DISABLED
ALLOW USER TO PROMPT FOR DATA
1) ENABLE   2) DISABLE     E) EXIT
```

Press **1** to Enable User Prompt For Data. Now press **E** repeatedly until you are back to the main menu. Press **E** to enter Operate mode. There will not be any data output. Press the following key sequences followed by **RETURN** to see the parameter associated with the key sequence:

```
D1 (DPC)
D2 (RH)
D3 (TMPC)
```

Please note that the "D" must be uppercase

In order to resume normal data output, press **ESC** twice to return to the main menu, return to Set RS-232 Units and Disable User Prompt For Data.

From the Set RS-232 Units sub-menu, press **2** to change the handshake protocol. The default is no handshake. You will be asked for a password:

```
ENTER ACCESS CODE:
```

Type "**ACCESS**" and press **RETURN**. The new status will be echoed. Press **E** to return to the main menu.

Display option

From the main menu press **4** to change the behavior of the front panel **DISPLAY** switch. The default behavior is that all units are available, the output(s) are viewable but not changeable.

One of the following sub-menus will appear:

```
1)DISPLAY UNITS  2)OUTPUTS  3)ALARM   E)EXIT
```

Press **1** to determine the behavior of the **DISPLAY** switch with regard to parameters. The following sub-menu will appear:

```
SELECTED UNITS =
1) SELECT   2) FIX/ALTERNATE DISPLAY   E) EXIT
```

Press **1** to select the parameters shown by the **DISPLAY** switch. One of the following sub-menus will appear:

```
1)DPC     2)DPF     3)RH     4)TMPC
5)TMPF    6)NONE    E)EXIT
```

Press numbers individually to add the associated parameter to the **DISPLAY** switch sequence. Press **6** to clear before adding parameters. Press **E** twice when you are done. ***This feature is not recommended for closed-loop operation.***

Press **2** to choose fix/alternate display. The following sub-menu will appear:

```
1) FIX     2) ALTERNATE
```

In the fix display mode, the display will show only the selected unit during normal operation. In the alternate display mode, the display will alternate between available units at a 2-second interval. ***This setting is not recommended for closed-loop operation.***

The default is fix. You can select **2** for alternate display. When you are done, press **E** to exit.

Press **2** from the Display Switch sub-menu to determine the behavior of the **DISPLAY** switch with regard to the output(s) units and scaling information. The current status will be echoed, followed by a sub-menu:

```
STATUS = VIEW ONLY
ENABLE/DISABLE SWITCH FUNCTIONS
1) VIEW ONLY  2) VIEW & CHANGE  3) HIDE  E) EXIT
```

Press **1** to have the information viewable but not changeable (the default). Press **2** so that it is viewable and changeable from the front panel. Press **3** to hide the information at the front panel. In this last case, the units and scaling are still in effect – they're just not accessible using the **DISPLAY** switch. When you are done, press **E** to exit.

Press **3** from the Display Switch sub-menu to determine the behavior of the **DISPLAY** switch with regard to alarm units and scaling. The following sub-menu will appear:

```
STATUS = VIEW ONLY
ENABLE/DISABLE SWITCH FUNCTIONS
1) VIEW ONLY  2) VIEW & CHANGE  3) HIDE   E) EXIT
```

Make a selection in the same manner described above. When you are done, press **E** to exit. Press **E** twice to exit to the main menu.

Set averaging

From the Main menu, press **5** to set the Electronics Modules data averaging parameter. This figure (1 - 20) determines how many of the most recent dew point readings are averaged to determine the reading displayed and output. The factory default is 20. The current value is echoed followed by a sub-menu:

```
NUMBER OF POINTS =20
1) SET AVERAGE    E) EXIT
```

Press **1** to change the value. You will be prompted for a new value:

```
VALUE =
```

Type a value between 1 and 20 and press **RETURN**. The value will be echoed. When you are done, press **E** to exit.

Please consult the factory before attempting to calibrate the analog outputs of the Electronics Module. All analog outputs are fac-

tory calibrated and normally do not require repeat calibration or field adjustment.

Service and troubleshooting procedures

This section deals with some procedures that are performed on a day-to-day basis by the operator, but contains additional elements and covers procedures appropriate only for trained electronic technicians.

Test and calibration

The procedures in this section test and/or calibrate the following aspects of the Electronics Module:

- Start-up and power supply voltage
- Normal sensor operation
- Front panel display
- Digital and analog outputs

The Electronics Module has been completely tested and calibrated at the factory, and is ready to plug in and operate. As received, it meets all of our published specifications.

When ordered as a complete hygrometer system with a chilled mirror sensor and cable, the system is checked at a number of points against a dew point system that has been certified by the U.S. National Institute of Standards and Technology (N.I.S.T.). A Certificate of Conformance is supplied with it to indicate traceability.

There are no calibration adjustments in the instrument that affect the digital display. The displayed reading is a microprocessor calculation from the platinum Resistance Temperature Detector (RTD) that measures the mirror temperature, which is controlled automatically at the dew point.

Troubleshooting the chilled mirror hygrometer system

The following factory test procedures can be performed for incoming inspection or for troubleshooting purposes. They should only be done by a trained electronics technician.

Front panel does not light when powered up.

- Check the **POWER** switch. Make sure it's **ON**.
- Check the line cord. Make sure it is plugged into a proper source of AC voltage.
- Check the power supply. Make sure it is connected and has the proper output voltage.
- Check the fuse. Make sure the proper fuse size is installed. Make sure the fuse is not open.

"S" appears on the front panel display.

The "**S**" means service is required. The usual problem is that the sensor mirror is contaminated and should be cleaned.

- Clean the sensor mirror as described in Chapter 5.
- Run the instrument through a Pacer cycle.
- If, at the end of the cycle, the "S" comes on again, balance the sensor optics as described in Chapter 5.

Invalid dew point display.

This can be caused by one of three problems.

- Clean the mirror as described in Chapter 5.
- Balance the sensor optics as described in Chapter 5.
- If the above procedures have been done and the problem persists, verify that the platinum resistance thermometer in the sensor is reading correctly:

1. Disconnect the 6-pin connector (J9) from the main circuit board in the Electronics Module. Once disconnected, the front panel dew point display should read ambient temperature after allowing sufficient time for the sensor mirror to stabilize at the new temperature.
2. Check the temperature reading against another reliable thermometer placed near the dew point sensor. Allow sufficient

equilibration time. On the Humilab simply compare the upper reading (if set to dew point) with the lower reading (temperature). They should agree.

3. If the platinum resistance thermometer in the dew point sensor is faulty, return the sensor to GE General Eastern for factory servicing. (See Appendix E for return procedures.)

"P" remains lit on the front panel.

When "**P**" remains lit on the front panel, the instrument has not recovered from a Pacer cycle.

- Check that the sensor and sensor cable are connected. If they are not connected, connect them now. The instrument will come out of Pacer mode after a short time.
- The sensor optical bridge may be out of balance. Perform the optical balance procedure as described in Chapter 5.

No analog output, but the digital display operates.

Check the analog output scaling. See the scaling procedure in *"Scale outputs"* on page 53.

No digital output from the RS-232C port.

The instrument may not have been scaled properly via the RS-232C port. Repeat the procedure in the Scale Outputs section in *"Scale outputs"* on page 53.

Have you established proper communications, correct COM port? See Appendix C for information.

No cooling and/or heating.

The front panel dew point display should indicate if you are not getting heating or cooling. When you turn on the sensor **HEAT** switch, the digital display should show an increase in temperature. When you turn on the **COOL** switch, it should show a decrease in temperature.

Helpful hints

This Section contains background information that will help you better understand the Humilab's chilled mirror hygrometer system operation and its use in the Humilab.

Time response

At dew points above 0°C, the system stabilizes within a few seconds on the correct dew or frost layer. Take dew/frost point readings only after the green control light has come on.

Time response depends on a number of factors: slew rate, dew point, etc. Slew rate is in turn dependent on dew point and depression; at higher dew points and moderate depressions, it is typically 1.5°C/second. At lower dew points and/or larger depressions (the temperature difference between the mirror and the sensor body), slew rate becomes progressively slower.

Flow rate affects response by determining the rate at which water vapor is supplied or carried off. There is, of course, a trade-off between response time, control system stability, and sensitivity to contamination. Install the sensor cover in the "open" position for proper response time. That is, the large holes in the cover allows maximum air sample into the sensor cavity.

Mirror cleanliness

Proper operation of a condensation hygrometer depends on the condition of the mirror surface. In general, accuracy is reduced when contaminants accumulate on the mirror.

However, the mirror does not have to be microscopically clean. In fact, the mirror performs best a few hours after cleaning. On an unscratched, freshly cleaned mirror, there are relatively few nucleation sites on which dew or frost deposits can form, so it takes longer to collect a condensate layer at low frost points. Also, overshoot occurs, which can cause oscillation.

Particulate contaminants. Particulate matter that is insoluble in water may accumulate on the mirror surface, but usually does not affect the instrument accuracy until the mirror reflectance is reduced substantially. In many cases, particulates improve instrument response by providing condensation sites.

Water-soluble contaminants. Material such as naturally occurring salts, which readily dissolve in water, are detrimental to accurate vapor concentration measurement by any condensation method. These materials readily go into solution with the water condensate on the mirror surface, then reduce the vapor pressure in accordance with Raoult's Law. As the concentration increases with time, the saturation vapor pressure of the liquid solution decreases.

The Electronics Module responds to lower vapor pressure by elevating the mirror temperature to maintain a vapor pressure that is in equilibrium with the partial pressure of the atmospheric water vapor. The displayed dew point, therefore, drifts upward with respect to the true dew point. Because the measurement error increases gradually, it often goes undetected.

To see if dissolved contaminants are affecting dew point measurement, do the following:

1. Note the indicated dew point.
2. Clean the mirror.
3. Balance the detector by initiating a Pacer cycle (see below).
4. Measure the dew point again.

If the new reading is lower than the first reading, there was probably soluble material in sufficient quantity to cause a measurement error. Consider decreasing the interval between Pacer cycles (see *"Set balance type"* on page 54), since the Pacer is completely effective in reducing contaminant-induced errors.

Minimizing effects of contaminants - the Pacer® feature.

Clean the mirror when necessary according to the optics cleaning procedure in Chapter 5. To determine the proper cleaning interval, take a dew point reading before and after cleaning. Any appreciable shift indicates that under the same conditions you should clean the mirror sooner.

GE General Eastern's patented PACER (Programmable Automatic Contaminant Error Reduction) rebalances the dew point sensor bridge and determines whether it requires cleaning. In normal operation the Pacer feature actually reduces contaminants. You can largely avoid frequent need to clean the mirror by using the Pacer feature of the Humilab's mirror system. This feature, used periodi-

cally, performs a cleaning cycle maintaining the mirror in optimum condition. Figure 14, showing the Pacer cycle, illustrates the way this feature operates.

The Pacer feature operates only when the **BALANCE** switch is in the AUTO position. When the Pacer is in operation and contaminants accumulate to a point where they can no longer be automatically reduced, the "S" (Service) light will indicate that the mirror needs cleaning.

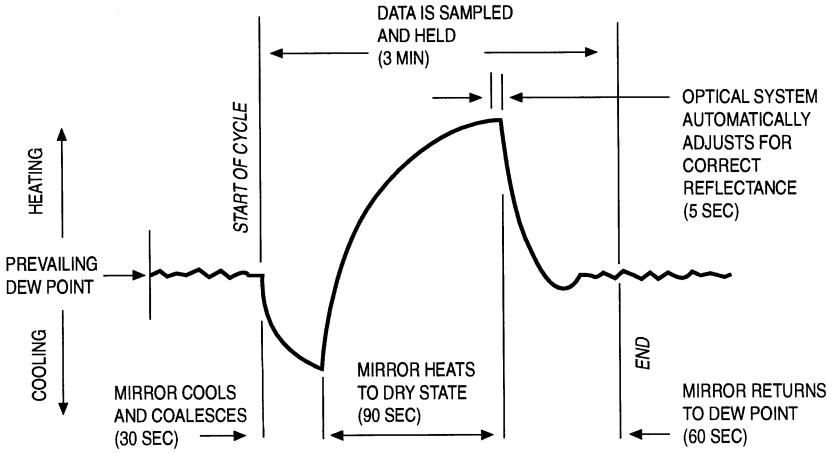


Figure 14 — PACER® Cycle

Figure 15 shows the effect on contaminants of using the Pacer cycle.

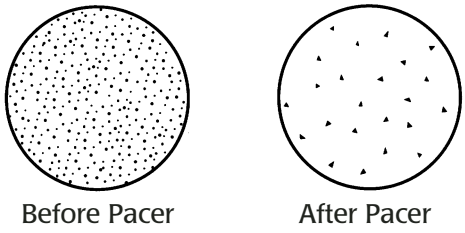


Figure 15 — contaminant Reduction Using the PACER® feature

Mirror flooding. If there is an abrupt transition from dry to moist conditions (particularly when accompanied by a transition from cold to warm temperatures) the mirror may accumulate an overload of moisture. It may then take several minutes for the sensor to dry out. The process can be speeded by switching to **HEAT** to temporarily heat the mirror.

Appendix C — Configuring the RS-232 Interface

Introduction

This appendix contains information you will need to establish RS-232 connections to the Humilab (and Electronics Module). Cables, communication software, and protocol information is provided. Note that the Humilab does not use the alarm function described below.

Establishing RS-232 communications

The easiest method of establishing RS-232 communications is to use the Microsoft Windows Terminal program.

Follow the steps below:

1. Click your mouse on the Terminal icon.
2. Select the Settings Menu.
3. Select Communications.

   A window is displayed for you to enter various communications parameters.
4. Select the following:

   Baud rate: 1200 baud
   Data bits: 8
   Start bits: 1
   Parity: none
   Hardware control: none
   COM Port: COM1or COM2 as required
5. Click on OK.

Communications should now be established and you will see fresh data on the screen, frequently updated. Percent R.H., Dew Point, and Temperature are provided and with more resolution than when displayed on the Humilab's front panel.

Using RS-232C communications

RS-232C communications can be divided into two sections — Operate mode and Reprogramming mode. See Appendix B for a complete discussion of the Re-programming mode used with the Electronics Module.

RS-232C operate mode

In Operate mode the RS-232C port outputs the following data.

- `DP C=XXXX`
- `DP F=XXXX`
- `RH=XXXX`
- `TMP C=XXXX`
- `TMP F=XXXX`

The data output by the Electronics Module can be modified in two ways. First, the user can customize the data output to some subset of the above. Second, the user can type various letters to obtain immediate output of a single parameter. See the Re-programming mode in Appendix B for details.

In addition to the output data, the Electronics Module will also output various status flags as shown below.

Status Flag	Description
ALARM	The alarm relay is activated. Disabling the alarm relay will also disable this prompt.
CONTROL	The Electronics Module is in control at a dew/frost point.
BALANCE	The Electronics Module is in PACER or AUTO balance mode.
SERVICE	The system optics require service, cleaning, or adjustment.
COOL	The sensor is in maximum cooling mode.
HEAT	The sensor is in maximum heating mode.
SHUTDOWN	The Electronics Module has shut down because of excessive temperature.

Some subset of these prompts will appear after the output data. They will be displayed with every system update as long as they are active. Each prompt is followed by a carriage return.

Computer connections

In order to communicate with the Electronics Module, you need a standard serial interface card installed in your computer. If your computer has one serial card, it is addressed as COM1. If there is a second serial card, it is addressed as COM2. You must also have a cable with the following connectors:

- A 9-pin male D-sub connector for the Reference Port
- A 9-pin female D-sub connector for the computer (some computers use a 25-pin connector, requiring an adaptor)

Appendix D – Humidity Equations and Conversion Charts

Introduction

The equations and charts in this appendix are supplied for users who are interested in more information about the relationships between vapor pressure, humidity, temperature, and dew point.

Symbols used

e = Vapor Pressure, millibars

e_i = Vapor Pressure with respect to ice, millibars

e_w = Vapor Pressure with respect to water, millibars

e_{is} = Saturation vapor pressure, ice, millibars

e_{ws} = Saturation vapor pressure, water, millibars

P = Total Pressure, millibars

T = Temperature, °C

T_a = Ambient temperature, °C

T_d = Dew point temperature, °C

T_f = Frost point temperature, °C

Vapor pressure

Saturation vapor pressure with respect to water is a function of temperature only and is given by the following:

$$e_{ws} = 6.1121 \exp\left[\frac{17.502\,T}{240.97 + T}\right]$$

Saturation vapor pressure with respect to ice requires a minor adjustment of the constants as given by the following:

$$e_{is} = 6.1115 \exp\left[\frac{22.452T}{272.55 + T}\right]$$

In addition to yielding saturation vapor pressure as a function of ambient temperature, the above equations also yield ambient vapor pressure as a function of dew/frost point.

The total pressure of a gas mixture is equal to the sum of the partial pressures each constituent gas would exert, were it to occupy the same total volume, according to Dalton's Law. The first term (in parentheses) in Equations 1 and 2 is the enhancement factor, and corrects for the slight difference between the ideal behavior of pure water vapor and the behavior of water vapor as a constituent of air.

Humidity

Relative Humidity is defined as the ratio of the water vapor pressure (e) to the saturation vapor pressure (e_s) at the prevailing ambient or dry bulb temperature (T):

$$\%RH = 100\left(\frac{e}{e_s}\right) = 100\left[\frac{e_w(T_d)}{e_{ws}(T_a)}\right]$$

Absolute humidity is expressed as water vapor density: water vapor mass per unit volume of dry air, according to the following:

$$\frac{g}{m^3} = \frac{216.7\,e(T_d)}{T + 273.16}$$

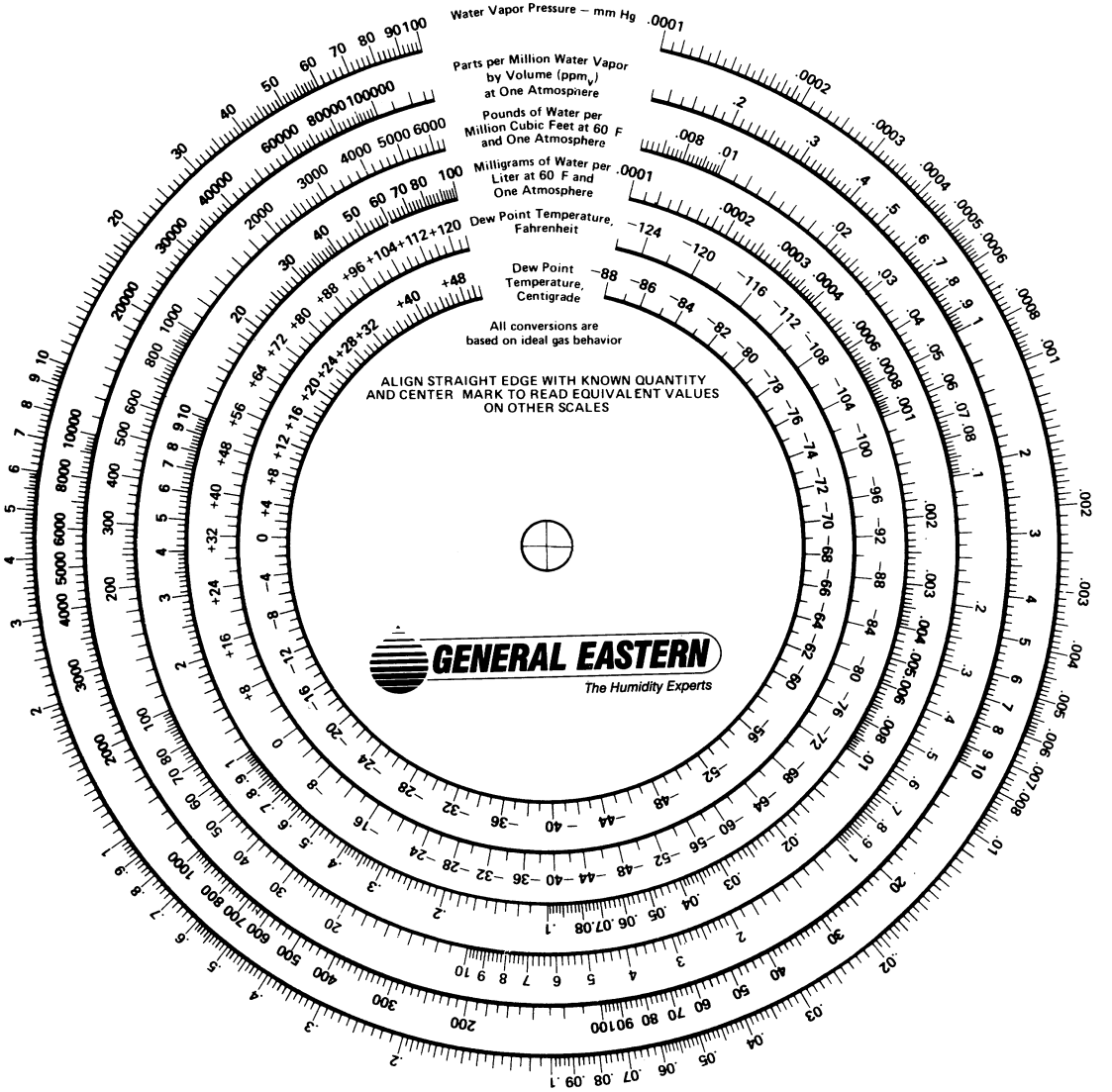
Water vapor content expressed as parts per million by volume is given by the following:

$$PPM_V = 10^6 \frac{e(T_d)}{P - e(T_d)}$$

Expressing water vapor content as parts per million by weight (or mixing ratio) requires multiplication of the above by the ratio of the molecular weight of water to that of air as given by the following:

$$PPM_W = 0.622 \times 10^6 \frac{e}{P - e}$$

See Figure 16 for a graphical conversion chart and Figure 17 for a Psychrometric chart.



WATER VAPOR CONVERSIONS

Figure 16 – Graphical Conversion Chart

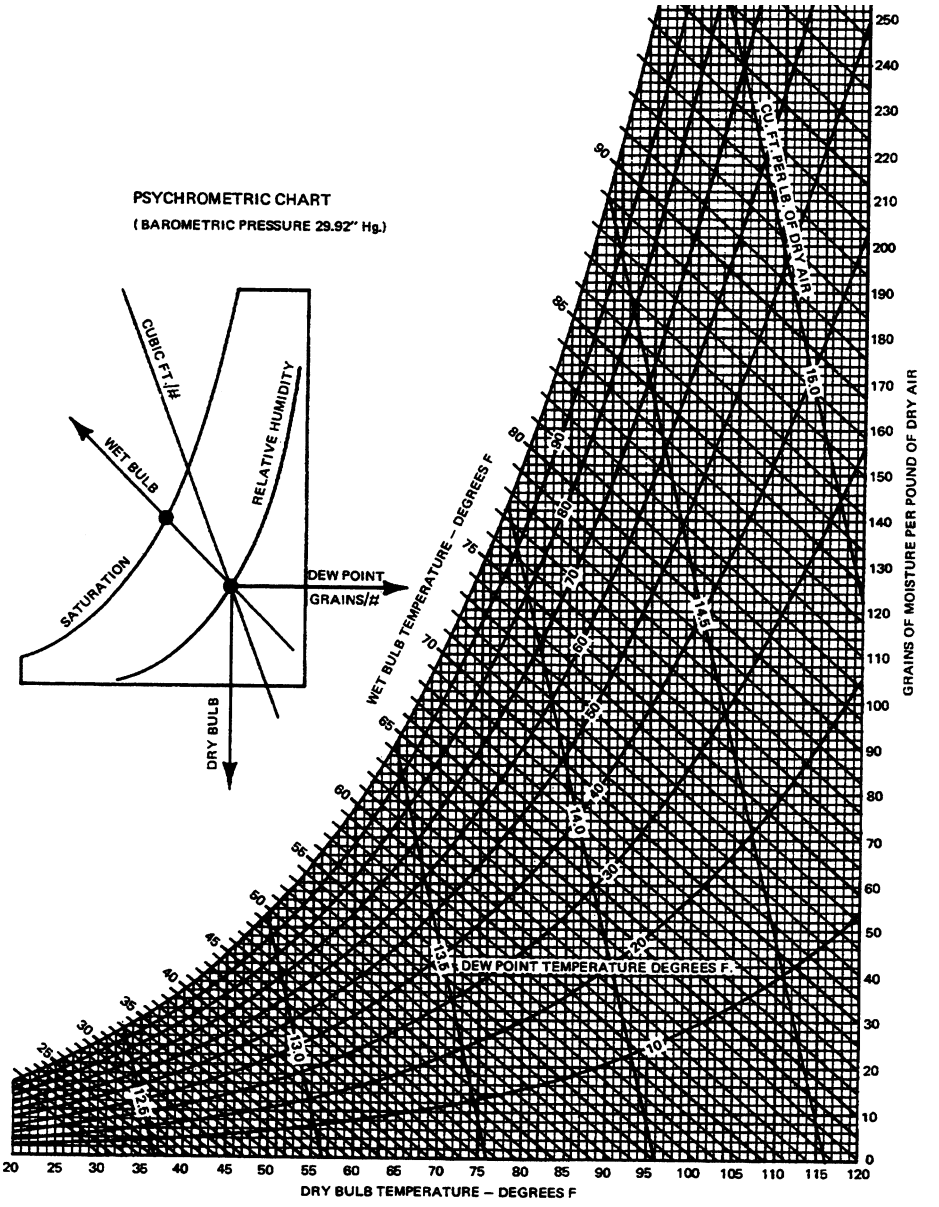


Figure 17 — Psychrometric Chart

Appendix E — Warranty information and return procedures

Warranty policy

GE General Eastern warrants equipment of its manufacture against defective materials or workmanship for a period of one year from date of shipment. Liability of the Seller under this warranty is limited, at the Seller's option, to:

- Repair or replacement of defective parts at no charge.
- Credit adjustment, not to exceed original equipment sales price.

This warranty is subject to the following conditions:

- Prompt notification to Seller upon discovery of defects or missing items.
- Obtaining return authorization number from Seller to return defective items to plant as directed.
- Return of equipment, freight charges prepaid, or as otherwise agreed.

Defects caused by negligence, misuse, improper installation, accident or unauthorized repair or alteration by buyer or user, or any modification, such as changing range resistors, may void this warranty.

This warranty does not include mechanical parts failing from normal usage nor does it cover limited life electrical components which deteriorate with age.

This warranty is in lieu of all other warranties, expressed or implied, including the implied warranty of fitness for a particular purpose to the original purchaser or to any other person. Seller shall not be liable for consequential damages of any kind.

Damaged shipments

In case of shipping damage, it is the Buyer's responsibility to file a claim. The customer should inspect the shipping container upon receiving and note any evidence of damage on the freight receipt. If concealed damage is found after opening the container, the customer should file a claim with the carrier at once. The customer must retain the shipping container and all materials.

Repaired equipment

All repairs are warranted for 90 days. Only the repairs and components replaced as part of these repairs are covered by this warranty. Other repairs or defective parts are covered by the original warranty if applicable.

The aforementioned provisions are do not extend the original warranty period of any article which has been either repaired or replaced by the Seller.

Instrument return procedure

All GE General Eastern instruments are fully tested and calibrated prior to shipment. Should a problem with the operation of the equipment arise, follow the procedure below:

1. Contact the factory to discuss the problem. In countries other than the U.S., the local agent can also be contacted. Sometimes a problem can be resolved by a change in operating procedure or an adjustment to the equipment.
2. If the equipment must be returned to the factory, obtain a return authorization number from GE General Eastern, and reference the number on the return shipping papers. A written description of the problem should also be included with the instrument.
3. If equipment is not covered by GE General Eastern's Warranty Policy, a purchase order should be submitted with the equipment returned. The order should cover one of the following:

- Open order, authorizing repair of equipment to meet published specs. Repair costs will be billed on actual basis, but will not exceed 50% of the replacement cost without prior customer approval.

- Order that is not to exceed $500.00 or 30% of the replacement cost, whichever is higher. If repair costs exceed this amount, the customer will be quoted costs before the work is done.
- Order to cover cost of test and evaluation only. Amount based on type of equipment returned. GE General Eastern will evaluate but not repair the unit, and call the customer to discuss the evaluation and quote the cost of repair or replacement.

GE General Eastern recommends the open order or the dollar- or percentage-limited order. Either of these will expedite repairs and reduce costs.

4. After receiving a Return Authorization number, the equipment must be returned freight PREPAID.
5. GE General Eastern reserves the right to apply a minimum service charge in cases where an instrument is returned for repairs or recalibration but does not require service.

Returning equipment without a Return Authorization number and Purchase Order significantly delays turnaround time and incurs additional costs. To expedite repairs and reduce costs, please follow the above instructions.

GE General Eastern guarantees N.I.S.T. traceability and operation within stated specifications. However, claims regarding accuracy or traceability will be covered under warranty only when verified at GE General Eastern, or by a fully independent testing laboratory Examples of independent labs are: National Institute of Standards and Technology in the U.S., the National Physical Laboratory (NPL) in the U.K.