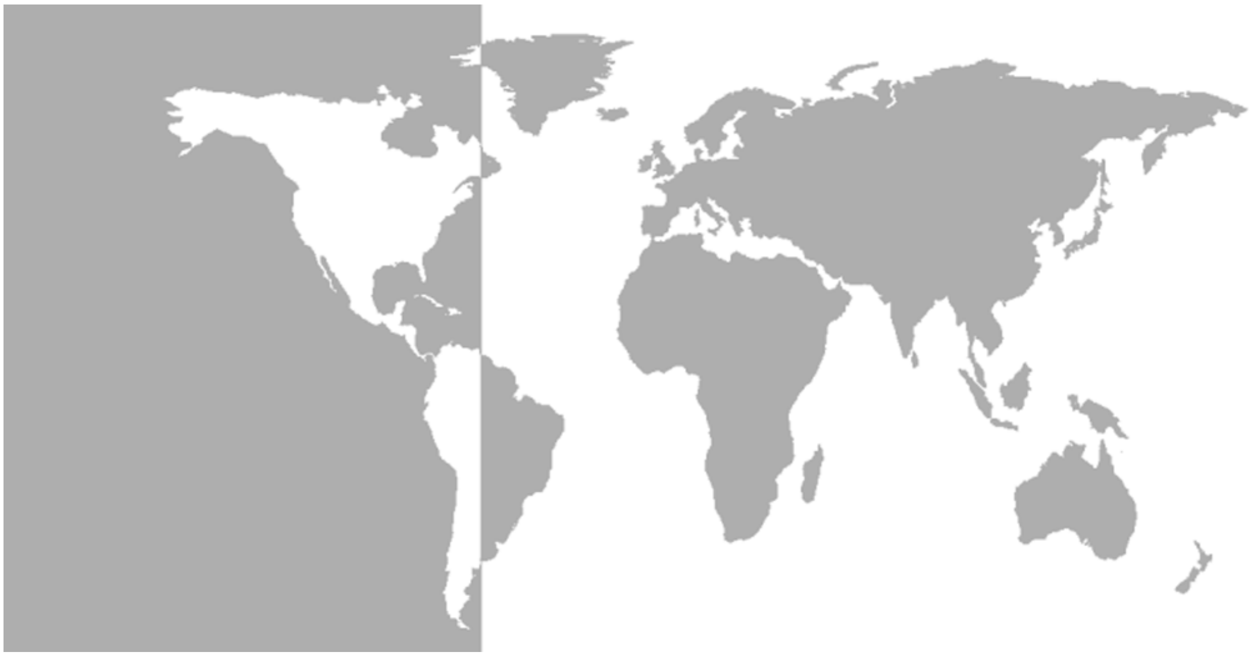
GE
Sensing



Hygro-M1 & Hygro-E1

General Eastern Optical Dewpoint Monitors

Owner's Manual

GE
Sensing

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Owner's Manual
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Hygro-M1 & Hygro-E1 Optical Dewpoint Monitors are General Eastern Instruments products. General Eastern has joined other GE high-technology sensing businesses under a new name—GE Sensing.

Warranty

Each instrument manufactured by GE Sensing is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to restoring the instrument to normal operation or replacing the instrument, at the sole discretion of GE Sensing. Fuses and batteries are specifically excluded from any liability. This warranty is effective from the date of delivery to the original purchaser. If GE Sensing determines that the equipment was defective, the warranty period is:

- one year for general electronic failures of the instrument
- one year for mechanical failures of the sensor

If GE Sensing determines that the equipment was damaged by misuse, improper installation, the use of unauthorized replacement parts, or operating conditions outside the guidelines specified by GE Sensing, the repairs are not covered under this warranty.

The warranties set forth herein are exclusive and are in lieu of all other warranties whether statutory, express or implied (including warranties or merchantability and fitness for a particular purpose, and warranties arising from course of dealing or usage or trade).

Return Policy

If a GE Sensing instrument malfunctions within the warranty period, the following procedure must be completed:

1. Notify GE Sensing, giving full details of the problem, and provide the model number and serial number of the instrument. If the nature of the problem indicates the need for factory service, GE Sensing will issue a RETURN AUTHORIZATION number (RA), and shipping instructions for the return of the instrument to a service center will be provided.
2. If GE Sensing instructs you to send your instrument to a service center, it must be shipped prepaid to the authorized repair station indicated in the shipping instructions.
3. Upon receipt, GE Sensing will evaluate the instrument to determine the cause of the malfunction.

Then, one of the following courses of action will then be taken:

- If the damage is covered under the terms of the warranty, the instrument will be repaired at no cost to the owner and returned.
- If GE Sensing determines that the damage is not covered under the terms of the warranty, or if the warranty has expired, an estimate for the cost of the repairs at standard rates will be provided. Upon receipt of the owner's approval to proceed, the instrument will be repaired and returned.

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Chapter 1

Introduction

Capabilities

The GE Sensing **Hygro-M1** and **Hygro-E1** are general-purpose optical condensation dewpoint hygrometers, suitable for use in many applications.

The **M1** is a benchtop indicator, ideal for both industry and laboratory. The **E1** is an environmentally enclosed indicator in a gasketed NEMA-12 housing, ideal for locations where dirt, dust, or moisture is present. These units can be used with a variety of GE Sensing chilled mirror dewpoint sensors to provide a measurement range of –75° to +95°C (–103° to +203°F).

Both the **Hygro-M1** and the **Hygro-E1** are calibrated against dewpoint standards that are traceable to the National Institute of Standards and Technology (NIST). When calibrated as such, the **Hygro-M1** or **Hygro-E1** can be used as a metrology standard in your laboratory or production area.

The **M1/E1** incorporates advanced microprocessor-based control, measurement, and display. Temperature readings can be displayed in Fahrenheit or Celsius units, as desired.

The **M1/E1** provides both analog and digital outputs. Analog outputs (4-20 mA and 0-5 VDC) as well as serial RS-232-C digital output are standard. The serial communications port gives direct access to the microprocessor and enables the user to program the limits on the analog outputs to fit the needs. Direct communication with a host computer is available over the RS-232-C port.

PACER and AUTO Options

The **M1/E1** is available with automatic balance (AUTO) only, or with GE's patented Programmable Automatic Contaminant Error Reduction (PACER) capability. The AUTO version of the **M1/E1** compensates for particulate contamination by periodically adjusting the light reflected off the dry mirror to match the sensor reference. This can be programmed to initiate at various intervals, or it can be manually activated.

The PACER uses an advanced design LED/photocurrent control, a significant improvement in autobalance circuitry. This feature drastically reduces the effects of airborne contaminants, and enables the instrument to check its own performance and to make any necessary optical adjustments. This helps to eliminate contamination induced errors and allows longer intervals between mirror cleanings.

Sensors

The **M1/E1** must be configured with a sensor. The dewpoint sensor is used with the electronics unit to determine the correct dew or frost point. Different sensors can be selected according to the dewpoint level and the environment in which the dewpoint is determined. GE Sensing provides the following sensors for various applications:

- Model 1111H - Single-stage sensor
- Model 1111L - Single-stage sensor
- Model 1211H - Two-stage sensor
- Model SIM-12H - Two-stage heated sensor
- Model 1311DR - Four-stage, liquid- or air-cooled sensor
- Model 1311XR - Five-stage, water-cooled sensor
- Model 11MP/12MP - Single- and two-stage aspirated sensors

Note: *See Appendix A for GE Sensing chilled-mirror dewpoint sensor specifications.*

Chapter 2

Features

System Components

The **M1/E1** system includes the following items:

- an electronic monitor
- a dewpoint sensor
- an interconnecting cable
- an AC line cord
- a maintenance kit
- an operations manual
- certification traceable to the National Institute of Standards and Technology (NIST)

The **M1** and E1 are functionally identical. They differ only in housing and location of switches and connectors. The E1 is in an environmentally enclosed version of the **M1**. See Appendix A for **M1/E1** and dewpoint sensor specifications.

Hygro-M1

Figure 2-1 below shows the **M1** with top and inner covers removed.

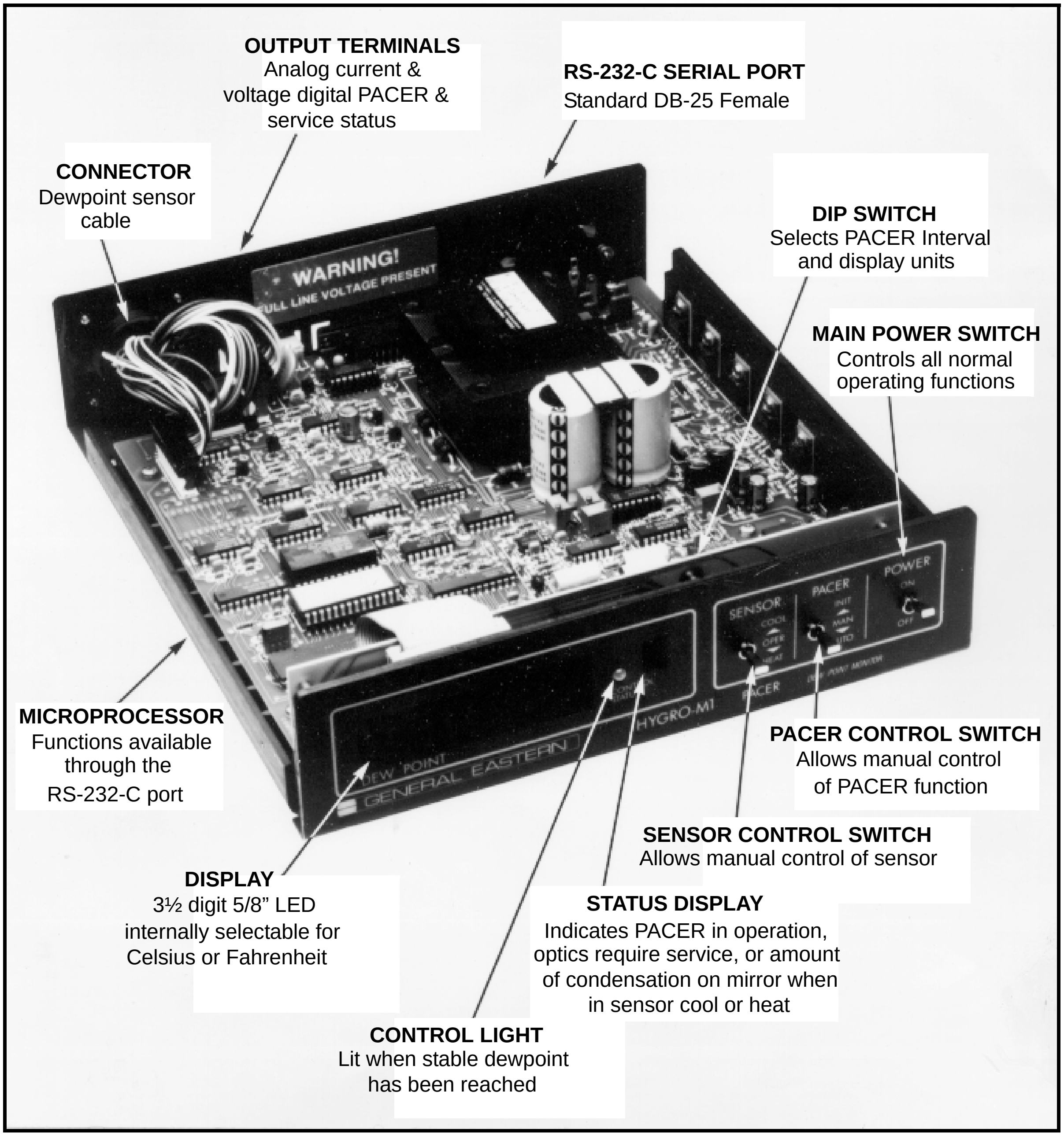


Figure 2-1: Hygro-M1 Dewpoint Monitor

Front Panel

Figure 2-2 on page 2-3 shows the **M1** front panel. The panel includes digital DEWPOINT and CONTROL/STATUS displays and three operating switches: SENSOR, PACER, and POWER.

DEWPOINT Display

The DEWPOINT display shows the dew or frost point in Celsius or Fahrenheit units.

CONTROL/STATUS Display

The CONTROL/STATUS display includes a green CONTROL light and a seven-segment display. The CONTROL light comes on when the system detects both a stable dew or frost layer and a stable dewpoint 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. (Seen only in HEAT or COOL mode.)

SENSOR Switch

The SENSOR switch 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.

OPERATE: Normal operation.

COOL: A momentary position that forces maximum cooling in order to check depression capability.

PACER Switch

AUTO: The PACER/AUTO cycle occurs at a preselected interval.

MANual: No PACER cycle unless manually initiated.

INIT: Momentary position that initiates a PACER/AUTO cycle.

POWER Switch

Main power.

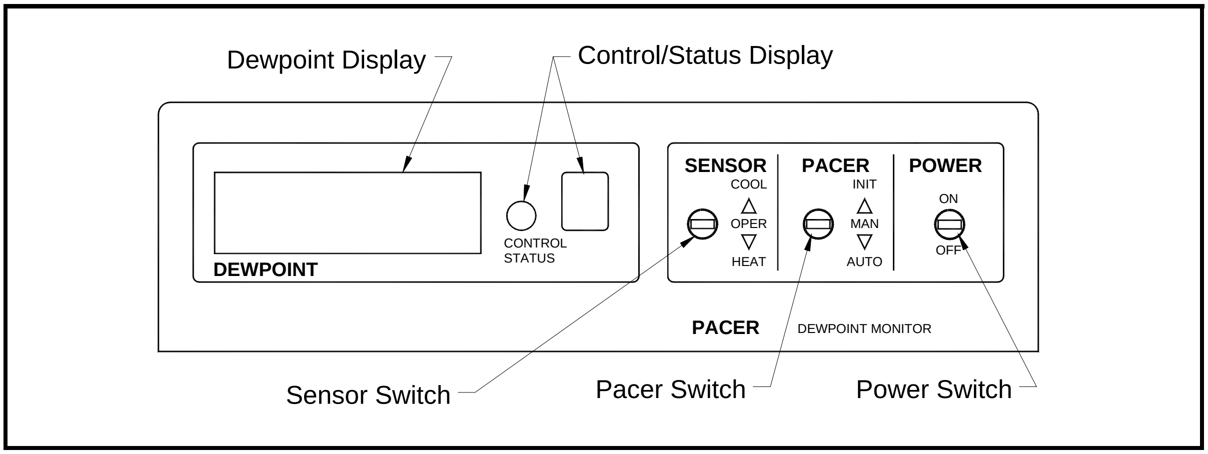


Figure 2-2: Hygro-M1 Front Panel

Rear Panel

Figure 2-3 below shows the rear panel of the **M1** dewpoint monitor, which includes input and output connectors and an RS-232-C interface.

- Line cord connector (AC).
- Fuse: 1A for 100 or 115VAC; ½A for 230VAC.
- RS-232-C digital output connector. Standard RS-232-C DB-25 female connector. For pin designations see Appendix C.
- Output terminal block.
- Dewpoint input connector for the sensor cable.

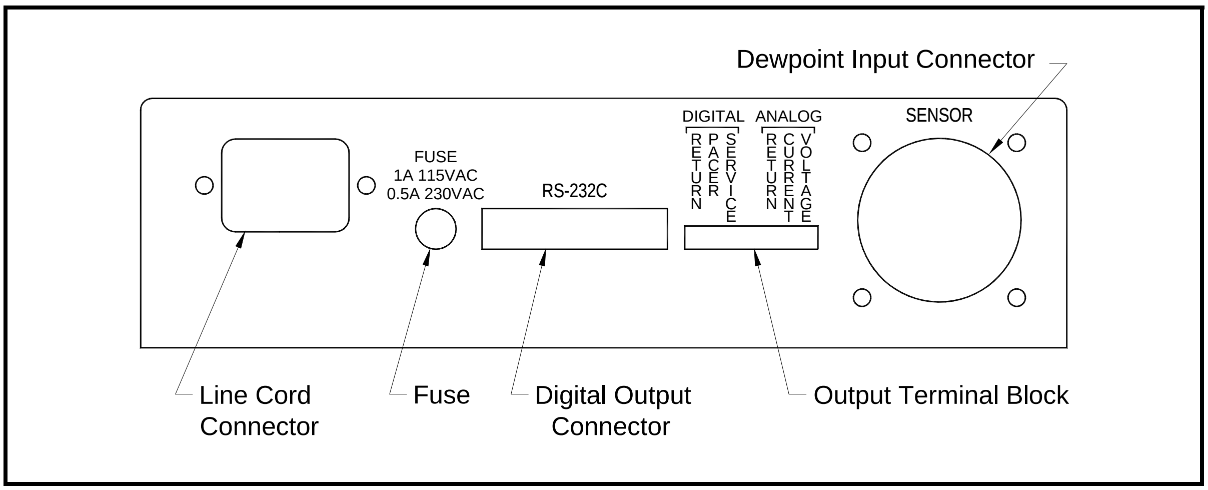


Figure 2-3: Hygro-M1 Rear Panel

Hygro-E1

Figure 2-4 below shows the E1 with the cover open. The E1 has a gasketed NEMA-12 housing to protect the unit from dirt and moisture.

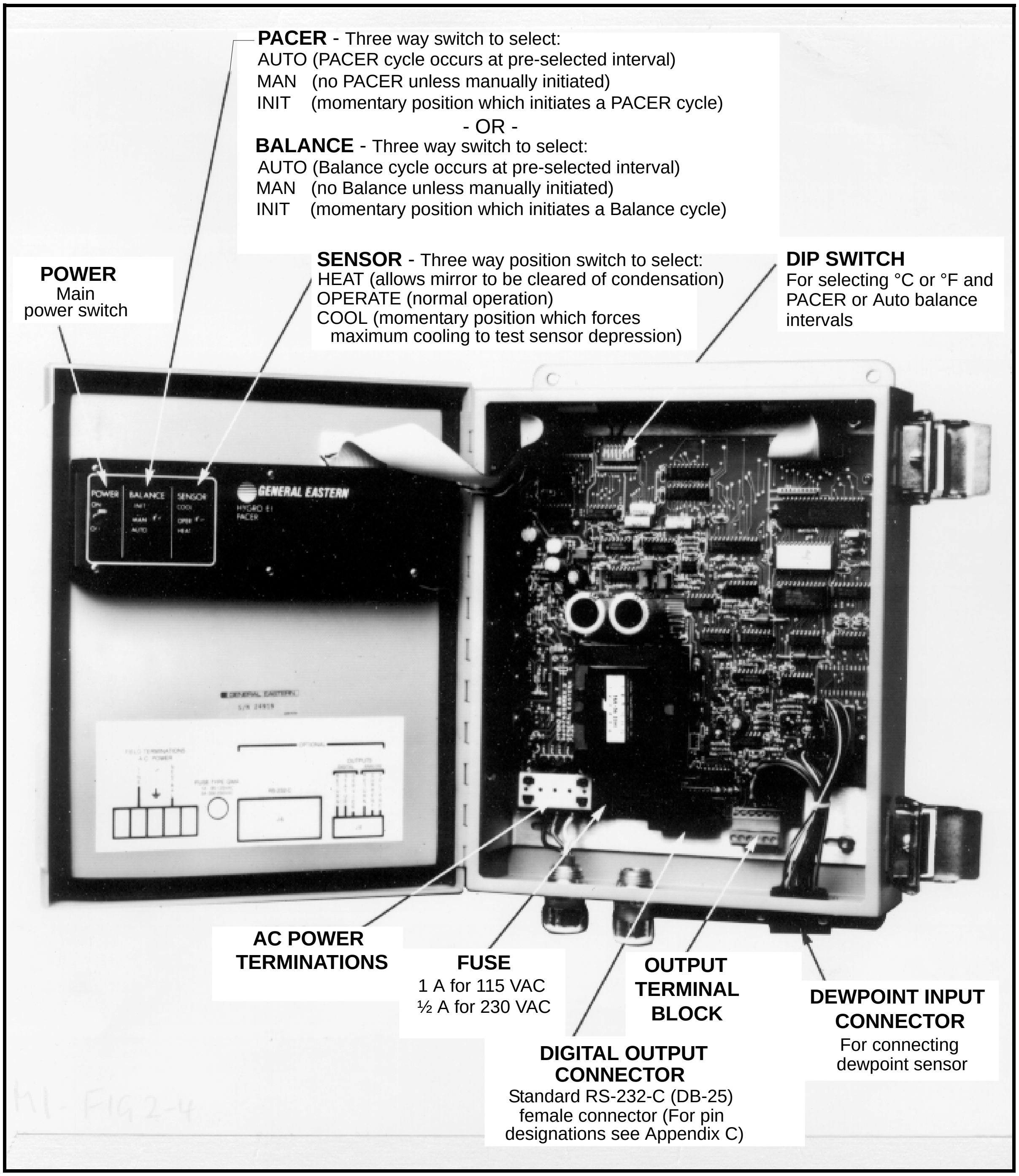


Figure 2-4: Hygro-E1 Dewpoint Monitor

Front Panel

Figure 2-5 below shows the E1 front panel. The E1 front panel displays the DEWPOINT and CONTROL/STATUS indicators. The SENSOR, PACER, and POWER switches are inside the housing. The input and output connectors are also within the housing.

DEWPOINT Display

The DEWPOINT display shows the dew or frost point in Celsius or Fahrenheit units.

CONTROL/STATUS Display

The CONTROL/STATUS display includes a green CONTROL light and a seven-segment display. The CONTROL light comes on when the system detects both a stable dew or frost layer and a stable dewpoint 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. (Seen only in HEAT or COOL mode.)

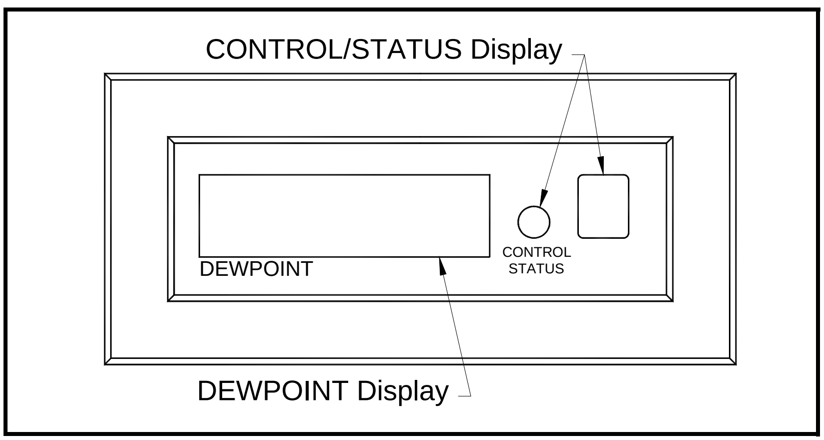


Figure 2-5: Hygro-E1 Front Panel

Theory of Operation

Optical Condensation Hygrometry

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

How Hygrometers Function

Figure 2-6 below illustrates how GE Sensing hygrometers detect and measure dew point. The condensate detection mirror is illuminated with a high-intensity, solid state, light emitting diode (LED). A photo detector monitors the LED light reflected from the mirror. A separate LED and photo detector combination are used to compensate for any thermally induced changes in the optical components.

The photo detectors are arranged in an electrical bridge circuit so that the specular detector is fully illuminated when the mirror is clear of dew. As dew forms on the mirror, the photo detector receives less light due to scattering losses. An optical offset is designed into the bridge, causing a large bridge output current to develop 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.

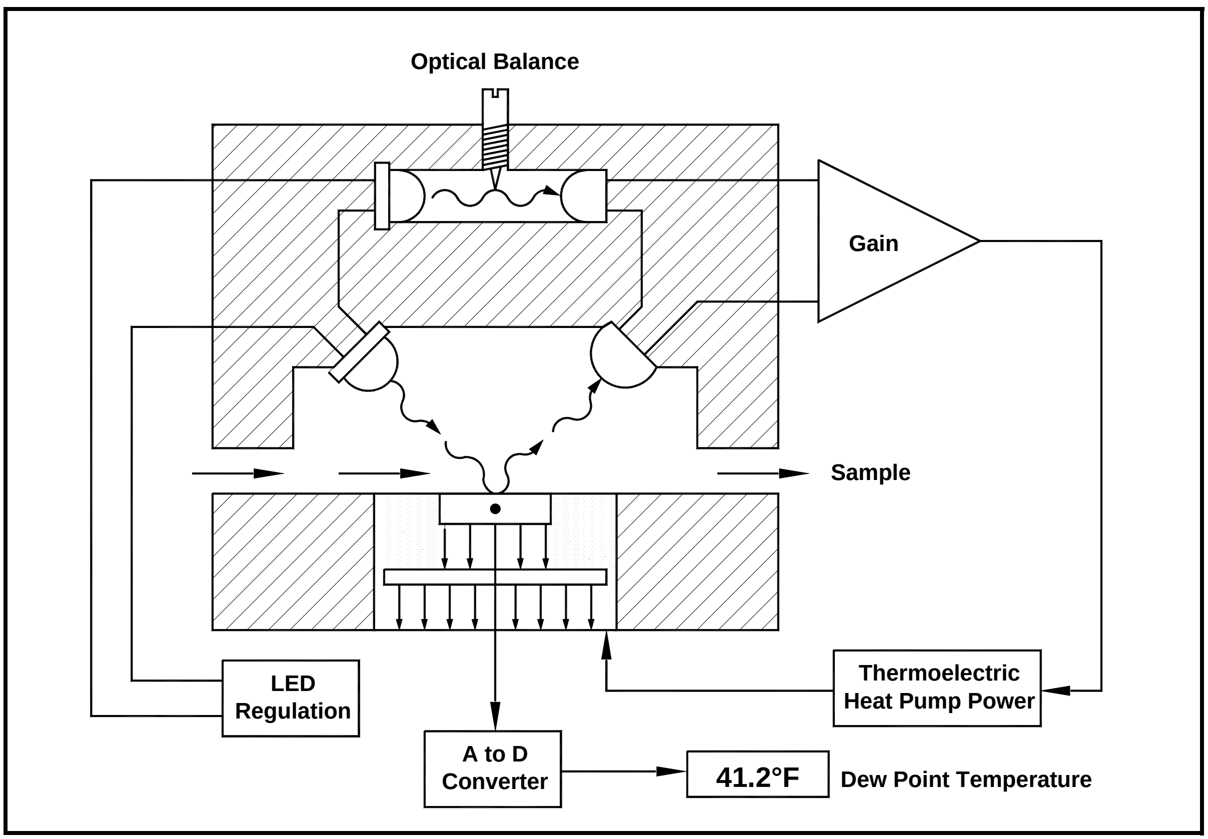


Figure 2-6: The Chilled-Mirror Hygrometer

How Hygrometers Function (cont.)

As dew begins to form on the mirror, the optical bridge is driven toward its balance point, causing a reduction in the mirror's light. This causes a reduction in bridge output and a decrease of the 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. A precision thermometer element embedded within the mirror directly monitors this dewpoint temperature.

Hygrometers as a Standard for Calibration

An optical condensation hygrometer such as the **M1/E1** can be sent to the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, for calibration against the NIST standard. These instruments can then be used as a transfer standards in local laboratories to calibrate lower echelon instruments. Hygrometers used as calibration standards must have the following characteristics:

- Mirror thermometers must have suitable long term accuracies (such as platinum resistance thermometers).
- A means must be provided for viewing the dew or frost formation on the mirror.

Other Optical Condensation Hygrometer Applications

The majority of condensation hygrometers in use in the world are applied to routine industrial problems, rather than to metrology. The optical condensation hygrometer, since it does not employ salt systems, resistance grids, or other secondary measurement schemes, is a totally inert sensor, and is not readily damaged or contaminated by industrial process gases. If the sensor or sampling components become contaminated with oils, salts, etc., they can be readily cleansed without harm to the sensor or impairment to the system accuracy. The performance of the hygrometer can be checked at any time by heating the mirror above the dewpoint, causing the dew deposit to evaporate, then reclosing the servoloop and noting that the system cools and controls at the same dew point.

The GE Sensing optical condensation hygrometer has a wide range of applications, limited only by the heat pumping capabilities of the thermoelectrically cooled mirror. At high dew points (up to 212°F/ 100°C), the sensor is limited only by the thermal properties of the solid state optical components and the thermoelectric heat pump.

To measure low dew points, a two-stage thermoelectrically cooled mirror can typically reach a temperature 40°C lower than an ambient (heat sink) temperature of +77°F (+25°C). By reducing the ambient temperature with auxiliary coolant such as tap water, or by applying the sensor in an environmental situation, such as in monitoring a test chamber, lower dew points can be measured. In meteorological applications where the heat sink temperature is considerably lower, frost points down to –103°F (–75°C) can be monitored.

Chapter 3

Installation

Introduction

This chapter shows how to set up the **Hygro-M1/E1** and its sensor unit. It also discusses filter requirements and recommended procedures for installing sample gas lines and fittings.

Installing Hygro-M1/E1

Before using the **M1/E1** for its intended purpose, give the system an initial bench check to become familiar with its operation and controls.

1. Visually inspect the exterior of the **M1/E1**.
2. Attach one end the AC line cord to the **M1/E1** and the other end (3-prong) to a suitable AC line receptacle. Check to see that the AC power line voltage is correctly set to one of the following options: 100V, 115V or 230V

Note: *If you are not sure what voltage the **M1/E1** is set to, remove the **M1** cover (or open the E1 hinged door) and check the jumpers shown in Figure 3-1 below.*

3. Obtain a compatible dewpoint sensor and connect the appropriate cable. Attach one end of the cable (plastic connector) to the **M1/E1** and the other end (metal connector) to the dewpoint sensor. This is necessary for the system to operate. See *Installing the Sensor* on page 3-3.
4. Set the SENSOR and PACER/AUTO switches to the center position and turn the instrument on, using the front panel POWER switch.

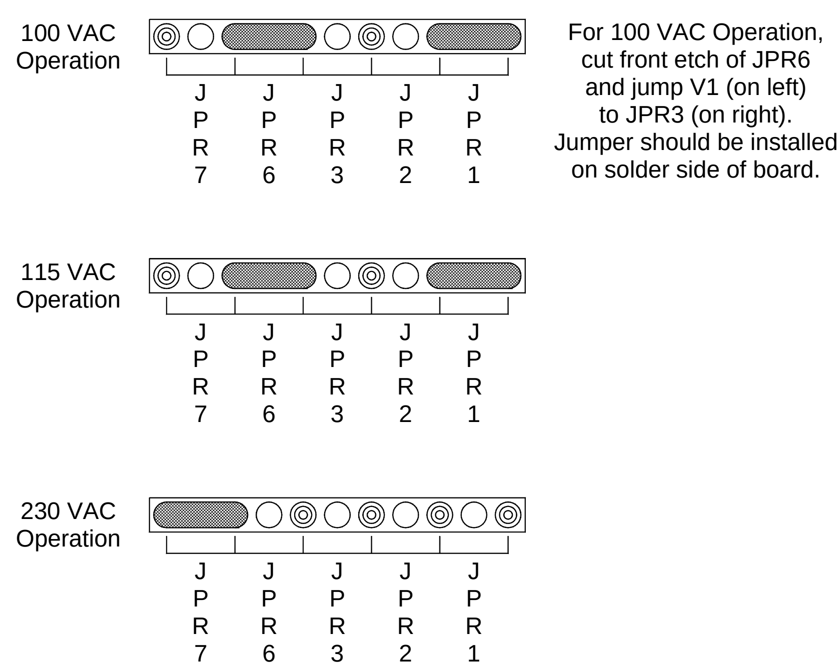


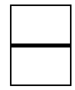
Figure 3-1: Jumpers for AC Line Voltage

Installing Hygro-M1/E1 (cont.)

At power on, the dewpoint display flashes

1888 °C

and the status block flashes a rectangular box with a horizontal bar.



The display clears, leaving **°C** lit. The status block then displays a series of bars in sequence: 1 bar, 2 bars, 3 bars, blank. After approximately two seconds, the status block displays

P

to indicate the **M1/E1** is in the initial PACER/AUTO cycle. After several minutes, the green CONTROL light comes on, the STATUS block goes blank, and the DEWPOINT display indicates the dewpoint temperature.

Note: *If the status block displays an "S" (Service), refer to* Minor Maintenance of Sensor Optics *on page 5-1, for information on cleaning, balancing, and checking the optics.*

5. GE Sensing ships the **M1/E1** with a Celsius display unless the order specifies otherwise. See *Selecting Fahrenheit or Celsius, and the PACER Interval* on page 4-4 for instructions on changing the display to Fahrenheit.

Panel and Rack Mounting

The **M1** can be mounted on an existing panel by ordering panel mounting brackets (PB-M1). See Figure 3-2 below for panel mounting dimensions.

A 19-inch adapter is also available for rack mounting. Contact the factory for more information.

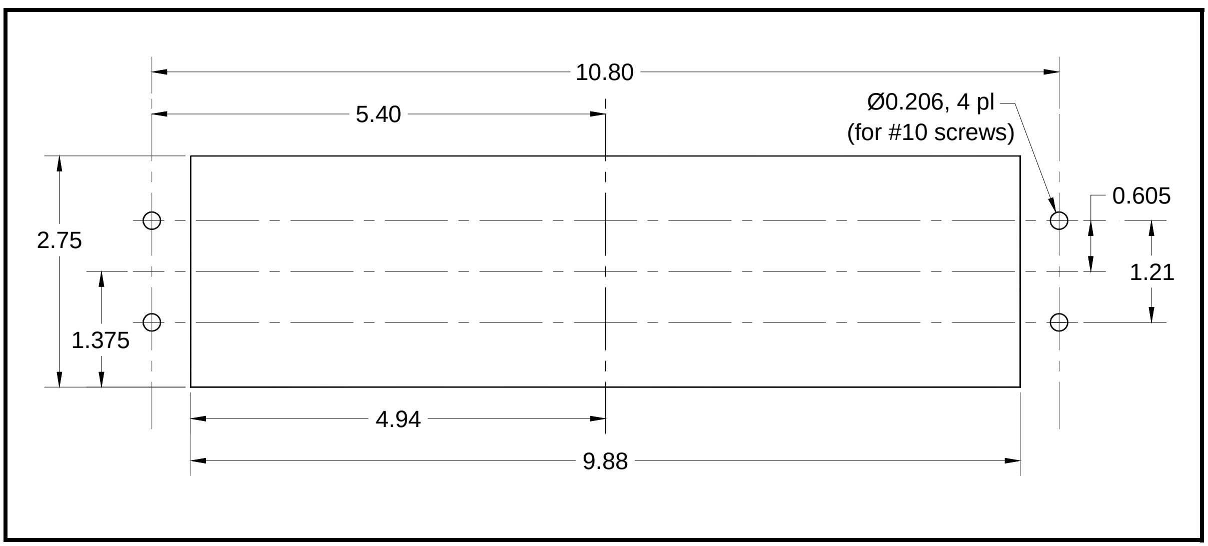


Figure 3-2: Hygro-M1 Panel Mounting Dimensions

Installing the Sensor - General Considerations

GE Sensing produces a variety of sensors compatible with the **M1/E1**, ranging from one to five stages of thermoelectric cooling. The following sections include information on installing these models of the GE Sensing dewpoint sensor.

- Model 1111H - Single-stage sensor
- Model 1111L - Single-stage sensor
- Model 1211H - Two-stage sensor
- Model SIM-12H - Two-stage heated sensor
- Model 1311DR - Four-stage, liquid- or air-cooled sensor
- Model 1311XR - Five-stage, water-cooled sensor
- Model 11MP/12MP - Single- and two-stage aspirated sensors

Location

The aspirated sensors have weatherproof housings. When ambient air measurement is required, they can be used for measuring humidity, either in a large indoor space (such as a manufacturing area, warehouse, or airplane hangar) or outdoors on a roof or tower for meteorological applications.

Note: *See Appendix A for GE Sensing chilled-mirror dewpoint sensor specifications.*

When selecting a location for a sensor, consider these criteria:

Locate the sensor as close to the measuring point as is practical. This minimizes the system response time and reduces error at low frost points due to line outgassing.

Choose a sensor location that provides read access to the dewpoint chamber cover. This facilitates periodic mirror cleaning.

The sensor must be able to transfer the heat pumped from the dewpoint mirror. For installations at typical ambient temperatures of 24° to 29°C (75° to 85°F), the sensor may be fastened to any smooth, flat surface that tends to remain at the ambient temperature (such as a metal plate, a metal wall, or a support beam).

Caution!
Never place the sensor in locations where temperatures rise above its maximum rated temperature. Refer to Appendix A for sensor specifications.

Sampling Lines

The points below are general information for any GE Sensing sensor. These are followed (on page 3-6) by instructions specific to particular models.

Use a short length of sample tubing between the source and the sensor. If compression fittings are provided, they are for ¼-inch diameter tubing. Allow for easy access to the sensor cover to facilitate periodic mirror cleaning.

The material used for the inlet lines can have an important bearing on the validity of the readings. Do not use rubber hose or plastic tubing such as PVC or Tygon because of their hygroscopic nature.

For measuring frost points below –30°C, stainless steel tubing and fittings must be used. Ensure that all plumbing is completely free from leaks. Venting should be done through an additional line 3 to 6 feet long, since backflow of ambient moisture into the sensor can take place even under positive pressure, altering the measured frost point.

At dew/frost points above –20°C, the choice is not as critical, and copper, PTFE, polypropylene, aluminum, or brass tubing and fittings may be used.

The sampling system design should allow for periodic cleaning. It may be helpful to install a tee and closing valve on the inlet side, to permit the sensor to be shut off while the sampling lines are flushed. At very low humidities, even a slight amount of contamination can alter measured frost point, so cleanliness is particularly important.

Ensuring Heat Transfer

Make sure the sensor has an adequate heat sink when operating in hot environments. The sensor must never be allowed to reach a temperature above its rated limit. It is not sufficient to merely ensure that the sensor is in an environment whose temperature is below its rated limit; it must also be able to transfer the heat pumped from the dewpoint mirror.

At typical ambient temperatures (24° to 29°C), full rated depression can be achieved when the sensor is mounted on a smooth thermally conductive surface such as a metal, which tends to remain at the ambient temperature. The GE Sensing maintenance kit supplied with each new instrument has a capsule of heat-conductive compound.

If possible, do not continuously operate the sensor at or near full depression. Doing so may decrease the anticipated life of the thermoelectric heat pump.

High Dewpoint Measurements

When measuring dewpoints at or above ambient temperature, the sensor must be heated to a temperature at least 5° to 10°C above the highest anticipated dewpoint, but not higher than the sensor temperature rating. Model 1211H sensors can be mounted on either a liquid heat exchanger or a temperature-controlled electric hot plate, or installed in a heated enclosure. The CJ-12 heat sink, which is available as an optional accessory, is intended for cooling chilled mirror sensors with chilled water or glycol to extend the low end of the frost point measurement range. This device is equally effective as a hot plate to extend the upper end of the measurement range beyond ambient temperature when used with hot water.

The sensor base should always be coated with zinc oxide-filled silicon thermal grease and securely anchored to the heat sink with suitable fasteners. Allow ½ hour for the sensor to reach thermal equilibrium after adjusting the temperature of the heat sink.

GE Sensing recommends controlling the elevated sensor body temperature. The GE Sensing SIM-12H high temperature sensor is designed for such applications, and measures dewpoints above ambient temperature without condensation problems. The SIM-12H should be used up to 50°C only when operated with the **M1/E1**. Control loop considerations may cause instability above this temperature.

Sampling Lines for High Dewpoint Measurements

Sampling lines carrying gas to the sensor must be heated and insulated when the dewpoint of the gas is above the ambient temperature at the location of the sample line. The simplest way to achieve this is to use heater tape that can be sized to provide the required temperature rise operating continuously, or can be thermostatically controlled. At high temperatures, use stainless steel tubing and insulation to avoid hot and cold sections in the line, and to avoid water absorption/desorption cycling when the heater is thermostatically controlled. Heated sampling lines are available from the factory.

Filter Requirements

If the gas to be monitored is free from particulates or hydrocarbon liquids or vapor, filtering is not necessary. However, most sample gas streams contain some particulates, and using a filter reduces the need for frequent mirror cleaning. On the other hand, filtering tends to slow response, particularly at low frost points.

The Balston Series 912 filters are effective for most applications; they are efficient, economical, and convenient, and their fittings are compatible with ¼-inch tubing. For particulates and liquid hydrocarbons, use a type DX filter element. To filter out very fine powder or dust, the type DX can be followed by a type BX filter. A type CI filter removes hydrocarbon vapors. If the sample gas is heavily and routinely contaminated, we recommend using a quickchange filter element. Avoid using glass wool, cellulose, and other hygroscopic materials as a filter medium.

Filter Requirements (cont.)

GE Sensing offers heated filters for dewpoints above ambient temperature. Contact the factory for more information.

Flow Rate

It is important to have adequate flow through the sensor. Too little flow can slow response (particularly at very low frost points). Too much flow can cause instability of the control system at high dewpoints and can reduce the depression capability of the cooling pump at very low dewpoints. Too much flow also accelerates the rate of system contamination. The range of 2 to 2.5 ft^3/h (a little over 1 L/min) is generally suitable, but in many cases it can be extended to the region between 0.2 to 5 ft^3/h (0.1 to 2.5 L/min).

Installing the Sensor - Details for Various Models

Models 1111H and 1211H

For maximum thermal conductivity, the base of the Model 1211H sensor can be coated with heat conductive grease. When so installed, the sensor handles dewpoints between ambient temperatures of 25.6° and –35°C (78° and –31°F).

Model 1311DR

Mount the 1311DR so that the air inlet and exhaust openings are free from obstruction. If the sensor is liquid cooled, vertical wall mounting is recommended.

For liquid cooling, tap water flowing at a rate of 0.5 to 1 gallon/min. should be available. Liquid cooling is not required for frost point measurements above –65°C (at 25°C ambient), although it may be desired for faster response. Switch the fan ON for air cooling. Switch the fan OFF for liquid cooling.

For the sample gas, use stainless steel lines that have a ¼-inch outside diameter. Carefully check all joints for leaks. If exhausting to atmosphere, place a few feet of unterminated tubing on the downstream side to prevent room air from entering the sensor cavity and causing a measurement error.

Model 1311XR

Connecting the System

All the electrical connectors on the Model 1311XR dew/frost point sensor are unique. The cables supplied with the sensor can interconnect the system in only one way.

1. Plug the instrument into a 115 VAC power outlet. Using the appropriate cable, connect the 37-pin round black connector (on the back of the instrument) to the 19-pin military style connector on the back of the 1311XR dew/frost point sensor.

Connecting the System (cont.)

2. Use the appropriate cable to connect the 17-pin military style connector on the back of the 1311XR to the 24-pin round connector on the back of the heat pump controller module.
3. Connect the 9-pin round connector (on the back of the heat pump controller module), using the appropriate cable, to the 8-pin rectangular connector on the back of the fourth stage heat pump power supply.
4. Plug the heat pump power supply into the 115 VAC outlet.

Note: *To operate the 1311XR on a voltage other than 115 VAC, a special unit must be ordered.*

Coolant

Connect the two 3/8-inch brass compression fittings on the back of the 1311XR sensor to the coolant lines. Do not run the instrument without sufficient coolant flow.

You can use water, glycol, alcohol, or another suitable noncorrosive liquid as the coolant. The coolant can be recirculated liquid or tap water that is cooled/chilled. If you are using a recirculating chiller, it should have a capacity of at least 600 watts.

Sample Gas Fittings

The 1311XR sensor has ¼-inch stainless steel compression fittings for sample gas inlet and outlet on the back of the sensor chassis.

Purging the Sensor

For maximum power operation, the sensor must be purged with a gas having a frost point lower than –20°C. For intermediate operation, any gas having a frost point at least as low as the sample gas is acceptable (the gas outflow can be used). Introduce the purge gas using the purge fitting on the rear of the sensor. The simplest method for purging is to run the sample gas outflow through the U-tube supplied with the sensor.

Caution!
The 1311XR must be purged either with sample gas after measuring it, or with another dry gas source. Otherwise, condensation inside the sensor housing may cause corrosion and eventual failure of thermoelectric coolers.

Aspirated Sensors: Models 11MP and 12MP

The following types of aspirated sensors are available:

- Model 11MP, a single-stage unit
- Model 12MP, a two-stage unit

When supplied as a meteorological system, the aspirated sensor comes with a 50-foot cable. The aspirator can be mounted by coupling to the ¾-inch NPT support. Alternatively, the support can be removed and the aspirator mounted directly to the boss on the casting, using stainless steel hardware.

If mounting on a tower, place the aspirator on the prevailing upwind side. Mount the aspirator at least six feet above a clear grassy area, away from sources of moisture or heat sinks, such as air conditioning vents. Avoid dust environments if possible.

Chapter 4

Operation

Starting Hygro-M1/E1

Startup and operation are simple. The instrument operates well in most environments, and no ongoing operational adjustments are required.

Units are normally supplied as a system consisting of the **M1/E1** monitor, a dewpoint sensor, an interconnecting cable, and an AC line cord. See *Hygro-M1* on page 2-2 and *Hygro-E1* on page 2-5 to become familiar with the **M1/E1** controls and displays. See *Installing Hygro-M1/E1* on page 3-1 and *Installing the Sensor* on page 3-3 for installation procedures.

At startup, the system goes through a brief self-testing mode. When the PACER/AUTO mode begins, the front panel dewpoint display goes blank and the status display shows a "P". The PACER/AUTO mode is automatically initiated on system startup or reset.

Although the displays and analog outputs are held static during this time, updated signals are still sent to the digital serial port. When the **M1/E1** finishes its startup and normalization cycle, it enters the CONTROL mode, indicated by the green CONTROL light. The system displays the dewpoint, which is updated once every second.

Control Status Indicators

The control status indicators consist of a green light and a seven-segment display. The CONTROL light comes on when the system detects both a stable dew or frost layer and a stable dewpoint temperature. The seven-segment display indicates the following:

(blank) Normal operation.

P PACER/AUTO cycle.

S System optics require service, cleaning, or adjustment. The "S" comes on after a PACER/AUTO cycle determines that the mirror is contaminated or the sensor needs adjustment. To remove the "S" from the display, correct the problem and execute another PACER/AUTO cycle.

(bars) The bars are approximate indicators of the thickness of the condensation layer on the mirror. These are displayed only while the sensor is switched to HEAT or COOL. In HEAT mode, the display enables the user to balance the sensor; in COOL mode the display indicates the level of condensation growth.

Analog Outputs

Analog outputs are derived from digital data, and are updated once every second along with the display and the serial RS-232-C output.

Unless specified otherwise, the analog scaling is set at the factory to be compatible with the selected sensor. Table 4-1 below shows the scaling used for the GE Sensing sensor models.

Table 4-1: Analog Scaling for GE Sensing Sensors

Sensor Model Number	Dewpoint °C	Dewpoint °F
1111L, 1111H, 1211H	–40° to +60°C	–40° to +140°F
SIM-12H	–25° to +100°C	–13° to +212°F
1311DR, 1311XR	–80° to +20°C	–112° to +68°F

The scaling can be changed in the field by means of the RS-232-C serial interface (see the section below on digital output). If no terminal or computer is available, the scaling can be changed at the factory.

Using the Digital Output

The **M1/E1** has an RS-232-C serial interface. This interface can be used to connect the **M1/E1** to devices such as a chart recorder, a printer, a terminal, or a personal computer.

The RS-232-C serial interface is configured as Data Terminal Equipment (DTE) and requires a null modem cable to the peripheral. This cable has leads 2 and 3 interchanged; the Request to Send (RTS) pin is not used. The baud rate is 1200. The format of the data word is as follows:

- 8 data bits
- 1 stop bit
- No parity

Other formats can be set at the factory. The system is full duplex, and echoes all characters it receives, except for backspace and delete. See Appendix C for information on configuring the RS-232-C interface.

At each update interval, dewpoint is sent to the serial output port. The format for each update cycle is as follows:

DP = *value*

In addition, the system sends the following status prompts using the interface for control purposes:

PACER	COOL	HEAT
SERVICE	SHUTDOWN	CONTROL

These prompts appear after the measurements themselves. The prompts are displayed with every update as long as they are active. All status words are followed by a carriage return.

Selecting Menu Functions Using the Serial Interface

The **M1/E1** presents the following menu on your terminal or computer screen using the serial interface:

1. Scale analog output.
2. Initiate a PACER/AUTO cycle.
3. Calibrate analog output.

To access this menu, press ESC (hexadecimal 1B) on the terminal and wait until the front panel of the **M1/E1** display goes blank. (On some computers or terminals, you may have to press ESC several times.) When interfacing to a computer, a terminal emulator must be used, and the emulator must be active before trying to access the menu.

The menu is not available when PACER/AUTO mode is active. When menu functions are active, the monitor deactivates the cooler control circuit and allows the mirror temperature to rise to ambient temperature. To exit the menu, type “E”. Upon exiting, the front panel returns to normal operation.

Scaling Analog Outputs

Tracking the analog outputs is always the same: 4 mA always corresponds to 0 VDC and 20 mA always corresponds to +5 VDC. Whenever current is changes, voltage is changed accordingly. Scale the analog outputs as shown below:

1. Type “1” and wait for the following menu (where value is the present setting of each parameter):

   DEWPOINT:
   20 mA = *value*
   4 mA = *value*

   PRESS ENTER TO SET LIMITS
   PRESS “E” TO EXIT

2. To change the 0 to 5 V analog output, enter the *value* (°C) desired to be 5.00 V at the 20mA prompt, then enter the *value* (°C) desired to be 0.00 V at the 4 mA prompt. The digital-to-analog converter is a 10 bit device having 1024 steps over the scaled range.
3. To change the entered values, press ENTER. The program then prompts for the appropriate values. Enter these values (in °C) and press ENTER again. To convert °F to °C, use the formula

   °C = (°F-32) / 1.8 Example: 77°F = 25°C

4. When entry is complete, the menu shown in Step 1 appears again with the new values.
5. To exit the menu, type “E”. The output is adjusted at the next update interval. The values are stored in nonvolatile memory and remain set until they are changed again in the same manner. Turning the power off does not change the values.

Initiating a PACER Cycle

To run a PACER/AUTO cycle, type “2”. This initiates the cycle, after which the instrument returns to normal operation.

Calibrating the Analog Outputs

Menu selection 3 is a utility for calibrating the analog outputs.

Note: *The analog outputs are calibrated at the factory and normally never require repeat calibration. To recalibrate the analog outputs, see* Testing Digital and Analog Outputs *on page 5-10.*

Selecting Fahrenheit or Celsius, and the PACER Interval

An 8-position DIP switch is mounted inside the **M1/E1**. Positions 1 and 2 of this switch determine whether the unit is displaying the dewpoint in degrees Fahrenheit or Celsius. Positions 5 through 8 determine the elapsed time interval between automatic PACER/AUTO cycles. Table 4-2 below defines the PACER DIP switch values.

Note: *On initial startup, the system initiates a PACER/AUTO cycle regardless of the DIP switch setting.*

Table 4-2: PACER/AUTO DIP Switch Values

Switch Position Closed (= ON)	Function/Value When Closed
1	(Switch No. 2 open) Display in °C
2	(Switch No. 1 open) Display in °F
Note: *One switch must be open and one closed at all times.*	
3	Reserved for future use.
4	Reserved for future use.
5	PACER/AUTO interval = 3 hours
6	PACER/AUTO interval = 6 hours
7	PACER/AUTO interval = 12 hours
8	PACER/AUTO interval = 24 hours
Note: *When switches 5 through 8 are open, there is no automatic PACER/AUTO interval. Only one switch (5 through 8) should be closed. If more than one switch is closed, the system defaults to the shortest interval switched on.*	

Helpful Hints

Time Response

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

Be careful in interpreting readings when the system is operating at very low frost points (below –40°C). As the frost point becomes lower, water molecules become scarcer in the air sample, and it takes longer to condense a frost layer on the mirror sufficiently thick to establish an equilibrium condition.

Time response depends on a number of factors: slew rate, dewpoint, upstream filtering, flow rate, etc. Slew rate is in turn dependent on dewpoint and depression; at high dewpoints and moderate depressions, it is typically 1.5°C/second. At lower dewpoints and/or larger depressions (the temperature difference between the mirror and the sensor body), slew rate becomes progressively slower. At very low dewpoints, response is also limited by the reduced availability of water molecules and the resulting slow crystal growth rate.

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.

Supercooled Dewpoints

When taking measurements in the frost point region of 0° to –20°C, the mirror may actually be controlling on the supercooled dewpoint, which is 0.5° to 1°C below the actual frost point. This can occur because water may exist in a liquid state for extended periods below 0°C, and the mirror deposit may not freeze for some time.

To assure that operation is in the ice phase at very low frost points, allow the instrument to operate continuously. Before a frost layer is cleared, take a reading, and afterwards allow sufficient time to reform a stable ice layer before taking further readings.

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

Materials 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 **M1/E1** 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 dewpoint, therefore, drifts upward with respect to the true dewpoint. Because the measurement error increases gradually, it often goes undetected.

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

1. Note the indicated dewpoint.
2. Clean the mirror.
3. Balance the detector by initiating a PACER/AUTO cycle.
4. Measure the dewpoint again.

If the new reading is lower than the first reading, soluble material is probably present in sufficient quantity to cause a measurement error.

Gaseous Contaminants

When a gaseous material is present (even in very low concentrations) that has a higher condensation temperature than that of water, the **M1/E1** will eventually control on that material rather than on water. The system then displays the condensation temperature of that material, not water. Such material accumulates on the mirror only while chilled. In the normal atmosphere, gaseous contaminants do not have a detectable effect.

Minimizing Effects of Contaminants

The PACER/AUTO feature reduces the effect of contaminants on **M1/E1** performance. The rate at which contaminants accumulate on the mirror can be reduced by reducing the gas flow rate. Clean the mirror when necessary (see *Cleaning the Sensor Mirror* on page 5-1). To determine the proper cleaning interval, take a dewpoint reading before and after cleaning. Any appreciable shift indicates that under the same conditions, the mirror should be cleaned sooner.

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 up by switching to HEAT to temporarily heat the mirror.

Sampling Line Maintenance

Contaminated sampling lines slow response time and can cause erroneous readings, usually on the high side. Clean the sampling lines as often as necessary. To determine required frequency, take dewpoint readings before and after cleaning the lines, sensor cavity, and mirror. If the two readings differ appreciably, the sampling lines should be cleaned more often. To reduce the rate of contamination, reduce flow and/or install a filter upstream.

Pressure Effects

If the pressure of the gas is increased or reduced from atmospheric pressure but the mixing ratio stays constant, the dewpoint is correspondingly increased or decreased. The **M1/E1** displays the dew/frost point at the pressure to which the sensor chamber is exposed. The sensor location and hookup arrangement can influence the pressure. The dewpoint change due to pressure change can be calculated by using Dalton’s Law and the Smithsonian Tables or a proper nomograph. Request a copy of GE’s *Humidity Handbook* for these tables and charts.

Operating the Sensors

The following sections provide operating instructions for various models of GE Sensing sensors (see *Installing the Sensor* on page 3-3).

Models 1111L and 1111H Sensors

The Model 1111L sensor is an open-type sensor, usually used for *in-situ* measurements, and can fit into a ¾-inch flange. In order to enclose the sensor and adapt it for a sampling system, the type 0111L sampling cell is available with ¼-inch compression fittings. The outer cover of the 1111L must be removed to put it in the sample cell.

The Model 1111H is also an open-type sensor, exhibiting higher accuracy and depression than the 1111L. It can be used *in-situ* or in a type 0111D pressure boss, which encloses it and adapts it for ¼-inch compression fittings. When using the 1111H as an open-type sensor with the black aluminum cover, be sure to install the cover in the closed rather than the open position. That is, install the cover so that light does not enter the sensor. Although the cover is a light baffle, it does allow an air sample to enter the sensor cavity. When installing the sensor in the pressure boss, remove the cover.

Model 1211H Sensor

The Model 1211H is an enclosed, general purpose sensor. For optimum operation, see *Installing the Sensor* on page 3-3.

Model SIM-12H Heated Sensor and Components

The SIM-12H heated sensor module enables heating of the chilled mirror sensor above the dewpoint of the sample gas. Three separate heaters are inserted in the walls 120° apart, three separate temperature sensors measure the body temperature at those points, and three separate control circuits precisely adjust the temperature of each heater. Thus, any sensed gradient across the sensor cavity is immediately eliminated, resulting in very even control. All three heaters are controlled at the temperature set by the front panel selector knob. The sensor is a two-stage unit, providing 65°C of depression capability, and a 60°C actual measurement range.

Type SIM-HFT Heated Filter Module

The SIM-HFT heated filter module enables the sample gas to be purged of particulate contaminants prior to entering the sensor. The incoming gas is first passed through a 90-micron pre-filter, then a 15-micron final filter. All parts in contact with the sample are heated to a constant 105°C, eliminating any possibility of condensation. The sintered filters are easily removed for cleaning or replacing if required.

Type SIM-HFM Heated Flow Meter

The SIM-HFM heated flow meter module enables the sample gas flow rate to be both measured and controlled at an optimum rate for the sensor. A front panel-mounted metering valve enables control over a range of 0 to 2 ft^3/h. All parts in contact with the sample gas are heated to a constant 105°C, so that no condensation occurs. The flow meter is normally mounted downstream of the heated sensor.

Type SIM-HSL Heated Sampling Line

The SIM-HSL heated sampling line is self-regulated at a temperature high enough to ensure that no condensation occurs. It is stocked in standard 15-foot lengths, and longer lengths are available on special order. The line is made of ¼-inch outside diameter PTFE, with stainless steel fittings.

Type SIM-MPL Mounting Plate

The SIM-MPL mounting plate is designed to accept one, two, or three heated modules: the heated sensor, the heated filter, and the heated flow meter. The mounting plate provides a convenient method for wall mounting the entire heated sampling system. When ordered with one or more modules, the factory does all the mounting, plumbing, and wiring, thus providing a complete system ready for installation.

Model 1311DR Sensor

The 1311DR is a stainless steel, liquid cooled, four-stage sensor. When operating it without liquid cooling, switch ON the built-in fan. At room temperature, in ambient conditions (25°C) with air cooling, measurements from +35° to –65°C can be taken. Sample flow rates from 0.5 to 5 standard cubic feet per hour (0.25 to 2.5 liters per minute) should be used. Do not exceed 5 ft^3/h.

For lower frost point measurements, ordinary tap water can be used for cooling. Measurements down to –75°C (1 ppm) can be made with 15°C water. Make sure the fan switch is OFF when using liquid cooling.

Caution!
If it can be avoided, do not continuously operate the sensor at or near full depression. Doing so may decrease the anticipated life of the thermoelectric heat pump.

Model 1311XR Sensor

The 1311XR is a stainless steel, water cooled, five-stage sensor. The system is operational when all connections have been made and the instrument turned on. The sample gas flow rate should be between 1 and 5 ft^3/h. The maximum permissible coolant temperature is +50°C; the minimum is –10°C. A minimum coolant flow rate of 0.1 gallons per minute must be maintained for most dewpoint measurements. If the fourth stage power supply control is set below –65°C, the minimum coolant flow rate is 0.25 gal/min. The coolant temperature affects the maximum dew/frost point depression. For frost points of –80°C, coolant temperature should be less than 20°C.

Setting the 1311XR Heat Pump Controller

The 1311XR heat pump controller module is part of the 1311XR sensor and has the following settings:

AUTO

When set to AUTO, the system operates completely automatically, controlling the heat pump in response to any dew/frost point within its operating range. In the AUTO mode, the controller senses the current supplied to the top two stages of the thermoelectric coolers by the **M1/E1**. The controller switches on the fourth stage power supply as required to maintain the mirror temperature at the dew/frost point.

Note: *AUTO is recommended for most applications.*

Below –55°C

If the frost point to be measured is BELOW –55°C, you can place the switch in this position to provide slightly faster response than the AUTO setting. However, depression is limited at this setting. For the lowest range, use AUTO.

–65° to –10°C If the dew/frost point is known to be between –65° and –10°C, place the switch in this position. This minimizes overshoot and settling time.

Above –25°C Set the switch to this position if the dew/frost point is ABOVE –25°C. This reduces overshoot and settling time.

Note: *The third-stage power indicator may blink in any range. This is normal.*

The Fourth Stage Power Supply Control Knob

The control knob on the 1311XR fourth stage power supply sets the power consumption limit and the coolant requirement when measuring dew/frost points in the AUTO or BELOW –55°C range. Set this knob to the lowest anticipated dew/frost point.

In the AUTO range, the stage power supply control knob can be set to the –80°C position to enable the Model 1311XR dew/frost point sensor to act as a turnkey system. The system will be able to cover its entire range automatically.

If the setting is too low for the true dew/frost point, the system dissipates excess power and requires cooling that is consistent with power dissipation. If the setting is too high, the system may not be able to reach the true dew/frost point.

1311XR Heat Pump Controller Error Conditions

The heat pump controller module has two overheat indicators connected to the thermal shutdown switches (one for the third stage, one for the fourth stage). If either (or both) of these indicators comes on, check for and correct problems before continuing operation. If the third stage overheat indicator is on, check the cable connections and the coolant flow and temperature. If the fourth stage overheat indicator is on, check the coolant flow and temperature.

Chapter 5

Service

Minor Maintenance of Sensor Optics

Periodically inspect and maintain the **M1/E1** sensor optics as described in the following paragraphs. These procedures can be done at any time but are necessary only when an "S" appears on the status display, indicating that service is required.

Cleaning the Sensor Mirror

Under normal conditions, the **M1/E1** is self-checking and self-balancing. However, there are occasions when particulate matter and water-soluble contaminants reduce sensor mirror reflectance and system accuracy (see *Mirror Cleanliness* on page 4-5). Clean the sensor mirror according to the procedure below:

1. Deactivate the sensor cooler by one of the following actions:
   - Turn the power OFF,
   - Place the SENSOR switch to HEAT, or
   - Disconnect the sensor cable.
2. Turn off the sample gas. Make sure the sensor cavity is depressurized before continuing to the next step.
3. Open the sensor by removing the sensor cover.
4. Moisten a cotton swab with a cleaning solution suitable for mirrors, such as the cleaning solution in the GE Sensing maintenance kit, or diluted methanol or alcohol. 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.
6. Return the switches to normal, initiate a PACER/AUTO cycle, and continue operation.

Balancing the Sensor Optics

If you observe that the service "S" flag reappears after a PACER/AUTO 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.

Place the SENSOR switch on HEAT, wait one minute, then observe the segment display on the **M1/E1**. If only the bottom bar is lit, the sensor is properly balanced. Otherwise, balance the sensor according to the following procedure. (See Figure 5-1 on page 5-2 for locating the adjustment screw and Figure 5-2 on page 5-3 for a flow diagram of the balancing procedure.)

Balancing the Sensor Optics (cont.)

1. If you have not already done so, clean the mirror as described above. Make sure to replace the sensor cover when checking the balance. If no bars are lit, or more than one bar is lit, go to Step 2.

Note: *Be sure to cover the mirror cavity while adjusting the balance screw, since ambient light can cause an offset. On the 1111H sensor, the cover should be installed with the side holes closed, not in the open position. On the 1211 and 1311 sensors, the hole can be covered by using a thumb or, if the sensor is horizontal, a coin can be dropped over the hole.*

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.

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 some light was allowed to enter the cavity. Place the SENSOR control switch back to OPERATE to stop heating the mirror.

4. Initiate a PACER/AUTO cycle by switching the PACER switch to INIT. At the completion of the cycle, the **M1/E1** is properly balanced.

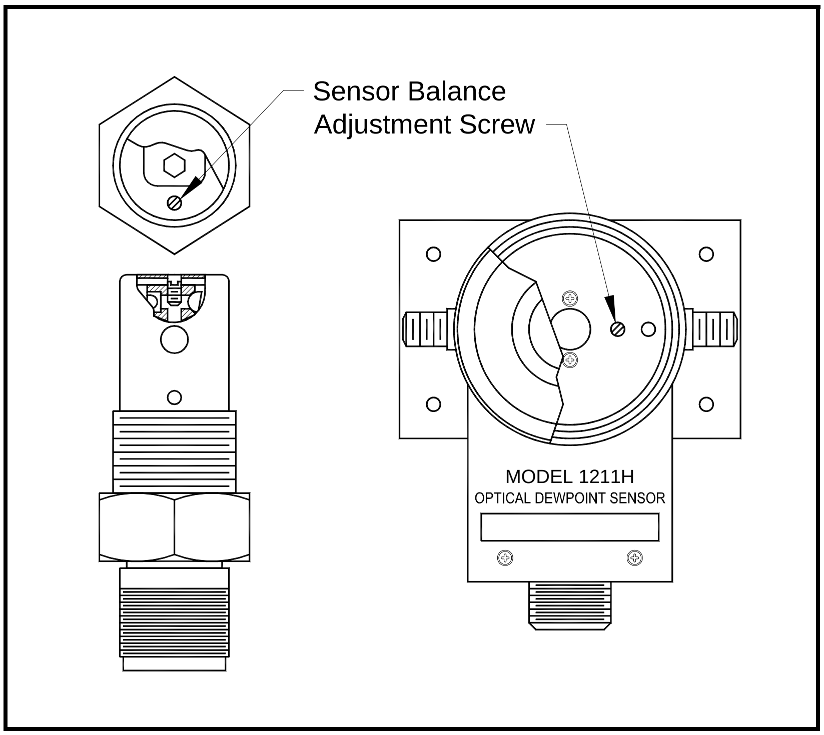


Figure 5-1: Sensor Balance Adjustment Screw Location

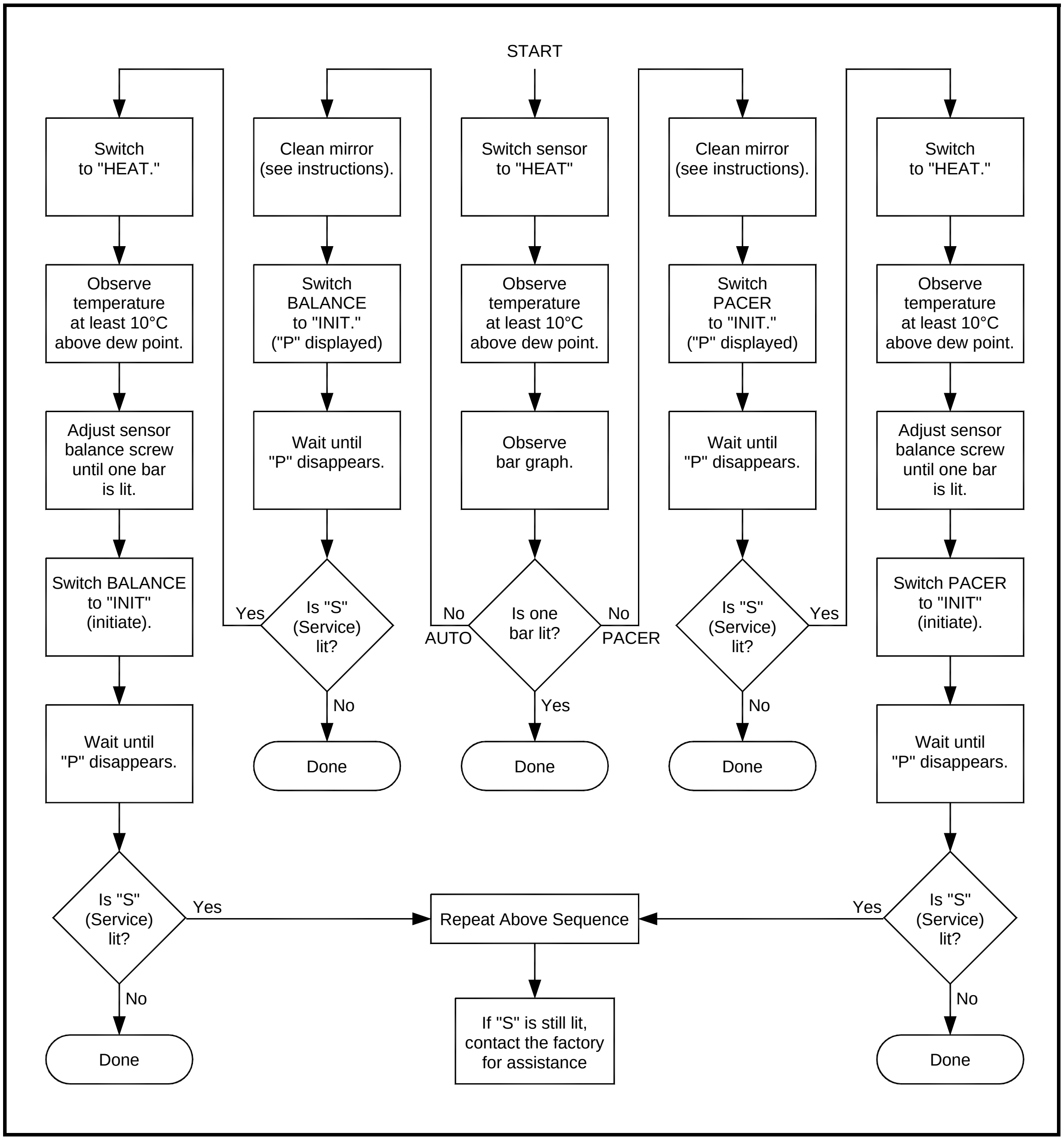


Figure 5-2: Sensor Balance Adjustment - Flow Diagram

Field Replacement of Sensor Mirrors

One advantage to using a GE Sensing chilled mirror dewpoint sensor is that the mirror can be replaced by the user. A sensor does not have to go back to the factory for replacement of the reflective surface, unless that is what is desired by the user. A mirror may require replacement for these reasons:

- The mirror is made of silver/rhodium plated copper. Copper provides excellent thermal conductivity to the platinum thermometer. However, some gas constituents, such as sulfur dioxide (SO_2) may react with the copper and eventually pit the surface or form a copper sulfate coating.
- The reflective surface may be gradually abraded by sharp dirt particles in the gas being measured.
- The mirror surface may be accidentally scratched or gouged during use or cleaning.

If the sensor mirror surface reacts with something corrosive in the gas sample, such as acid or sulfur compound, replace it with a solid platinum mirror so that there is no copper for the gas to attack.

A platinum mirror has occasionally been the difference between the success and failure of the hygrometer. For example, measurements in tobacco factories and malting houses have drastically improved after this change, since both have sample gas constituents that attack copper. In addition, fine scratches can be buffed out of a solid platinum surface, restoring the mirror to new condition, since it is of solid construction.

Replacing the Sensor Mirror

Required equipment: Torque wrench set to 20 inch-ounces of torque. A GE Sensing type TW-1 torque wrench can be ordered if needed.

1. Open the sensor by removing the sensor cover.
2. Using a 3/16-inch (0.187) hex socket, unscrew and then discard the old mirror.

Note: *The kit supplied by the factory includes the replacement mirror, a container of white thermal compound for proper heat transfer, and (in some models) a mylar washer that goes under the mirror.*

3. 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.

Replacing the Sensor Mirror (cont.)

4. Carefully screw in the new mirror and tighten it to the proper torque (20 inch-ounces).

Caution!
The mirror only protrudes approximately 1/16 inch above the surface. Ensure that the hex socket does not slip off while tightening, as this may mar the new mirror.

5. Carefully clean the mirror surface, using a cotton swab and the cleaning solution supplied in the maintenance kit. Alternatively, distilled water or diluted alcohol may be used.

6. 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.

Modification for Platinum Sensor Mirror

If an upgrade from the standard plated copper mirror to the solid platinum mirror is chosen, a circuit board change must also be made in the **M1/E1**. Capacitor C4 must be increased from 33 microfarads to approximately 68 microfarads, or instability may result.

If a system with the platinum mirror installed at the factory was received, an additional 33 microfarad capacitor, on nearby pads, has been added in parallel with C4.

If a platinum mirror was purchased to replace a standard mirror, the instrument may be returned to the factory for a no-charge circuit board modification. If the user prefers to install the modification, the factory will supply a field modification kit at no charge. A trained electronics technician with soldering skills is required for proper circuit board modification.

Test and Calibration

The procedures in this section test and/or calibrate the following aspects of the **M1/E1**:

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

The **M1/E1** 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.

Test and Calibration (cont.)

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

Since analog outputs are provided in this instrument for recording or controlling, a digital-to-analog converter is included, which can be adjusted as specified in the analog output calibration procedures of *Testing Digital and Analog Outputs* on page 5-10.

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

Testing Startup and Power Supply Voltage

Required equipment: Digital voltmeter.

1. Make sure the **M1/E1** has the correct fuse rating:

   1 A for 115 VAC

   0.5 A for 230 VAC

   Locate the fuse on the **M1/E1**. See Figure 2-3 on page 2-4 for the **M1** and Figure 2-4 on page 2-5 for the **E1**.

2. Set all the display and operating switches to OFF. (The ON/OFF switch is down, the SENSOR and PACER switches are in the middle position.)

3. With the sensor attached, switch ON the **M1/E1**. Monitor the startup voltage across C15. (See Appendix E for component layout diagrams and Appendix F for schematics.) The voltage should be at least 8.6 V.

4. Disconnect the sensor. While the **M1/E1** is ON, measure the power supply voltages after the front display has lit up. Use C15 as ground. Voltages should be as follows:

   BRI (TP1): 10 ±0.5 V

   Cathode of D2: 18 ±3 V

   Anode of D4: –8 ±2 V

   C9 or C20 positive (Digital Supply): 5 ±0.25 V

   Pin 5 of U2 (LM324): 2.5 ±0.05 V

Testing Normal Sensor Operation

1. Turn OFF the main power switch.
2. Open the **M1/E1** and locate the DIP switch on the display board. See Figure 2-1 on page 2-2 for the **M1** and Figure 2-4 on page 2-5 for the **E1**.
3. Select either the °F or the °C function, using the DIP switch.

   Set switch 1 ON (switch 2 OFF) for °C.

   Set switch 2 ON (switch 1 OFF) for °F.

   See *Selecting Fahrenheit or Celsius, and the PACER Interval* on page 4-4 for more information on setting the DIP switch.
4. Connect the sensor. Turn ON the power. The front display goes blank, then either °F or °C appears on the dewpoint display, according to the DIP switch setting.
5. Observe the following sequence:

   One bar appears on the bottom of the seven-segment display.

   Two more bars appear.

   A “P” appears on the front panel display, indicating that the **M1/E1** has started a PACER/AUTO cycle.
6. After the “P” goes off, the sensor is either in CONTROL mode with the green CONTROL light on, or an “S” appears on the display. If “S” appears, balance the sensor optics as described on page 5-1, or calibrate the **M1/E1** according to the next procedure.

M1/E1 Initial Calibration

Perform this procedure if an “S” appears when *Testing Normal Sensor Operation* (above) is being carried out.

Required equipment: Digital voltmeter.

1. Measure between ground (TP5) and pin 1 of U2 (LM324) (R75, right side). If the voltage is not –2.1±0.1 V, place the SENSOR switch on HEAT and note that the temperature rises.
2. Adjust the voltage for –2.1±0.1 V by using the balance adjustment screw on the sensor (refer to *Balancing the Sensor Optics* on page 5-1).
3. After adjusting the voltage, turn off the HEAT cycle and initiate a PACER/AUTO cycle. At the end of the PACER/AUTO cycle, the sensor resumes functioning and the “S” disappears from the front panel display. Also, the green CONTROL light comes on.
4. Check the control voltage. It should be between –1.6 and –1.8 V.

M1/E1 Initial Calibration (cont.)

5. Start another PACER/AUTO cycle. Measure the voltage between ground and R35 (top pin) (U23, pin 7). The voltage should be 0.62±0.03 V. When the sensor is balanced, voltage should change rapidly from 0 to 1.
6. Check the control voltage again.
7. Whenever a PACER/AUTO cycle begins, the sensor cools down until the time voltage on pin 1 drops to 1.5 V or until 90 seconds passes, whichever comes first. The **M1/E1** then heats up to –2.6 V, which may take 4 to 5 minutes, depending on the dewpoint. When the unit balances, the following sequence should occur:

   The voltage reaches –2.1 V ±0.1 VDC.

   The sensor controls within four minutes.

   The "P" disappears.

   The green CONTROL light comes on.

Note: *If the above sequence does not happen or the dewpoint display varies more than ±0.2°C, perform the* M1/E1 Fine Calibration *below.*

M1/E1 Fine Calibration

Perform these fine calibration procedures when the *M1/E1 Initial Calibration* does not produce the results specified above.

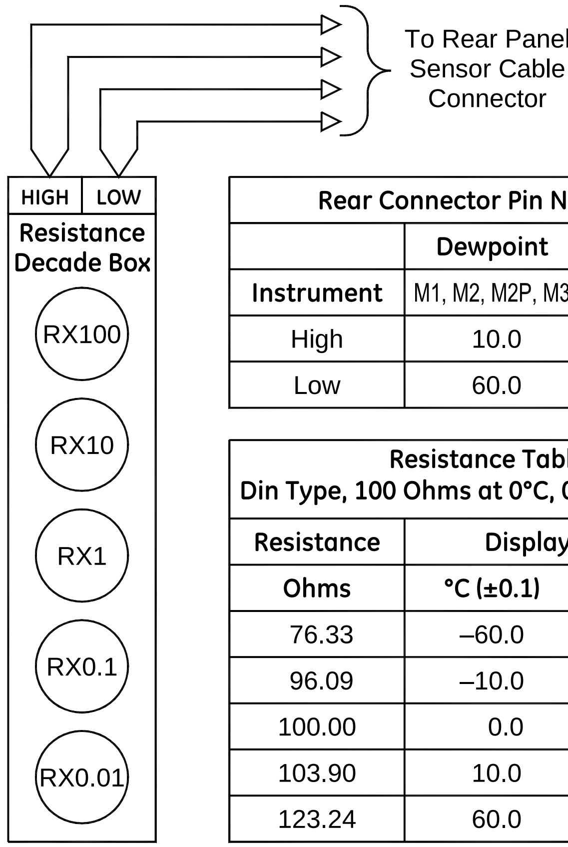
Required equipment:
Digital voltmeter.
Precision resistance decade box. (The resistance decade box simulates the sensor platinum thermometer resistance.)

Testing the Thermometry

1. Connect the decade box through the input for the sensor, using the wiring configuration shown in Figure 5-3 on page 5-9.
2. After connecting the resistance decade box, check to see that the resistance values in Table 5-1 correspond to the dewpoint display.

Table 5-1: Resistance and Dewpoint Values

Resistance	°C Display	°F Display
76.33 ohms	–60.0	–76.0
92.16 ohms	–20.0	–4.0
96.09 ohms	–10.0	+14.0
100.00 ohms	0.0	+32.0
103.90 ohms	+10.0	+50.0
123.24 ohms	+60.0	+140.0



Rear Connector Pin Numbers		
	Dewpoint	**Air Temp.**
Instrument	M1, M2, M2P, M3	M2, M3
High	10.0	50.0
Low	60.0	140.0

Resistance Table Din Type, 100 Ohms at 0°C, 0.385 Ohms/°C		
Resistance	**Display Reading**	
Ohms	**°C (±0.1)**	**°F (±0.2)**
76.33	–60.0	–76.0
96.09	–10.0	14.0
100.00	0.0	32.0
103.90	10.0	50.0
123.24	60.0	140.0

Figure 5-3: Resistance Decade Box Wiring Configuration

Testing the High Temperature Interlock

1. Keep the resistance decade box connected to the **M1/E1**.
2. Jumper pins A and B on the dewpoint sensor connector with a bus wire. Select HEAT mode with the SENSOR switch.
3. Measure across the R28 0.1 ohm resistor. It should read 0.07 V.
4. Switch to COOL mode and measure again. The R28 should read approximately 0.220 V.
5. Switch the **M1/E1** back into HEAT mode.
6. Set the resistance box dial to 140.5 ohms, which is 105.0°C. The voltage across the R28 0.1 ohm resistor should go close to 0, activating shutdown.
7. Now decrease the resistance value. When the voltage goes to 0.07 V across R28 (below 103°C), the system should reactivate.
8. Remove the jumper between A and B. Set the SENSOR switch to OPERATE.

Testing Automatic Dew/ Frost Switching

1. Keep the resistance decade box connected to the **M1/E1**. Measure the following between C15 (ground) and R16 (bottom pin).
2. Set the resistance box dial to 100.0 ohms (0°C). Voltage should be Low (0.160V ±0.03V).
3. Select 92.16 ohms (–20°C). Voltage should go High (3.62±0.03V).
4. Select 97.5 ohms. Voltage stays High.
5. Select 98.5 ohms. Voltage goes Low.

Testing Digital and Analog Outputs

Required equipment:
Digital voltmeter.
Precision resistance decade box.
Computer terminal.

Testing Service Status Voltage

1. Simulate a service condition by starting a PACER/AUTO cycle with no sensor attached.
2. Locate the PACER and SERVICE outputs in the Output Terminal Block (see Figure 2-3 on page 2-4 for the **M1** and Figure 2-4 on page 2-5 for the **E1**).
3. Connect the voltmeter to the PACER output. When the PACER/ AUTO cycle is in progress, the PACER output should be High (3.8 to 4.6 V).
4. Connect the voltmeter to the SERVICE output. When “S” appears on the display, the SERVICE output should be High (3.8 to 4.6 V).
5. Check to see that the SERVICE and PACER outputs are Low (less than 1V) during normal operation.

Scaling Analog Outputs

1. Connect the computer terminal to the **M1/E1**. See Appendix C for information on configuring and interfacing on a computer terminal.
2. Connect the precision resistance decade box to the **M1/E1** as described in *Fine M1/E1 Calibration* on page 5-8.
3. Turn on the **M1/E1** and allow it to go through its normal startup.
4. Locate the analog voltage connector of the Output Terminal Block on the **M1/E1** (refer to Figure 2-3 on page 2-4 for the **M1** and Figure 2-4 on page 2-5 for the **E1**).
5. Connect the voltmeter to the analog voltage connector.
6. Dial in 140.50 ohms. SHUTDOWN will appear on the computer terminal.
7. Reduce the resistance to 139 ohms. This deactivates SHUTDOWN.

Scaling Analog Outputs (cont.)

8. Press ESC on the terminal keyboard. The computer displays the following menu:

1. Scale analog output
2. Initiate a PACER/AUTO cycle
3. Calibrate analog output

9. Select "1" and press ENTER. The following menu appears:

DEWPOINT:
20 mA = *value*
4 mA = *value*

PRESS RETURN TO SET LIMITS
PRESS "E" TO EXIT

Note: *If voltage output (0 to 5 VDC) is entered instead of current output, simply enter the desired values for the 4 to 20mA current range on the computer display, i.e., enter a value at the 20mA prompt to apply to 5 VDC and enter a value at 4mA to apply to 0 VDC. The 0 to 5 VDC voltage output scaling is identical to the current scaling.*

10. All analog output is in the range of 4 to 20mA (and 0 to 5 VDC). Set the dewpoint range according to the type of sensor being used. Table 5-2 below shows the standard analog output ranges for GE Sensing sensors.

Table 5-2: Analog Scaling for GE Sensing Sensors

Sensor Model No.	Dewpoint °C	Dewpoint °F
1111L, 1111H, 1211H	–40° to +60°C	–40° to +140°F
SIM-12H	–25° to +100°C	–13° to +212°F
1311DR, 1311XR	–80° to +20°C	–112° to +68°F

For example, if the Model 1211H sensor is being used, type in 60 (and press ENTER) after the 20 mA prompt. Next, type in –40 (and press ENTER) after the 4 mA prompt:

DEWPOINT:
20 mA = *60*
4 mA = *–40*

This sets the analog output range. The computer displays the main menu again. Now continue with the next procedure to calibrate the analog outputs.

Calibrating Analog Outputs

1. Select “3” from the main menu for calibrating the analog outputs. The computer prompts for

   Input -

   These are the counts. The digital-to-analog converter is a 10-bit device having 1024 steps (0 to 1023) over the scaled range of 4 to 20 mA.

2. Type *0* and press ENTER.

   Input = *0*

3. Using a small screwdriver, adjust R33 for 0.00 V output.
4. Press ENTER. The computer prompts for input.
5. Type *1023* (5 V) and press ENTER.

   Input = *1023*

6. Adjust R32 for 5.00 V output.
7. Press ENTER to get the input prompt. Repeat Steps 2 through 5. Adjust the voltage until the 0 to 5 V output is precise.
8. Press ENTER to get the input prompt. Type *511* and press ENTER. The voltmeter displays 2.50 V.
9. Switch the voltmeter to the Current connector on the Output Terminal Block.
10. Press ENTER to get the input prompt. Enter *0* (4 mA).

    Input = *0*

11. Adjust R48 for 4.00 mA output.
12. Press ENTER to get the input prompt. Enter *1023* (20 mA).

    Input = *1023*

13. Adjust R48 for 20.00 mA output.
14. Press ENTER. Repeat Steps 10 through 13. Adjust the current until the 4 to 20 mA output is precise.
15. Press ENTER to get the input prompt. Enter 511. The voltmeter displays 12.00 mA.
16. Type “E” and press ENTER. The scale analog output menu appears with the new values. Type “E” to exit the program.

Troubleshooting

The following troubleshooting procedures refer to various components inside the **M1/E1**. To locate a component, refer to the component layout diagrams in Appendix E. To understand the function of a component, see the schematic diagrams in Appendix F.

M1/E1 Doesn't Light When Powered Up

- Check the POWER switch on the front panel. Make sure it is ON.
- Check the line cord. Make sure both ends are plugged in and 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 (refer to *Installing the Hygro-M1/E1* on page 3-1).
- Check the fuse. Make sure the proper fuse size is installed. Make sure the fuse is not open.
- Check the black and white wires that go from the main board to the display board. Make sure they are properly connected to both boards.

No Cooling and/or Heating

The front panel dewpoint display should indicate if heating or cooling is not functioning. When the sensor HEAT switch is turned on, the digital display should show an increase in temperature. When the COOL switch is turned on, it should show a decrease in temperature.

It is possible that the sensor thermoelectric cooler has failed. To test this, do the following:

1. Disconnect the sensor from the sensor cable. Using a wire jumper, jump pins A and B at the sensor end of the cable connector. Place a digital voltmeter across resistor R28 on the main board. The voltmeter should read approximately 0.24 VDC when the COOL switch is depressed.
2. Actuate the SENSOR HEAT switch on the front panel. The digital voltmeter should read approximately 0.06 V.
3. If these voltages read correctly, the sensor thermoelectric cooler has failed. Return the sensor to the factory for servicing.

"S" Appears on the Front Panel Display

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

Clean the sensor mirror as shown on page 5-1. Next, run the instrument through a PACER/AUTO cycle. If at the end of the cycle the "S" comes on again, balance the sensor optics as described on page 5-1.

The sensor optics can be more precisely balanced by using a voltmeter when adjusting the balance screw. Follow the steps below:

1. Open the **M1/E1** and place a digital voltmeter between test point 1 and test point 3 on the chassis. The voltage should read between 2.00 and –2.08 V.

"S" Appears on the Front Panel Display (cont.)

2. If the voltage is out of range, adjust the optical balance screw for the proper voltage. Turn CLOCKWISE to increase the voltage; turn COUNTERCLOCKWISE to decrease the voltage.
3. When the optical balance adjustment is complete, put the SENSOR switch on OPERATE and initiate a PACER/AUTO cycle.

At the end of this cycle, the "S" should not be illuminated and correct dewpoint readings should be obtained.

Invalid Dewpoint Display

1. Clean the mirror as shown on page 5-1.
2. Balance the sensor optics as described on page 5-1.
3. If the above procedures have been done, verify that the platinum resistance thermometer in the sensor is reading correctly:
   a. Disconnect the 6-pin J9 connector from the main circuit board in the **M1/E1**. Once J9 has been disconnected, the front panel dewpoint display should the read ambient temperature after a few minutes. Allow sufficient time for the sensor mirror to stabilize at the new temperature.
   b. Check the temperature reading against another reliable thermometer placed near the dewpoint sensor. The thermometers should match the specifications of the test thermometer within ±0.2°C.
   c. If the platinum resistance thermometer is faulty, return the sensor to the factory for servicing.

Alternatively, a precision resistance decade box can be connected to the sensor cable to simulate the platinum resistance thermometer. Use the fine calibration procedure on page 5-8.

"P" Remains Lit on the Front Panel

When "P" remains lit on the front panel, the instrument has not recovered from a PACER/AUTO cycle.

1. Check to see that the sensor and sensor cable are connected. If they are not connected, connect them now. The instrument will come out of PACER/AUTO mode after a short time.
2. The sensor optical bridge may be out of balance. Perform the optical balance procedure described on page 5-1.

No Analog Output (but the Digital Display Operates)

1. Check the digital-to-analog converter stage.
2. Check the analog output scaling. Refer to *Scaling Analog Outputs* on page 5-10.

No Digital Output from the RS-232-C Port

The instrument may not have been scaled properly using the RS-232-C port. Repeat the procedure in *Testing Digital and Analog Outputs* on page 5-10.

Appendix A

Specifications

Operating Range

Dewpoint Sensors

Dewpoint:	–80° to +50°C (–112° to +122°F) Consult factory for higher temperature operation.
Ambient Temperature:	–40° to +93°C (–40° to +200°F)
Pressure:	0 to 300 psia (to 21 kg/cm^2)

M1/E1 Instrument

Temperature Range:	0° to +50°C (+32° to +122°F)
Humidity Range:	0% to 85% relative humidity
Sample Flow Rate:	0.5 to 5 ft^3/h (0.25 to 2.5 liters/min)

Performance

Accuracy (at 25°C ambient):	Complete system: ±0.2°C M1/E1 electronics unit only: ±0.05% of input
Sensitivity:	Better than 0.05°C, complete system
Hysteresis:	None
Response Time (Sensor):	1.5°C/s (typical above 0°C)
Update Time:	1 second

Available Outputs

Analog:	Current: 4 to 20 mA, 0 to 500 ohm load Voltage: 0 to 5 VDC, 5 mA max.
Output Scaling:	See *Analog Outputs* on page 2-2
Digital:	RS-232-C serial I/O (RS-422 available as an option)
Resolution:	±0.1° on 3½ digit display
Dew/Frost Point:	Celsius or Fahrenheit, internally selectable

Power 100/115/230 VAC, jumper selectable; 50 to 60 Hz; 35 watts

Weight

M1: 3.6 kg (8 pounds)

E1: 5 kg (11 pounds)

Available Sensors Optically detected condensation type dewpoint sensor, 1 to 5 stages:

Models:

- Model 1111H - Single-stage sensor
- Model 1111L - Single-stage sensor
- Model 1211H - Two-stage sensor
- Model SIM-12H - Two-stage heated sensor
- Model 1311DR - Four-stage, liquid- or air-cooled sensor
- Model 1311XR - Five-stage, water-cooled sensor
- Model 11MP/12MP - Single- and two-stage aspirated sensors

Sensor Cable Length: 3 m (10 ft) standard
90 m (300 ft) available

Appendix B

Humidity Equations and Conversion Chart

Introduction

The following symbols appear in the equations which follow:

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:

$$e_{ws} = 6.1121 \exp\left[\frac{17.502T}{240.97 + T}\right] \qquad \text{(B-1)}$$

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

$$e_{is} = 6.1115 \exp\left[\frac{22.452T}{272.55 + T}\right] \qquad \text{(B-2)}$$

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 pressure each gas would exert, were it to occupy the same total volume, according to Dalton’s law.

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_a):

$$\%RH = 100\left(\frac{e}{e_s}\right) = 100\left[\frac{e_w(T_d)}{e_{ws}(T_a)}\right] \qquad \text{(B-3)}$$

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

$$\frac{g}{m^3} = \frac{216.7e(T_d)}{T + 273.16} \qquad \text{(B-4)}$$

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

$$PPM_V = 10^6\frac{e(T_d)}{P - e(T_d)} \qquad \text{(B-5)}$$

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:

$$PPM_W = (0.622 \times 10^6)\frac{e}{P - e} \qquad \text{(B-6)}$$

See Figure B-1 on page 3 for a graphical humidity conversion chart.

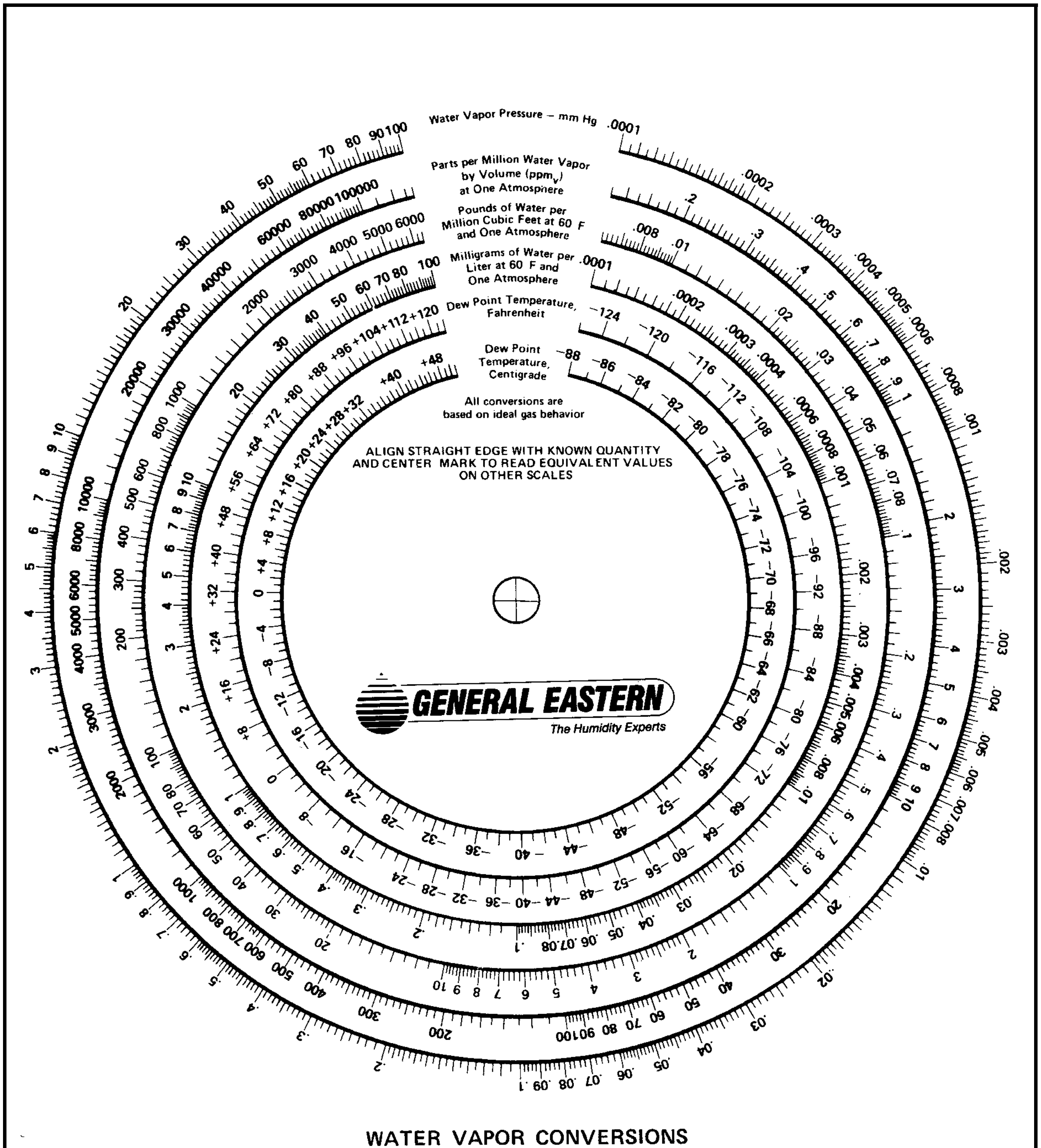


Figure B-1: Temperature/Humidity Conversion Chart

Appendix C

Configuring the RS-232-C Interface

Wiring to a Terminal or Terminal Emulator

The **Hygro-M1/E1** is configured as Data Terminal Equipment (DTE). The following pins are used on the RS-232-C interface:

- 2 - Transmitted data (**TXD**)
- 3 - Received data (**RXD**)
- 7 - Signal ground (**GND**)

To send the output of the **M1/E1** to a terminal or a terminal emulator, use the cable arrangement shown in Figure C-1 below.

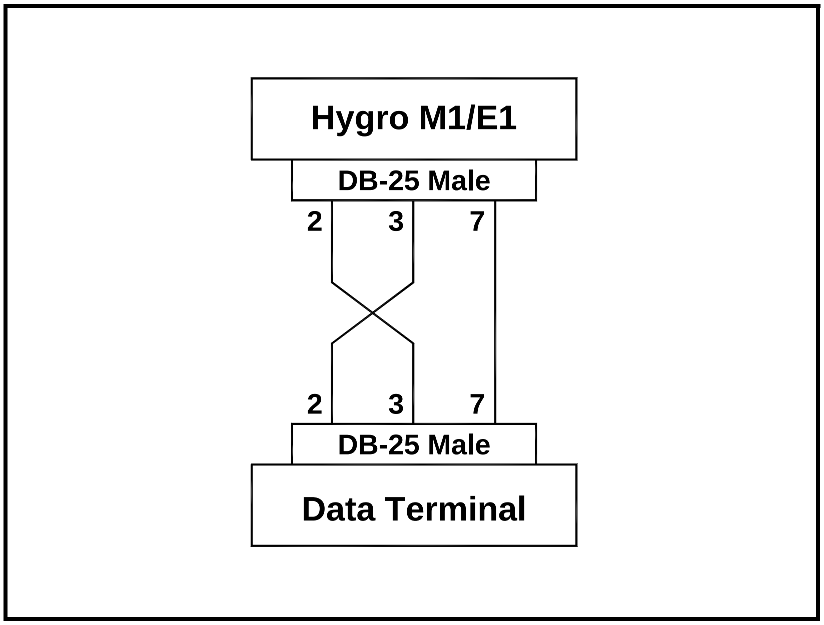


Figure C-1: Wiring Diagram - M1/E1 to Data Terminal

Some communications protocols require that the following pins also be used:

- 4 - Request to send (**RTS**)
- 5 - Clear to send (**CTS**)
- 6 - Data set ready (**DSR**)
- 20 - Data terminal ready (**DTR**)

The M1/E1, as shipped from the factory, has pins 4 and 5 connected and pins 6 and 20 connected using jumpers JPR4 and JPR5, generating the appropriate control signals for devices requiring these lines. To gain independent control over these signals, JPR4 and JPR5 can be removed. These jumpers are located on the printed circuit board and are clearly marked.

Wiring to a Personal Computer or Modem

To interface the **M1/E1** to Data Communications Equipment (DCE), use the cable configuration shown in Figure C-2 below.

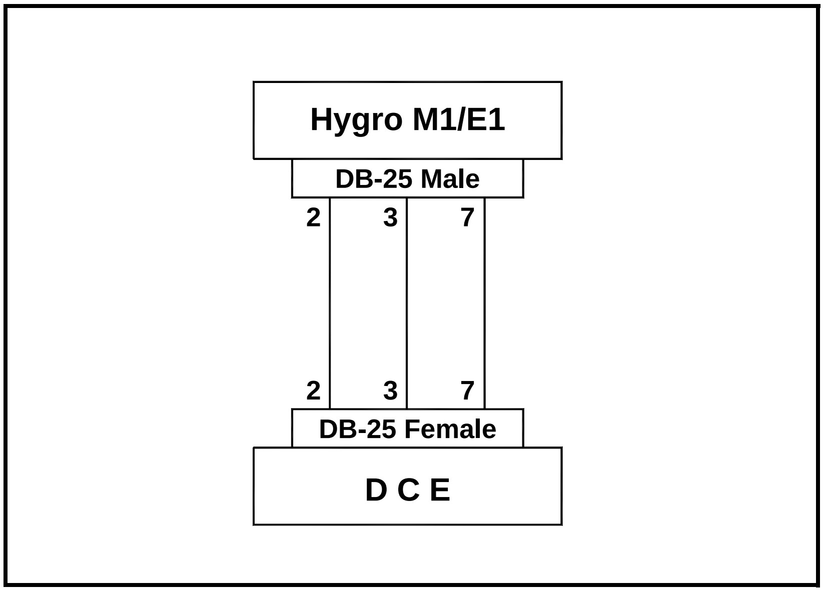


Figure C-2: Wiring Diagram - M1/E1 to PC or Modem

Communicating with the M1/E1, requires a standard serial interface card installed in the computer. If the computer has one serial card, it is addressed as COM1. If there is a second serial card, it is addressed as COM2. There must also be a cable with the following connectors:

- A 25-pin male D connector connecting to the M1/E1
- A 25-pin female D connector connecting to the computer

Only pins 2, 3, and 7 are used by the M1/E1. They are connected straight through: 2 to 2, 3 to 3, and 7 to 7.

Communicating with the Hygro-M1/E1

Once the serial card is installed and the cable connected, the following BASIC program can be used to interface to the instrument:

```
 10 ON ERROR GOTO 90
 20 OPEN "COM1: 1200,n,8,1,CS,DS,CD" AS #1
 30 OPEN "SCRN:" FOR OUTPUT AS #2
 40 B$ = INKEY$: IF B$ <> "" THEN GOTO 100                  'CHECK KEYBOARD
 50 IF EOF(1) THEN 40                             'CHECK END OF TRANSMISSION
 60 A$ = INPUT$(LOC(1), #1)                              'GET DATA FROM PORT
 70 PRINT #2,a$;                                DISPLAY DATA FROM SERIAL PORT
 80 GOTO 40                                                      'REPEAT LOOP
 90 CLOSE: GOTO 20                                     'ERROR, CLOSE AND REPEAT
100 IF B$<>CHR$(27) THEN PRINT $1,B$;: GOTO 50                'CHECK FOR ESCAPE
110 FOR I=1 TO 5                      'SEND BURST OF ESCAPE CHAR UNTIL RECOGNIZED
130 PRINT #1, A$
150 LINE INUT #1, A$                                               'GET STRING
160 IF INSTR(A$, "VERSION") THEN 210
170 IF INSTR(A$, "SCALE") THEN 210
180 IF INSTR(A$, "CALIBRATE") THE 210
190 NEXT I
210 GOTO 70
```

Notes:

Line 20: Serial input = **COM1**
Baud rate = **1200**,
Parity = **NONE**
No. of data bits = **8**
No. of stop bits = **1**
Time-out = **10 SECONDS**
Set to file **#1**.

Line 30: File #2 set as the video display terminal.

Line 40: Input from keyboard. If there is no input then continue. If there is input, send it to **M1/E1** and to video display terminal.

To send data to your printer, insert the following line in the program:

```
75 LPRINT A$
```

For further information on interfacing, refer to the factory or to the Electronic Industries Association (EIA) standard for interfacing.

Appendix D

Hygro-M1/E1 Parts

Main PC Board

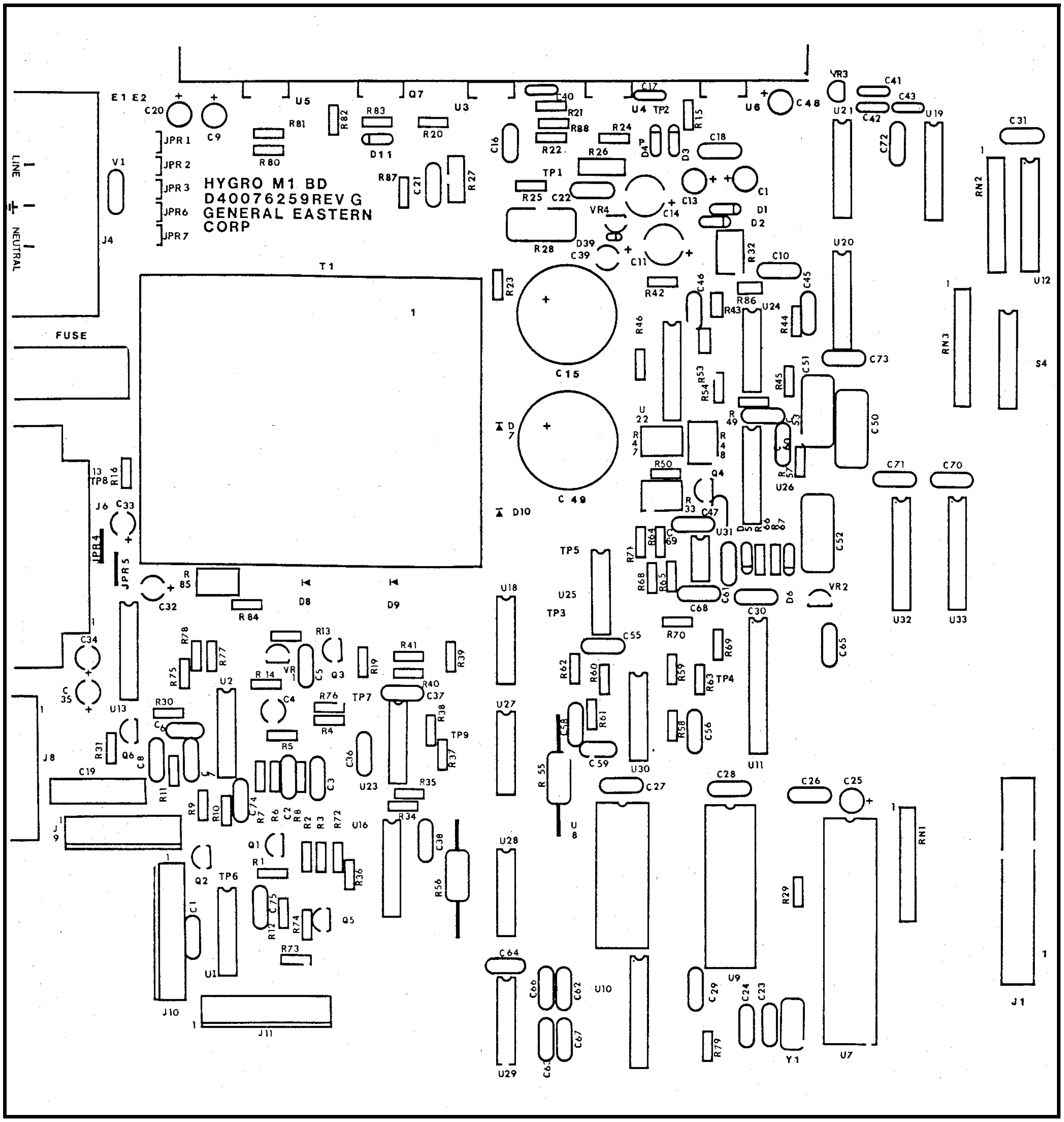


Figure D-1: Main Board Component Layout Diagram

Main Board Parts

Table D-1: Main Board (#40076770) Parts List

GE Sensing Part No.	Description	Reference Designation
40027708	IC, Quad Comparator, LM339N	U1
40022261	IC, Quad Op Amp, LM324N	U2
40022261	IC, Quad Op Amp, LM324N	U23-24
40051351	Microcomputer, ID8031AH	U7
40074445	Socket, IC, 28-pin, 3852628-02	U9
40063182	IC, 8-bit Latch, 74LS373N	U10, U12
40063182	IC, 8-bit Latch, 74LS373N	U33
40074460	IC, Programmed PAL12L10	U11
40070658	IC, TTL-to-RS232, MAX232	U13
40076796	IC, Quad, DFF, 74L5377N	U32
40071672	IC, 8-bit Buffered DAC, AD7524	U16
40076887	IC, 74LS32W	U18
40076804	IC, Quad, DFF, 74LS174	U19-20
40066383	IC, Converter, Analog, AD7533LN	U21
40071664	IC, Voltage to Current Conv	U22
40023004	IC, Quad Bilateral Switch CMOS	U25
40023004	IC, Quad Bilateral Switch CMOS	U27-29
40070633	IC, Converter, Analog Proc	U26
40070609	IC, Op Amp, OP227/GN	U30
40052946	IC, CA3240AE	U31
40030058	IC, +2.5V, Ref Diode LM3362.2.5	VR1-3
40012932	Res, 1%, 1K, 1/8W, 50ppm	R4, R71
40013310	Res, 1%, 2.49K, 1/8W, 50ppm	R44, R70
40015141	Res, 1%, 200K, 1/8W, 50ppm	R75, R78
40014185	Res, 1%, 20.0K, 1/8W, 50ppm	R5, R7
40014185	Res, 1%, 20.0K, 1/8W, 50ppm	R86
40012320	Res, 1%, 232 ohm, 1/8W, 50ppm	R59-60
40014896	Res, 1%, 110K, 1/8W, 50ppm	R8, R22
40014896	Res, 1%, 110K, 1/8W, 50ppm	R23
40014292	Res, 1%, 26.1K, 1/8W, 50ppm	R11, R49
40015331	Res, 1%, 316K, 1/8W, 50ppm	R57
40015422	Res, 1%, 392K, 1/8W, 50ppm	R38
40011686	Res, 1%, 49.9 ohm, 1/8W, 50ppm	R61-62
40011686	Res, 1%, 49.9 ohm, 1/8W, 50ppm	R68-69
40011686	Res, 1%, 49.9 ohm, 1/8W, 50ppm	R46
40013617	Res, 1%, 5.11K, 1/8W, 50ppm	R3, R12

Table D-1: Main Board (#40076770) Parts List

GE Sensing Part No.	Description	Reference Designation
40013617	Res, 1%, 5.11K, 1/8W, 50ppm	R64
40013617	Res, 1%, 5.11K, 1/8W, 50ppm	R66-67
40012650	Res, 1%, 511 ohm, 1/8W, 50ppm	R36
40082372	IC, RAM, Mk48T02B-25	U8
12681409	Res, 5%, 1/4W, 2.4K, 50ppm	R9, R14
12681003	Res, 5%, 51 ohm, 1/4W, 50ppm	R10
12681722	Res, 5%, 51K, 1/4W, 200ppm	R2
12681193	Res, 5%, 330 ohm, 1/4W, 200ppm	R82, R83
40014854	Res, 1%, 100K, 1/8W, 50ppm	R34-35
40014854	Res, 1%, 100K, 1/8W, 50ppm	R19, R37
40014854	Res, 1%, 100K, 1/8W, 50ppm	R40-41
40014854	Res, 1%, 100K, 1/8W, 50ppm	R74
40014854	Res, 1%, 100K, 1/8W, 50ppm	R76-77
40013898	Res, 1%, 10K, 1/8W, 50ppm	R20, R21
40013898	Res, 1%, 10K, 1/8W, 50ppm	R24, R25
40013898	Res, 1%, 10K, 1/8W, 50ppm	R80, R81
40013898	Res, 1%, 10K, 1/8W, 50ppm	R43
40013898	Res, 1%, 10K, 1/8W, 50ppm	R1, R16
40013898	Res, 1%, 10K, 1/8W, 50ppm	R63, R65
40013898	Res, 1%, 10K, 1/8W, 50ppm	R29, R31
40013898	Res, 1%, 10K, 1/8W, 50ppm	R79, R58
40013898	Res, 1%, 10K, 1/8W, 50ppm	R72, R73
40013930	Res, 1%, 11K, 1/8W, 50ppm	R6
40014979	Res, 1%, 133K, 1/8W, 50ppm	R39
40015026	Res, 1%, 150K, 1/8W, 50ppm	R13, R30
40013773	Res, 1%, 7.5K, 1/8W, 50ppm	R45
40076747	Pot, 100K, 3299W-1-503	R47
40063018	Res, .01%, 60.0 ohm, SA16	R55
40047888	Res, 5%, 0.1 ohm, 2W	R28
40047904	Res, 5%, 1 ohm, 1/2W, RC20	R26-27
40048100	Res, .01%, 138.9 ohm, SA16	R56
40055733	Xstr, PNP Switching, 2N3906	Q1
40034837	Xstr, NPN Switching, 2N3904	Q2
40034837	Xstr, NPN Switching, 2N3904	Q5-6
40015810	Res, 1%, 1.00M, 1/8W, 50ppm	R50
40014110	Res, 1%, 16.9K, 1/8W, 50ppm	R53
40014094	Res, 1%, 16.2K, 1/8W, 50ppm	R54

Table D-1: Main Board (#40076770) Parts List

GE Sensing Part No.	Description	Reference Designation
40001539	Pot, 1K, 3299W-1-102	R32
40047524	Pot, 20K, 3299W-1-203	R33
40076754	Pot, PC Mount, 25T, 200K	R48
40000838	Cap, 10μF, 20V, 196D106X9020JAI	C9, C20
40044240	Cap, 4.7μF, 35V	C25
40082323	Cap, Electrolytic	C15, C49
40044307	Cap, .1μF, 500V, Ceramic	C19
40043952	Cap, 30pF, 500V, DD300KK	C23-24
40044190	Cap, 22μF, 15V, 196D226X9015KA1	C32-35
40044075	Cap, 1μF, 50V, Z5B105J	C50-52
40074858	Crystal, 3.6864MHZ	Y1
40037442	Cap, 47μF, 35V, ULB1V47OMCA	C13
40037442	Cap, 47μF, 35V, ULB1V47OMCA	C48, C12
40000853	Cap, 100μF, 35V, ULB1V101M	C11, C14
40066490	Xstr, NFET, #J112	Q3
40066474	Xstr, PNP, MPSA64	Q4
40076820	Diode, 1N5818	D1, D2
40076820	Diode, 1N5818	D3, D4
40076820	Diode, 1N5818	D11
40061764	Diode, 1N4148	D5, D6
40043911	Cap, 1000pF, 500V, DD-102	C2, C8
40043911	Cap, 1000pF, 500V, DD-102	C10
40081432	Cap, 33μF, 25V, Nonpolar	C4
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C26-30
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C53, C55
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C56, C58
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C59-75
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C43, C45
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C46-47
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C36-38
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C16-18
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C21-22
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C1, C3
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C5-7
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C31
40013690	Res, 1%, 6.19K, 1/8W, 50ppm	R15, R42
40048407	Switch, DIP	54

Table D-1: Main Board (#40076770) Parts List

GE Sensing Part No.	Description	Reference Designation
40082414	IC, Pwr Amp, ULN3751ZV	U3-4
40082414	IC, Pwr Amp, ULN3751ZV	U6
40070492	Varistor, V275LA4	V1
40081556	Sil Pad, #1007-54	11
40003618	Fuse, Glass, 1A, Slo-blo	13
40081465	Fuse, 1/2A, Slo-blo	14
40075921	Res Network, 10K	RN1-3
40082331	Transformer	T1
40081697	Regulator, IC, LM2935	U5
40081713	Diode, Schottky, 805Q045	D7-10
40081705	Xstr, Pwr, MJE3055T	Q7
40082562	Regulator, Volt, 3-pin, Neg	VR4
40082570	Regulator, Volt, 3-pin, Pos	VR3
40000804	Cap, .01µF, 25V, UK25-103	C41, C42
40044018	Cap, 1µF, 35V, TAGS1M35	C39
40022550	Diode, 1N914	D39
40001372	Cord, AC Line	

Display PC Board

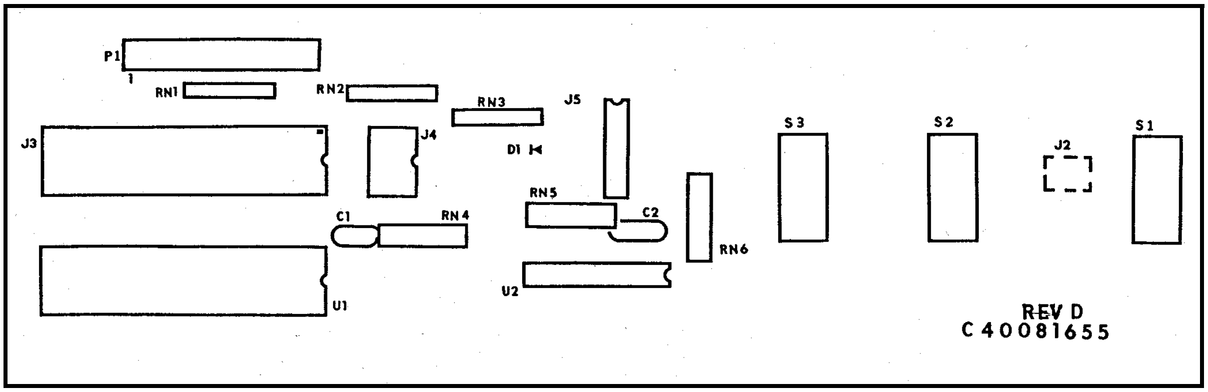


Figure D-2: Display Board Component Layout Diagram

Display Board Parts

Table D-2: Display Board (#40081663) Parts List

40071615	IC, 4-digit Display Decoder	U1
40052557	IC, Octal D-Flipflop SN74LS273	U2
40081572	Res Network, 330 ohm	RN1-6
40074478	Display, LED, 1/2-digit, HDSP5507	DS1
40071631	Display, 7-segment, HDSP 5501	DS2, DS4
40071623	Display, 7-segment, HDSP 5521	DS3
40074486	Display, 7-segment, HDSP 3601	DS5
40070724	Cap, .1μF, 50V, C323C104M5M5CA	C1, C2
40080962	Switch, SPDT, ON/OFF/MOM	S2, S3
40080970	Switch, SPDT, ON/ON, PC Mnt	S1
40082364	LED, Grn, Spacer, CHD5453-550	D1
40082547	Cable, PCB, 26-pos, 3-in	P1

Appendix E

M1/E1 PC Board Schematics

M1/E1 Main PC Board
Schematic, sht 1

M1/E1 Main PC Board Schematic, sht 2

M1/E1 Display PC Board Schematic

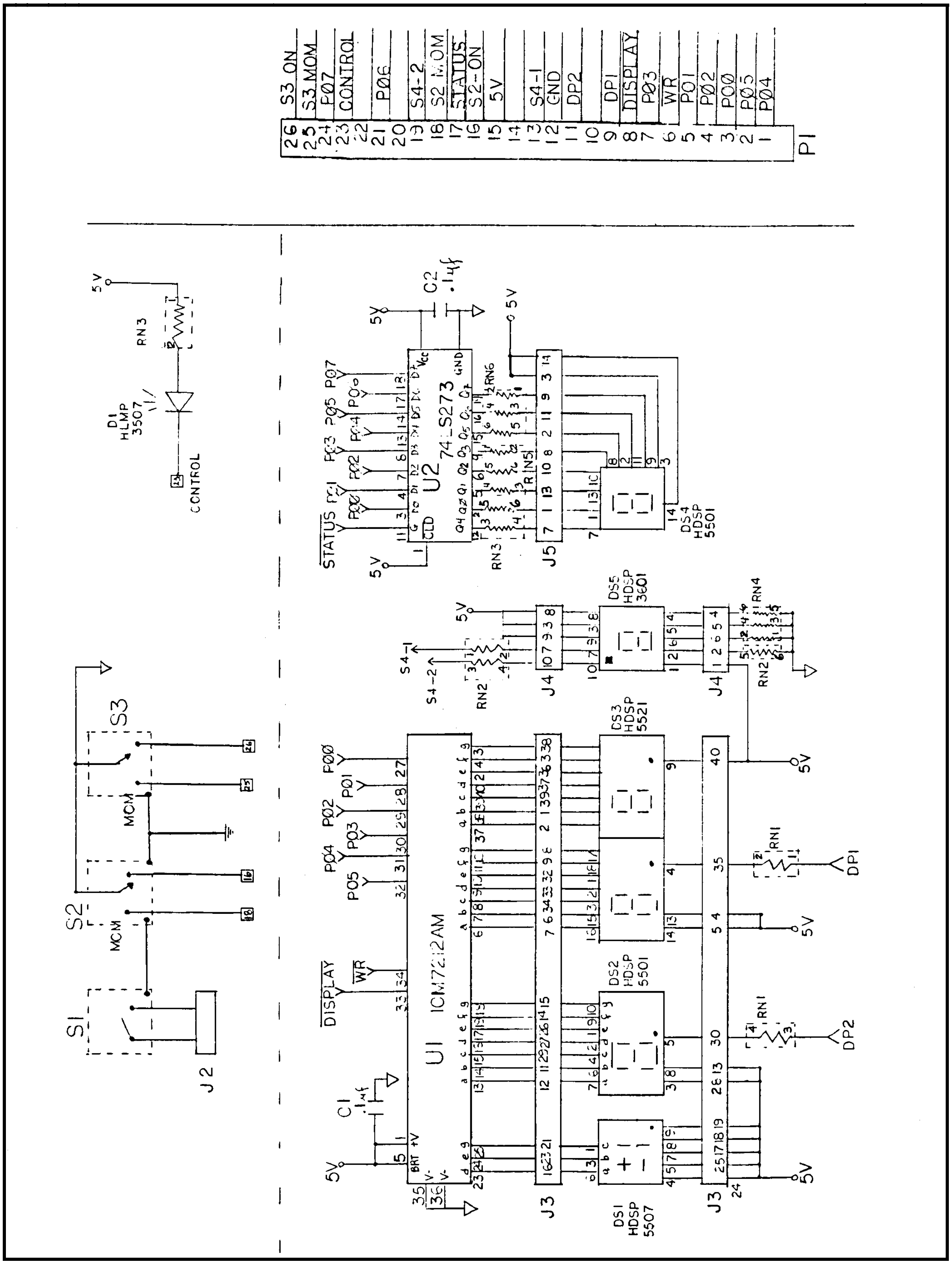
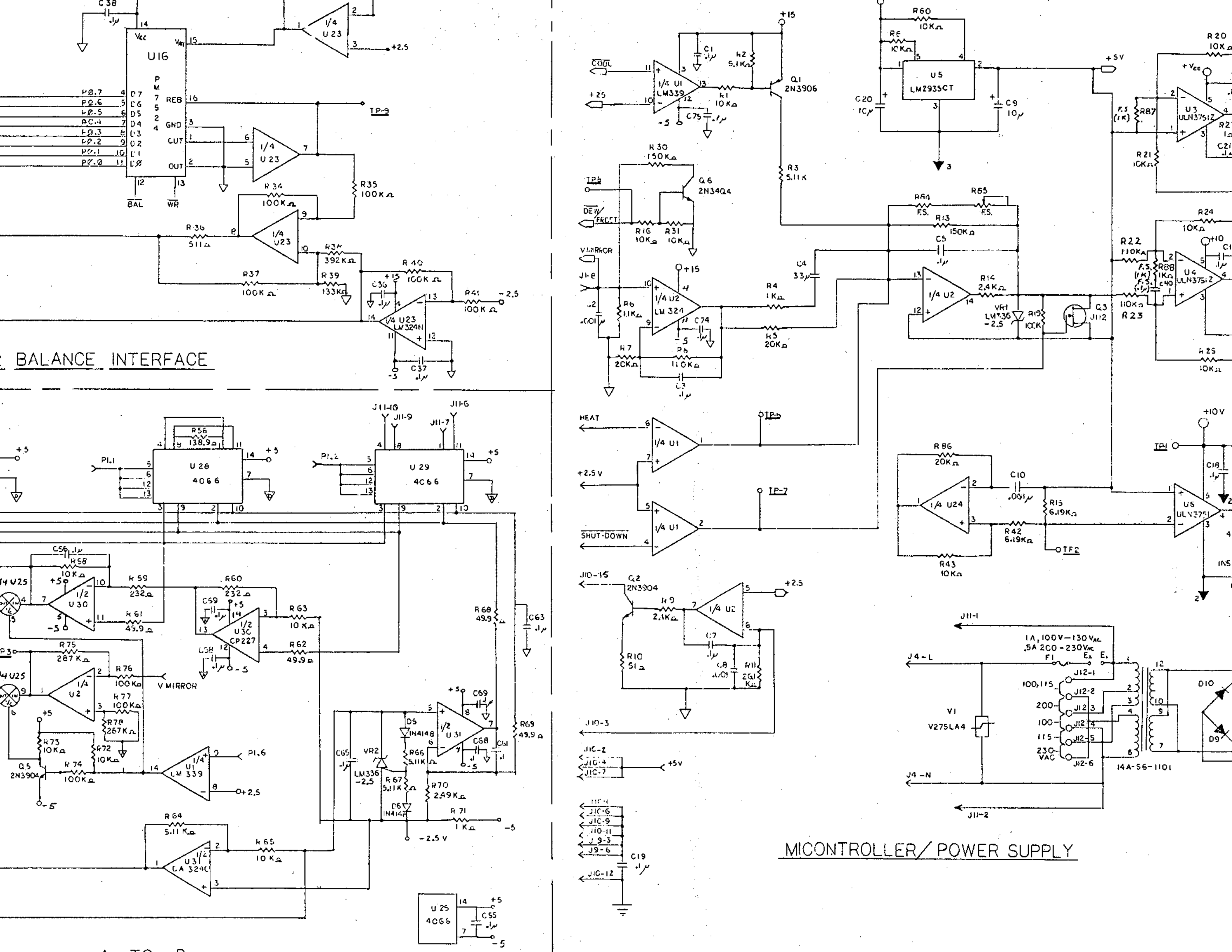
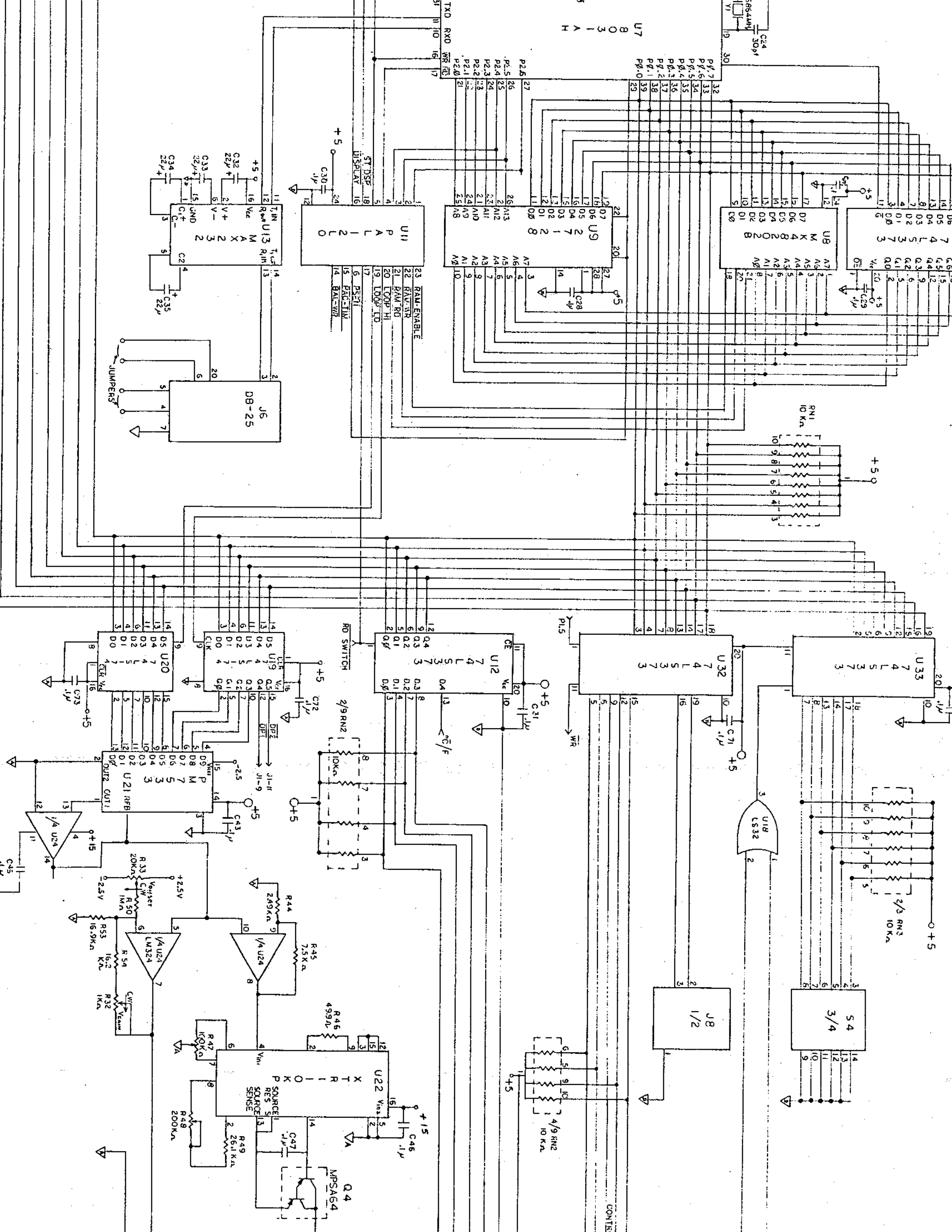


Figure E-3: M1/E1 Display PC Board Schematic (ref. dwg 40081671C)


BALANCE INTERFACE
MICONTROLLER/ POWER SUPPLY



U7
8031
TXD
RXD
U9
2817
U8
2028KM
U11
PAL12L10
U13
MAX232
J6
DB-25
JUMPERS
U12
74LS373
U19
74LS174
U20
74LS174
U21
PM7533
U32
74LS373
U33
74LS373
U18
LS32
U22
XTR101
Q4
MPSA64
J8
1/2
S4
3/4
RN1
10 KΩ
2/9 RN2
4/9 RN2
2/3 RN3
RAM ENABLE
RAM WR
RAM RD
LOOP HI
LOOP LO
PEST1
PAC-TIM
BAL-WR
ST DISP
DISPLAY
RD SWITCH
°C/°F
+5
+15

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