Moisture Target Series 4

User's Manual *910-112A*

PANAMETRICS

Warranty

Each PANAMETRICS-manufactured instrument is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to servicing, calibrating, and replacing any defective parts of the instrument returned to the factory for that purpose. Fuses and batteries are specifically excluded from any liability. This warranty is effective from the date of delivery to the original purchaser. The equipment must be determined by Panametrics to have been defective for the warranty to be valid. This warranty is effective with respect to the following:

- one year for electronic failures
- one year for mechanical failures (shorts or opens) to the sensors
- six months for calibration of sensors.

If damage is determined to have been caused by misuse or abnormal conditions of operation, the owner will be notified and repairs will be billed at standard rates after approval.

Maintenance Policy

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and provide the model and serial number of the instrument. On receipt, Panametrics will give you a RETURN AUTHORIZATION NUMBER and/or shipping instructions, depending on the problem with your system.

2. If Panametrics instructs you to send your analyzer back to the factory, please send it prepaid to the authorized repair station as indicated in the shipping instructions.

3. If damage has been caused by misuse or abnormal conditions, or if the warranty has expired, an estimate will be provided upon request before repairs are started.

Purpose of This Manual

The Panametrics *Moisture Target Series 4 User's Manual* (910-112) explains how to install, use, and maintain the Moisture Target Series 4. Should field service that is beyond the scope of this manual become necessary, contact the Panametrics office nearest you. A list of Panametrics offices is located on the back page of this manual.

Intended Audience

This manual is intended for people who install, use, and maintain instrumentation devices. This manual presumes the audience has some general familiarity with pipe terminology and analytical devices as used in their application; however, no knowledge of Panametrics systems is necessary to use this manual.

This manual is a general reference for personnel who have overall responsibility for using and maintaining process monitoring devices. It also contains sections intended specifically for installers (electricians, pipe fitters, etc.). The manual organization is outlined below.

Manual Organization

This manual consists of five sections, three appendices, and an index.

Chapter 1, *Features and Capabilities,* provides an overview of the Series 4.

Chapter 2, *Installing the Series 4*, describes how to install the Series 4 electronics. In addition, this section describes how to make probe(s), power, alarms, and recorder connections.

Chapter 3, *Programming the Series 4*, explains how to enter measurement and display data into the Series 4.

Chapter 4, *Troubleshooting and Maintenance*, describes common problems that may occur, as well as how to replace the user program, and how to replace and recalibrate the moisture probe(s).

Chapter 5, *Specifications*, contains the electronic and moisture measurement specifications for the Series 4.

Appendix A, *Application of the Hygrometer,* details the specifics of moisture measurement calculations. In addition, moisture probe maintenance and some helpful hints are included.

Appendix B, *Outline and Dimension Drawings*, provides the necessary detailed dimensions for installing the Series 4 easily and properly.

Appendix C, *Series 4 Menu Map*, provides a top level diagram that can be used as a reference for moving through the user program.

How to Use This Manual

Since this manual is written for a multi-user audience, each section can be used separately. All sections and subsections appear in the order they are to be read. Additional or less frequently used information is included in the appendices which are referenced throughout this manual.

Revision Information

This manual may require updating due to corrections or changes to the product. Publication dates are on the top corner of each page of the manual. Changes are indicated by a different date on the changed page. The date and document number on the title page are also changed. This is the first version of the Series 4 manual.

Related Documentation

Panametrics supplies Calibration Data Sheets (containing all necessary probe data) along with the moisture probes. In addition, Panametrics will provide detailed drawings and schematics for special purposes upon request.

Getting Technical Help

For other technical documentation related to particular applications or for the assistance of an applications engineer, call Panametrics' PCI Division at: 1-800-833-9438 (within the U.S.A.) or 781-899-2719 (outside the U.S.A.).

Typographical Conventions

Conventions used throughout this manual are listed below:

- Characters enclosed in brackets, such as [ENT], represent a key on the keypad. There are the four keys on the front panel.

Questions

If you have any questions, call our toll free number, 1-800-833-9438 within the U.S.A., or 781-899-2746 outside the U.S.A.

Commenting on This Manual

We welcome your comments and suggestions for improving the quality of our manuals. You can comment four ways:

- Fill out the prepaid postage response card in the front of this manual.
- Send comments to Panametrics, PCI Division, Technical Publications Department, 221 Crescent Street, Waltham, Massachusetts 02154. Attention: Comments.
- Fax us at 781-894-8582, attention Technical Publications Department.
- Call us at 1-800-833-9438 (within the U.S.A.) or 617-899-2746 (outside the U.S.A.), and ask for the Technical Publications Department.

Notes

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Appendix B: Outline and Installation Drawings

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Chapter 1

Features and Capabilities

Introduction to the Series 4

The Series 4 is a microprocessor-based, single-channel hygrometer that measures moisture content in gases. It is intended for Original Equipment Manufacturer (OEM) applications, and is suitable for a wide range of process conditions requiring real-time moisture measurement. It operates over a range of -80° to 20 °C (-112 to 68°F) with data to -110°C (-166°F), and comes equipped with two alarm relays and a single analog output.

Electronics Unit

The Series 4 electronics displays measurement data on a one-line, 6-digit LCD. All probe information is entered into the unit using the four-button front panel keypad (see Figure 1-1 below). The Series 4 has a universal power supply that automatically adjusts to line voltages from 100 to 240 VAC. In addition, the Series 4 can also be powered at 24 VDC.

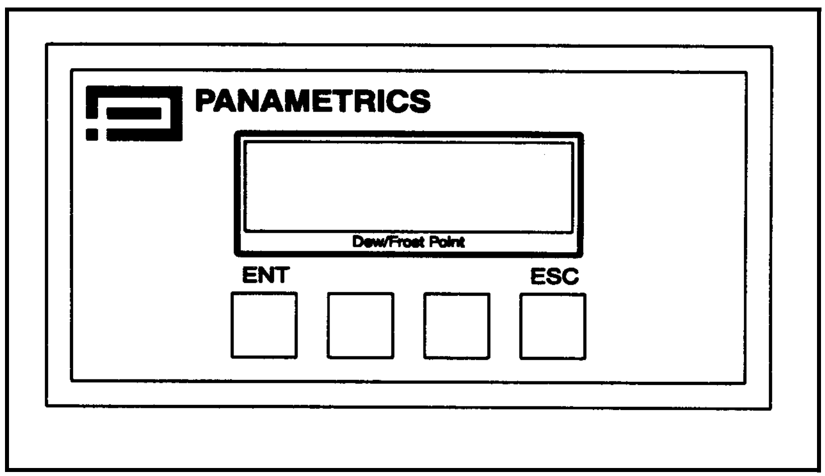

Figure 1-1: Series 4 Front Panel

Probes

The moisture probe is that part of the system that comes in contact with the process. The Series 4 uses any M Series probe to measure dew point temperature in ^{o}C or ^{o}F. The sensor assembly is secured to the probe mount and protected with a sintered-stainless-steel shield (see Figure 1-2 below). Other types of shields are available.

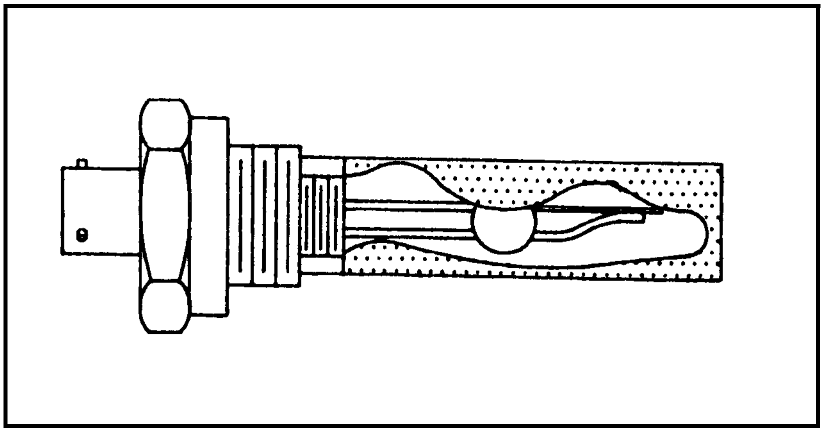

Figure 1-2: The M Series Probe

Proceed to the following section for installation instructions.

Chapter 2

Installing the Series 4

Getting Started

Installing the Series 4 consists of the following procedures:

- mounting the unit and the sample system
- installing the probe into the sample system
- wiring the probe, recorder output, and alarm connections to the back of the unit.

Mounting the Unit and Sample System

Follow the instructions below to mount the Series 4 and the sample system.

Mounting the Unit

Standard Panel Mount:

The standard Series 4 panel mount unit is designed for mounting into a rectangular cutout on most panels up to one inch thick. (See Appendix B for outline and installation drawings.)

Follow the instructions below to mount the standard Series 4.

1. Remove the two clip-on mounting brackets (see Figure 2-1 below).
2. Place the Series 4 through the cutout in your panel.
3. Replace the two mounting brackets.
4. Use a screwdriver to secure the mounting brackets to the panel.

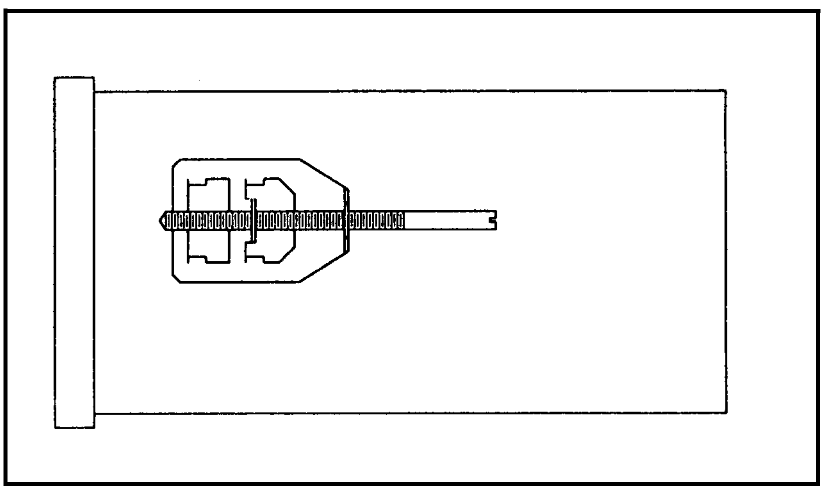

Figure 2-1: A Clip-On Mounting Bracket

Note: *The brackets may be mounted on either the sides or the top and bottom of the unit.*

Mounting the Sample System

The sample system is normally fastened to a metal plate that has four mounting holes. Panametrics also provides the sample system in an enclosure if requested. Sample system outline and dimension drawings are included in your shipment if ordered.

Follow the steps below to mount the sample system:

1. Fasten the sample system plate or enclosure with four bolts--one in each corner.
2. Connect the sample system inlet and outlet to the process and return using the appropriate stainless steel fittings and tubing.

Caution!
Do not start a flow through the system until the probe has been properly installed

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Installing the Probe into the Sample System

Panametrics probes are usually installed in a sample system. The sample system protects the probes from any damaging elements in the process. The probes are inserted into a cylindrical shaped container called the sample cell, which is included as part of your sample system.

M2 probes have 3/4 inch-16 straight threads with an O-ring to secure the probes into the sample system or directly into the process line. Other fittings are available for special applications.

Caution!
If mounting the probe directly into the process line, consult Panametrics for proper installation instructions and precautions.

Follow the steps below to install the probe into the sample cell:

1. Insert the probe into the sample cell so it is perpendicular to the sample inlet.
2. Screw the probe into the receptacle fitting, making sure not to cross the threads.
3. Tighten the probe securely.

Figure 2-2 on the next page shows a typical probe installation with the probe mounted into a sample cell.

Note: *For maximum protection of the aluminum oxide sensor, the stainless steel end cap should always be left in place.*

Installing the Probe into the Sample System (cont.)

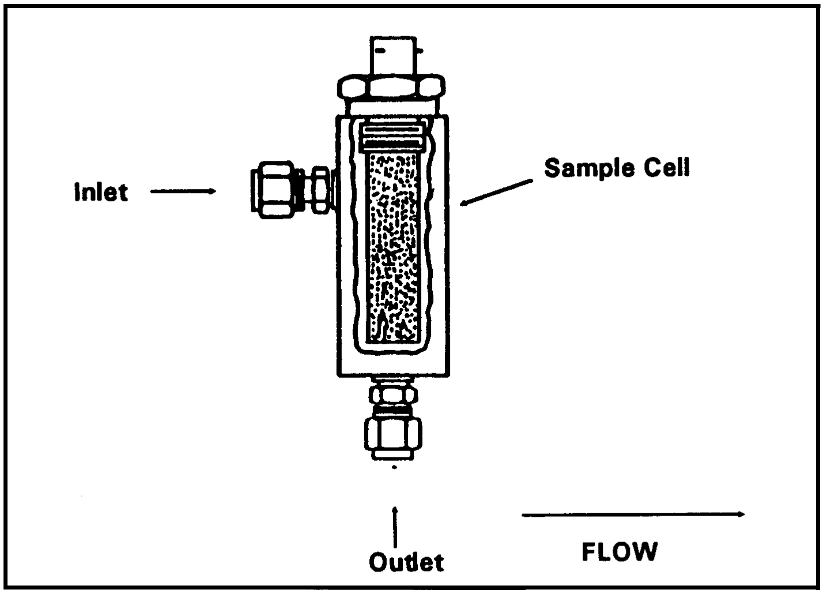

Figure 2-2: Typical Probe Installation

Making Wiring Connections

Making wiring connections to the Series 4 consists of the following procedures:

- Connecting the probe
- Connecting the recorder output
- Connecting the alarms
- Connecting the unit to a power source

Connecting the Probe

The probe must be connected to the Series 4 with a continuous run of Panametrics two-wire shielded cable (see Figure 2-3 below).

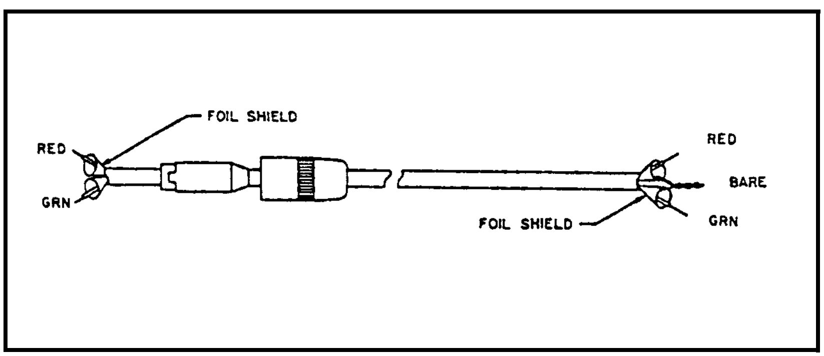

Figure 2-3: Two-Wire Shielded Cable

Connecting the Probe (cont.)

Protect cables from excessive strain (bending, pulling, etc.). Do not subject cables to temperatures above +65^{o}C (149^{o}F) or below -50^{o}C (-58^{o}F). Standard cable assemblies (including connectors) can be ordered from Panametrics in any length up to 1,200 meters (4,000 feet).

First connect the cable to the probe by inserting the bayonet-type connector onto the probe and twisting the shell clockwise until it snaps into a locked position (approximately 1/8").

Next, connect the probe cable to the terminal block on the back of the Series 4 as shown in Table 2-1 and Figure 2-4 below.

Table 2-1: Probe Connections

Pin Number	Probe Wire Color
1	Shield
2	Green
3	Red

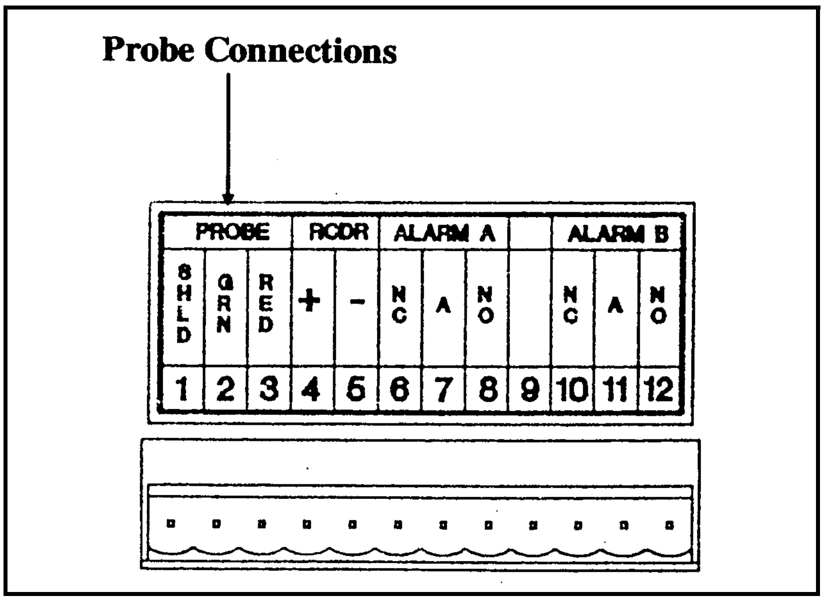

Figure 2-4: Probe Cable Connections

Connecting the Recorder Output

The Series 4 has one isolated recorder output. This output provides either a current or voltage signal, which is set using a switch block. Although the Series 4 is configured at the factory, you should check the switch block position before making connections.

Use the following steps to check or reset the switch block setting.

1. Make sure the Series 4 is turned off and unplugged.
2. To access the electronics board, remove the four screws on the back panel and slide the electronics unit out of its enclosure.
3. Locate switch block S1 next to the relays. (See Figure 2-5 for switch block location.)
4. Set switch S1 in the appropriate position: I for current; V for voltage.
5. Once the switch is set, slide the electronics unit back into its enclosure and fasten the screws.

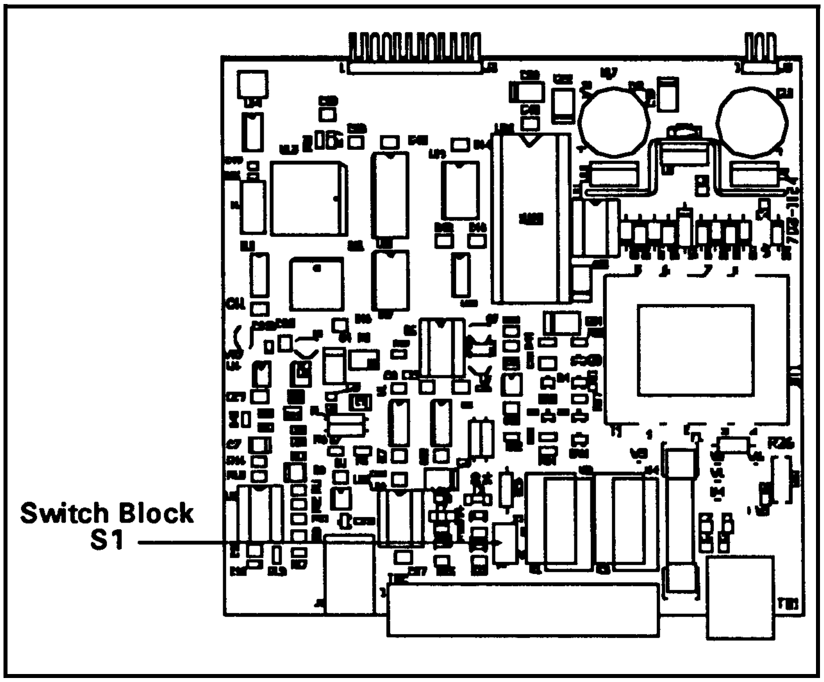

Figure 2-5: Switch Block Location

Connecting the Recorder Output (cont.)

To make recorder output connections, connect the recorder output to the terminal block on the back of the Series 4 as shown in Table 2-2 and Figure 2-6 below.

Table 2-2: Recorder Output Connections

Pin Number	Recorder Output
4	+
5	-

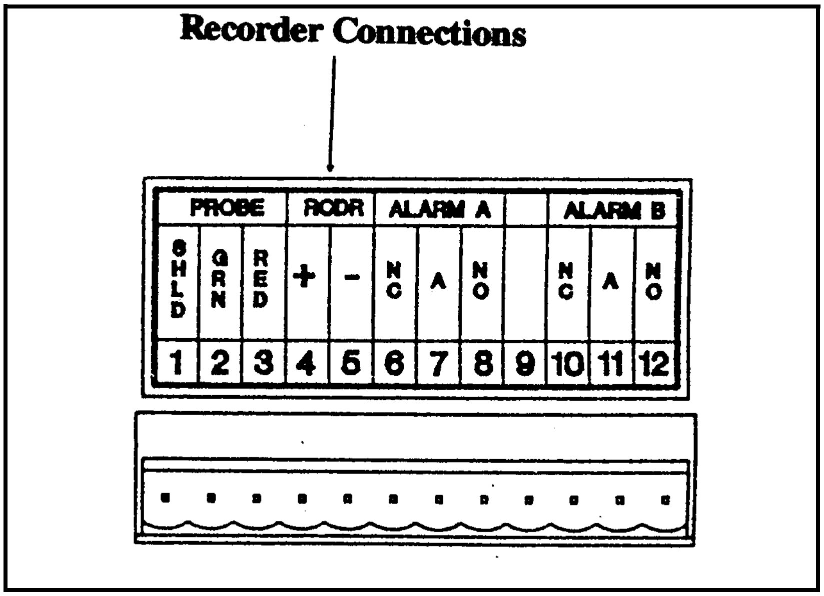

Figure 2-6: Recorder Output Connections

Connecting the Alarms

The Series 4 has optional high and low alarm relays. Hermetically sealed alarm relays are also optionally available. Each alarm relay is a single-pole double throw contact set that contains the following contacts:

- Normally Open (NO)
- Armature Contact (A)
- Normally Closed (NC)

Connect Alarm A and Alarm B relays to the terminal block on the back of the Series 4 as shown in Table 2-3 and Figure 2-7.

Table 2-3: Alarm Connections

Pin Number	Relay
Alarm A	
6	NC
7	A
8	NO
Alarm B	
10	NC
11	A
12	NO

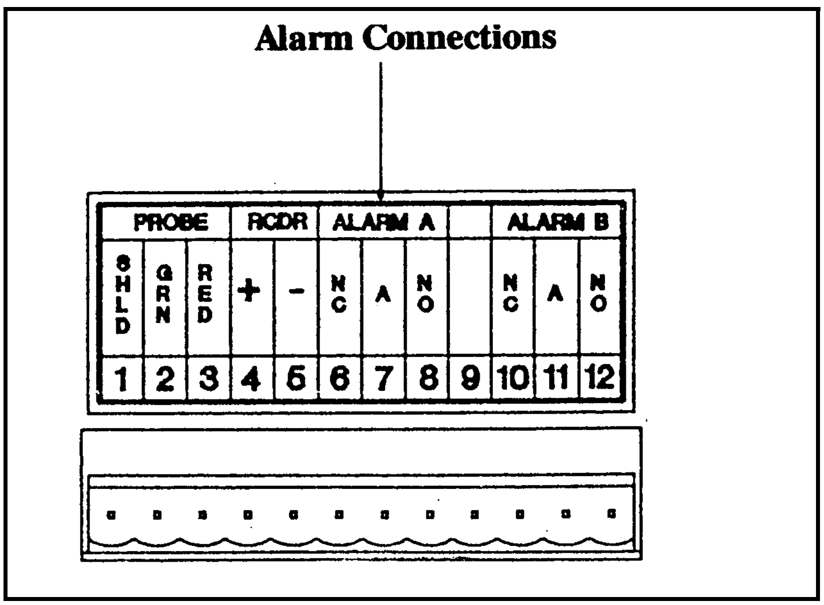

Figure 2-7: Alarm Relay Connections

Connecting Power

Use Table 2-4 and Figure 2-8 below to connect the power supply to the three-pin terminal block on the back of the Series 4.

Table 2-4: Power Connections

Pin Number	AC Unit	24 VDC Unit
1	Line	+
2	Neutral	-
3	Ground	Ground

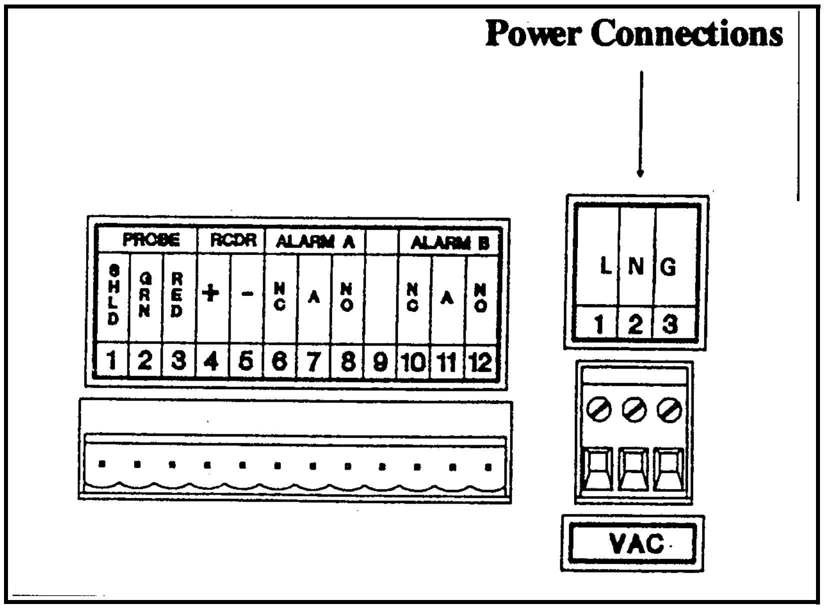

Figure 2-8: Power Connections

After you make power connections to the terminal block, connect the power cord to an appropriate source. The Series 4 will display "busy. . ." while it initializes, then begin displaying the dew/frost point temperature.

Chapter 3

Programming the Series 4

Programming the System

The Series 4 contains a system program that enables the user to change moisture probe data, as well as set up and test alarms and recorders. (Refer to the menu map in Appendix C to move through the programming menus more quickly.)

The front keypad of the Series 4 contains the following four keys for programming the system:

ENT - confirms changes
△ - scrolls forward
▽- scrolls backward
ESC - cancels and ignores changes

Note: *During numerical entry, holding down the scroll key will speed up the numerical increment or decrement.*

To enter data into the system program, follow the steps below.

Note: *While entering data in the programming mode, the Series 4 suspends making measurements.*

To enter the programming mode, you must perform the first two steps within 5 seconds, or the unit will time out and return to the measurement mode. First, press and hold the [ESC] key until ESC is displayed.

ESC	Press the [ENT] key, then the [ESC] key.

Once you have entered the Main Menu, use the following steps to program the Series 4.

unit	Use the arrow keys to scroll through the ten submenus in the Main Menu.
d p	
P r o b e	
A L	
r c r d	

Programming the System (cont.)

O f f s e t

d e f a l t

t e s t

r e f

S e t u p

Refer to the sections that follow to enter data into each submenu.

Submenu Options

The following sections briefly describe how to use each of the submenus. Once you have scrolled to the desired submenu, follow the steps below to enter data.

UNIT

The UNIT submenu lets you select one of the following measurements to display:

- degree C
- degree F
- MH (H)

Note: *MH is the moisture sensor's raw response value which is recorded along with dew point during calibration.*

At the "unit" prompt, press the [ENT] key to enter this submenu.

Display	
d E G C	Use the arrow keys to scroll through the options to the desired selection.
d E G F	
H	Press [ENT] at your selection.

The Series 4 returns to the Main Menu.

Dew Point (DP)

Use the DP submenu to enter a high and low dew point range. This range is used to determine the number of points in the calibration curve.

Note: *The high (max) and low (min) dew points are listed on the Moisture Probe Calibration Data Sheet.*

At the "dp" prompt, press the [ENT] key to enter this submenu.

d p Lo	Use the arrow keys to scroll through the options to the desired selection. Press
d p Hi	[ENT] at your selection to display the current value of the selected range.
-110	Use the arrow keys to change the value, then press [ENT] to confirm your entry.

Note: *The default values are as follows:*
Low: -110
High: 20

XXX	(The X's represent your value.) Press ESC to return to the Main Menu.

Probe

Once the range for the calibration curve has been determined, use the PROBE submenu to enter a value for each of the points in the range.

Note: *The point automatically increases in increments of 10 °C.*

Probe (cont.)

At the "Probe" prompt, press the [ENT] key to view the first point in the curve.

-110	Press [ENT] again to display the current MH value for that point.
0.1890	Use the arrow keys to change the value, then press [ENT] to confirm your entry.

Note: *To increase or decrease the value more than one digit at a time, press and hold down the appropriate arrow key.*

X.XXXX	(The X's represent your value.) Use the arrow keys to move to the next point in the curve.
20	Once you've entered a value for each point, press [ESC] to return to the Main Menu.

Alarm (AL)

The Series 4 has two optional alarms, each of which can be configured as high or low. To program the alarms, first select the alarm unit, then select high or low, and finally enter the alarm trip point. At the "AL" prompt, press the [ENT] key to enter this sub-menu.

d E G F	Use the arrow keys to scroll to the desired unit, then press [ENT] at your selection.
d E G C	
H	
A L A	Use the arrow keys to scroll to the desired alarm, then press [ENT] at your selection.
A L b	
AL Hi	Use the arrows keys to scroll to either Hi or Lo, then press [ENT] at your selection.
AL Lo	

Alarm (AL) (cont.)

Note: *The alarm range limits are as follows:*
-202.0 °F to 160 °F
-130 °C to 70 °C.

-202.0 °F	Use the arrow keys to change the value, then press [ENT] to confirm your entry.
X.XC	(The X's represent your value.) Press [ESC] twice to return to the Main Menu.

Recorder (RCRD)

Use the RCRD submenu to enter the recorder units, the recorder output signal, and the low and high (zero and span) recorder points. At the "rcrd" prompt, press the [ENT] key to enter this submenu.

d E G F	Use the arrow keys to scroll to the desired units, then press [ENT] at your selection.
d E G C	
H	
r-out	Use the arrows keys to scroll to the recorder output option, then press [ENT] to confirm your selection.
r c d Lo	
r c d Hi	
4 - 20	Use the arrow keys to scroll to the desired output range, then press [ENT] at your selection.
0 - 20	
0 - 2	

Recorder (RCRD) (cont.)

Note: *Be sure the output range you select agrees with the recorder switch setting (see Chapter 2,* Connecting the Recorder*, page 2-5). The output ranges are as follows:*

4 - 20 mA
0 - 20 mA
0 - 2 VDC

Display	Action
r c d Lo	Use the arrow keys to scroll to the desired recorder setpoint, then press [ENT] at your selection.
r c d Hi	
r - out	
0.0°F	Use the arrow keys to enter the setpoint value, then press [ENT] to confirm your entry.

Note: *The recorder range limits are as follows:*

-202.0 °F to 160 °F
-130 °C to 70 °C.

Display	Action
X.XF	(The X's represent your value.) Press [ESC] twice to return to the Main Menu.

OFFSET

Use this submenu to adjust the displayed dew point reading. A positive number will increase the reading; a negative number will decrease the reading. This value is always in dew point degrees C. At the "OFFSET" prompt, press the [ENT] key to view the current offset value.

X.XC	(The X's represent the current value.) Use the arrow keys to change the value, then press [ENT] to confirm your entry and return to the Main Menu.

Note: *The offset range is ±15°C.*

DEFAULT

Use the "defalt" sub-menu to reset the Series 4 program to its default values.

Caution!
Resetting the default values will overwrite all previous settings. Use this option only if you have replaced the instrument program.

At the "defalt" prompt, press the [ENT] key.

Sure?	To reset the default values, press [ENT] at the "Sure?" prompt.
done	The system will display "done" before returning to the Main Menu.

TEST

Use this submenu to test the recorder, alarms, and display, and also to adjust the recorder. At the "test" prompt, press the [ENT] key to enter this submenu.

t _ rcrd	Use the arrow keys to scroll to the desired test, then press [ENT] at your selection.
t _ AL	
dSPtSt	
rAdj	

To Test Recorders:

This option lets you test the recorder output to make sure it is operating properly. You can test three percentages of the full scale recorder range, as follows:

H = 100% of the full scale recorder range;
t = 50% of the full scale recorder range;
L = 0% of the full scale recorder range.

Note: *Be sure the recorder is connected as described in Chapter 2,* Connecting the Recorder, *page 2-5, before proceeding with the following steps.*

X - XX H	Use the arrow keys to scroll to the "t - rcrd" prompt, then press [ENT] to view the
X - XX L	selections. (The X's represent the recorder output signal already selected.)
X - XX t	Use the arrow keys to scroll to the required value; the recorder pen should swing to the appropriate value.

Note: *If the recorder needs to be adjusted, refer to "Adjust Recorders" on page 3-10.*

X - XX H	Press [ESC] to return to the test options.

TEST (cont.)

To Test Alarms:

This option lets you trip or reset the alarm relays.

ALA OF

Use the arrow keys to scroll to the "t _ AL" prompt, then press [ENT] to view the selections.

ALA On

ALb OF

ALb On

Use the arrow keys to scroll to the alarm you want to test

Note: *The alarms test choices are as follows:*
Alarm A off;
Alarm A on;
Alarm B off;
Alarm B on.

ALA On

Press [ESC] to return to the test options. Repeat the procedure as desired.

To Test the Display:

Use this option to test that all segments of the display are working. Use the arrow keys to scroll to the "dSPtSt" prompt, then press [ENT] to test the display.

8. 8. 8. 8. 8. 8.

Press [ESC] to return to the test options.

TEST (cont.)

To Adjust Recorders:

Use this option to trim the recorder. The measured value of the recorder can vary from the programmed value due to varying load.

To accurately trim the recorder, you will need a digital voltmeter capable of measuring 0 to 2 V with a resolution of ±0.0001 VDC (0.1 mV), or 0 to 20 mA with a resolution of ±0.01 mA. (The range you use depends on your recorder output.)

Note: *Be sure the recorder switch is set for the correct output. (Refer to Chapter 2,* Connecting the Recorder*, page 2-5).*

Disconnect the chart recorder and connect the digital voltmeter.

rAdj	Use the arrow keys to scroll to the "rAdJ" prompt, then press [ENT].
XXX	Use the arrow keys to scroll to the desired trim value.

Note: *If the recorder output is reading too high, enter a negative number.*

Press [ENT] followed by [ESC] to return to the Main Menu.

Note: *The trim resolution is limited to ±0.05 mA or ±0.5 mV. Choose the trim value that produces an output closest to the value you want.*

REF

The Series 4 requires reference values for its moisture measurement circuitry. Reference values are factory calibration values that are specific to each unit. They are listed on the label located on the side or bottom of the Series 4 electronics unit.

Note: *All high and low reference values are factory set and normally do not need adjustment. If for some reason you need to adjust or re-enter the values, follow the steps below.*

At the "ref" prompt, press [ENT] to enter this submenu.

Display	Action
H rEF	Use the arrow keys to scroll through the choices to the desired selection, then press [ENT].
L rEF	
X.XXXX	Use the arrow keys to change the value, then press [ENT] to confirm your entry. (The X’s represent your value.) Press [ESC] to return to the Main Menu.

SETUP

This submenu option is for field-service use only.

Caution!
To save data entered in the programming mode, you must return the Series 4 to the measurement mode before turning the unit off. If the Series 4 is turned off while in the programming mode, all data entered will be lost.

Submenu Options (cont.)

To Exit the Programming Mode:

At any Submenu prompt, press [ESC].

r u n?	Press [ENT] to exit the programming mode and return to the measurement mode.
busy. . .	

Chapter 4

Troubleshooting and Maintenance

Introduction

The Moisture Target Series 4 is designed to be maintenance and trouble free; however, because of process conditions and other factors, minor problems may occur. Some of the most common problems and procedures are discussed in this section. If you can not find the information you need in this section, please consult Panametrics.

Caution!
Do not attempt to troubleshoot the Series 4 beyond the instructions in this section. If you do, you may damage the unit and void the warranty.

This section includes the following information:

- Common Problems
- Replacing the User Program
- Replacing and Recalibrating the Moisture Probes

Common Problems

If the Series 4 measurement readings seem strange, or they do not make sense, there may be a problem with the probe or a component of the process system. Table 4-1 contains some of the most common problems that affect measurements.

Table 4-1: Troubleshooting Guide for Common Problems

Symptom	Possible Cause	System Response	Action
Accuracy of moisture sensor is questioned.	Insufficient time for system to equilibrate.	Probe reads too wet during dry down conditions, or too dry in wet up conditions.	Change the flow rate. A change in dew point indicates the sample system is not at equilibrium, or there is a leak. Allow sufficient time for sample system to equilibrate and moisture reading to become steady. Check for leaks.
	Dew point at sampling point is different than the dew point of the main stream.	Probe reads too wet or too dry.	Readings may be correct if the sampling point and main stream do not run under the same process conditions. The different process conditions cause readings to vary. Refer to Section A1.1 in Appendix A for more information. If sampling point and main stream conditions are the same, check sample system pipes, and any pipe between the sample system and main stream for leaks. Also,, check sample system for adsorbing water surfaces, such as rubber or plastic tubing, paper-type filters, or condensed water traps. Remove or replace contaminating parts with stainless steel parts.
	Sensor or sensor shield affected by process contaminants (refer to A2.1 and A2.2).	Probe reads too wet or too dry.	Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall sensor.
	Sensor is contaminated with conductive particles (refer to A2.2).	Probe reads high dew point.	Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall sensor. Also, install a proper filter (i.e. sintered or coalescing element).
	Sensor is corroded (refer to A2.3).	Probe reads too wet or too dry.	Return the probe to factory for evaluation.
	Sensor temperature is greater than 70°C (158°F).	Probe reads too dry.	Return the probe to factory for evaluation.
	Stream particles causing abrasion.	Probe reads too wet or too dry.	Return the probe to factory for evaluation.

Table 4-1: Troubleshooting Guide for Common Problems (cont.)

Symptom	Possible Cause	System Response	Action
A blinking E on the left side of the display. Screen always reads the wettest (highest) programmed moisture calibration value while displaying dew/frost point.	Probe is saturated. Liquid water present on sensor surface and/or across electrical connections.		Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall sensor.
	Shorted circuit on sensor.		Run "dry gas" over sensor surface. If high reading persists, then probe is probably shorted and should be returned to the factory for evaluation.
	Sensor is contaminated with conductive particles (refer to A2.2).		Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall sensor.
	Improper cable connection.		Check the cable connections to both the probe and the Series 4.
A blinking E on the left side of the display. Screen always reads the driest (lowest) programmed moisture calibration value while displaying dew/frost point.	Open circuit on sensor.		Return the probe to the factory for evaluation.
	Non-conductive material is trapped under contact arm of sensor.		Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall the sensor. If the low reading persists, return the probe to the factory for evaluation.
	Improper cable connection.		Check the cable connections to both the probe and the Series 4.
Slow response.	Slow outgassing of system.		Replace the system components with stainless steel or electro-polished stainless steel.
	Sensor is contaminated with non-conductive particles (refer to A2.1).		Clean the sensor and the sensor shield as described in Section A3.2 in Appendix A. Then reinstall the sensor.

Replacing the User Program

The user program is stored on an EPROM (Erasable Programmable Read Only Memory) chip. The chip is embedded on the controller board, which is located inside the Series 4 electronics unit. In order to replace the user program, you must remove the controller board and replace the EPROM. Record all data before replacing the EPROM.

A. Removing the Controller Board

1. Turn the power off and unplug the unit.

2. Discharge static from your body.

Caution!
EPROMs can be damaged by static electricity.

3. Open the Series 4 enclosure by removing the screws on the back panel.

4. Remove the controller board by pulling it straight out.

B. Replacing the EPROM

1. Use Figure 4-1 to locate the EPROM on the controller board. The EPROM is labeled U20.

2. Use a chip puller to remove the EPROM. If you do not have a chip puller, use a small screwdriver to wedge the chip out of its mounting. Once you remove the EPROM, make sure none of the legs of the EPROM are stuck in the socket.

Caution!
EPROMs can be damaged by static electricity.
Observe static precaution when handling EPROMs.

3. Place the new EPROM in the socket labeled U20 making sure that the notch on the EPROM matches the notch on the socket. See Figure 4-1 on the next page.

4. Make sure the legs of the EPROM fit into the socket. If they do not, gently remove the EPROM. Place the EPROM on its side (each side of the EPROM has legs) on a flat surface; then gently tilt the EPROM to bend the legs slightly inward.

Replacing the User Program (cont.)

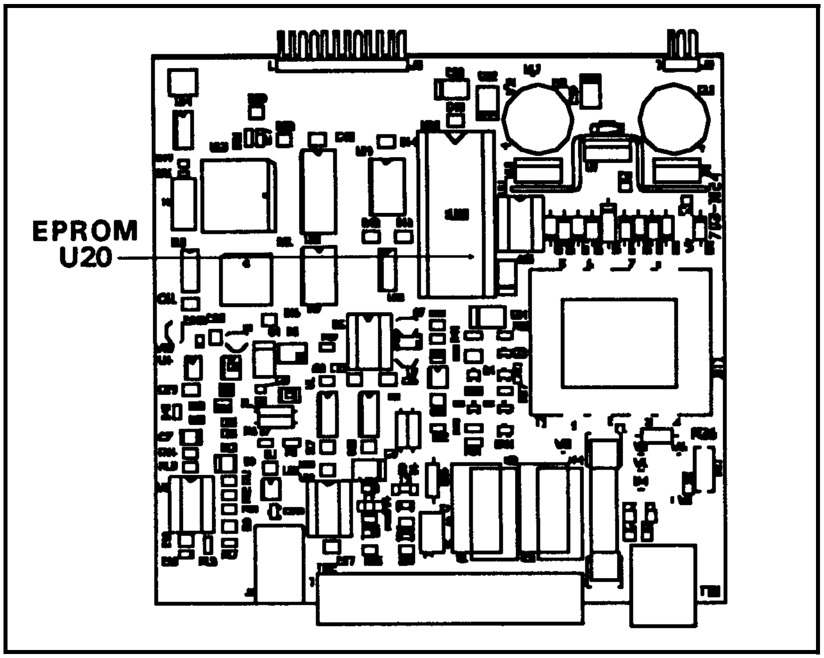

Figure 4-1: EPROM and Notch Location

Caution!
Do not bend the legs on the EPROM too much. The legs are very delicate and may snap off if bent too far or too many times.

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5. Repeat step 4 for the opposite side of the EPROM; then place the EPROM back in the socket. Make sure that the EPROM notch matches the socket notch.
6. Press the EPROM into place, making sure that you do not bend or break any of the legs. DO NOT FORCE THE EPROM INTO THE SOCKET. Repeat steps 4 and 5 if necessary.
7. Insert the controller card into the casing.
8. Replace the back panel on the casing. Do not over tighten screws.

Power up the Series 4 and check to make sure the calibration and reference data is not corrupted (refer to Chapter 3). If data is corrupted, re-enter data as described in Chapter 3.

Replacing and Recalibrating the Moisture Probes

For maximum accuracy you should send probes back to the factory for recalibration every six months to one year, depending on the application. Under severe conditions you should send the probes back for recalibration more frequently; in milder applications you do not need to recalibrate probes as often. Contact a Panametrics applications engineer for the recommended calibration frequency for your application.

When you receive new or recalibrated probes, be sure to install and connect them as described in Chapter 2*, Installing the Series 4.* Once you have installed and connected the probes, enter the calibration data as described in Chapter 3, *Programming the Series 4*. Note that each probe has its own Calibration Data Sheet with the corresponding probe serial number printed on it.

Chapter 5

Specifications

Electronics

Input	Moisture signal from Panametrics thin-film aluminum oxide moisture sensor.
Intrinsic Safety	External safety barrier for moisture input (optional).
Analog Output	Single recorder output for dew point; Internally optically isolated 10-bit (0.1%) resolution
Programmable Recorder Outputs	0 to 2 V, 10 k ohm minimum load resistance; 0 to 20 mA, 400 ohm maximum series resistance. 4 to 20 mA, 400 ohm maximum series resistance. Zero and span are user-programmable within the range of the instrument and the corresponding probe.
Alarm Relays	2 optional Form C relays SPDT; rated for 2A at 28 VDC and .5A at 120 VAC. Standard and hermetically-sealed designs available for high and low limits; set to trip at any level within the range of the instrument; programmable from front panel.
Alarm Setpoint Accuracy	±0.1°C dew point.
Display	1-line, 6-digit Liquid Crystal Display (LCD).
Display Functions	Dew point temperature °C or °F & MH.
Power Requirements	100/120/220/240 VAC, 50/60 Hz, 24 VDC; 3.6 Watts.
Temperature	Operating: 0° to 60°C. Storage: -30° to 70°C.
Warm-Up Time	Meets specified accuracy within 3 minutes.

Configurations	Panel mount version.
Dimensions	H x W x D Panel: 2.83 x 5.67 x 5.55" (71.9 x 144 x 141mm)

Moisture Measurement

Sensor Type	Thin-film aluminum oxide moisture sensor probe.
Moisture Probe Compatibility	Compatible with all Panametrics M-Series aluminum oxide moisture probes.
Moisture Probe Pressure Rating	5000 psig.
Dew/Frost Point Temperature	Overall calibration range: -110°C to +60°C. Available calibration range options: Standard, -80°C to +20°C with data to -110°C; Extended high, -80°C to +60°C with data to -110°C. Accuracy: ±2°C from -65°C to +60°C; ±3°C from -110°C to -66°C. Repeatability: ±0.5°C from -65°C to +60°C; ±1.0°C from -110°C to -66°C.

Appendix A

Application of the Hygrometer (900-901E)

Introduction

This appendix contains general information about moisture monitoring techniques. System contaminants, moisture probe maintenance, process applications and other considerations for ensuring accurate moisture measurements are discussed.

The following specific topics are covered:

- Moisture Monitor Hints
- Contaminants
- Aluminum Oxide Probe Maintenance
- Corrosive Gases and Liquids
- Materials of Construction
- Calculations and Useful Formulas in Gas Applications
- Liquid Applications
- Empirical Calibrations
- Solids Applications

Moisture Monitor Hints

GE Panametrics hygrometers, using aluminum oxide moisture probes, have been designed to reliably measure the moisture content of both gases and liquids. The measured dew point will be the real dew point of the system at the measurement location and at the time of measurement. However, no moisture sensor can determine the origin of the measured moisture content. In addition to the moisture content of the fluid to be analyzed, the water vapor pressure at the measurement location may include components from sources such as: moisture from the inner walls of the piping; external moisture through leaks in the piping system; and trapped moisture from fittings, valves, filters, etc. Although these sources may cause the measured dew point to be higher than expected, it is the actual dew point of the system at the time of measurement.

One of the major advantages of the GE Panametrics hygrometer is that it can be used for *in situ* measurements (i.e. the sensor element is designed for installation directly within the region to be measured). As a result, the need for complex sample systems that include extensive piping, manifolds, gas flow regulators and pressure regulators is eliminated or greatly reduced. Instead, a simple sample system to reduce the fluid temperature, filter contaminants and facilitate sensor removal is all that is needed.

Whether the sensor is installed in situ or in a remote sampling system, the accuracy and speed of measurement depend on the piping system and the dynamics of the fluid flow. Response times and measurement values will be affected by the degree of equilibrium reached within system. Factors such as gas pressure, flow rate, materials of construction, length and diameter of piping, etc. will greatly influence the measured moisture levels and the response times.

Assuming that all secondary sources of moisture have been eliminated and the sample system has been allowed to come to equilibrium, then the measured dew point will equal the actual dew point of the process fluid.

Some of the most frequently encountered problems associated with moisture monitoring sample systems include:

- the moisture content value changes as the total gas pressure changes
- the measurement response time is very slow
- the dew point changes as the fluid temperature changes
- the dew point changes as the fluid flow rate changes.

Moisture Monitor Hints (cont.)

GE Panametrics hygrometers measure only water vapor pressure. In addition, the instrument has a very rapid response time and it is not affected by changes in fluid temperature or fluid flow rate. If any of the above situations occur, then they are almost always caused by a defect in the sample system. The moisture sensor itself can not lead to such problems.

Pressure

GE Panametrics hygrometers can accurately measure dew points under pressure conditions ranging from vacuums as low as a few microns of mercury up to pressures of 5000 psig. The calibration data supplied with the moisture probe is directly applicable over this entire pressure range, without correction.

Note: *Although the moisture probe calibration data is supplied as meter reading vs. dew point, it is important to remember that the moisture probe responds only to water vapor pressure.*

When a gas is compressed, the partial pressures of all the gaseous components are proportionally increased. Conversely, when a gas expands, the partial pressures of the gaseous components are proportionally decreased. Therefore, increasing the pressure on a closed aqueous system will increase the vapor pressure of the water, and hence, increase the dew point. This is not just a mathematical artifact. The dew point of a gas with 1000 PPMv of water at 200 psig will be considerably higher than the dew point of a gas with 1000 PPMv of water at 1 atm. Gaseous water vapor will actually condense to form liquid water at a higher temperature at the 200 psig pressure than at the 1 atm pressure. Thus, if the moisture probe is exposed to pressure changes, the measured dew point will be altered by the changed vapor pressure of the water.

It is generally advantageous to operate the hygrometer at the highest possible pressure, especially at very low moisture concentrations. This minimizes wall effects and results in higher dew point readings, which increases the sensitivity of the instrument.

Response Time

The response time of the GE Panametrics standard M Series Aluminum Oxide Moisture Sensor is very rapid - a step change of 63% in moisture concentration will be observed in approximately 5 seconds. Thus, the observed response time to moisture changes is, in general, limited by the response time of the sample system as a whole. Water vapor is absorbed tenaciously by many materials, and a large, complex processing system can take several days to “dry down” from atmospheric moisture levels to dew points of less than -60°C. Even simple systems consisting of a few feet of stainless steel tubing and a small chamber can take an hour or more to dry down from dew points of +5°C to -70°C. The rate at which the system reaches equilibrium will depend on flow rate, temperature, materials of construction and system pressure. Generally speaking, an increase in flow rate and/or temperature will decrease the response time of the sample system.

Response Time (cont.)

To minimize any adverse affects on response time, the preferred materials of construction for moisture monitoring sample systems are stainless steel, Teflon® and glass. Materials to be avoided include rubber elastomers and related compounds.

Temperature

The GE Panametrics hygrometer is largely unaffected by ambient temperature. However, for best results, it is recommended that the ambient temperature be at least 10°C higher than the measured dew point, up to a maximum of 70°C. Because an ambient temperature increase may cause water vapor to be desorbed from the walls of the sample system, it is possible to observe a diurnal change in moisture concentration for a system exposed to varying ambient conditions. In the heat of the day, the sample system walls will be warmed by the ambient air and an off-gassing of moisture into the process fluid, with a corresponding increase in measured moisture content, will occur. The converse will happen during the cooler evening hours. This effect should not be mistakenly interpreted as indicating that the moisture probe has a temperature coefficient.

Flow Rate

GE Panametrics hygrometers are unaffected by the fluid flow rate. The moisture probe is not a mass sensor but responds only to water vapor pressure. The moisture probe will operate accurately under both static and dynamic fluid flow conditions. In fact, the specified maximum fluid linear velocity of 10,000 cm/sec for The M Series Aluminum Oxide Moisture Sensor indicates a mechanical stability limitation rather than a sensitivity to the fluid flow rate.

If the measured dew point of a system changes with the fluid flow rate, then it can be assumed that off-gassing or a leak in the sample system is causing the variation. If secondary moisture is entering the process fluid (either from an ambient air leak or the release of previously absorbed moisture from the sample system walls), an increase in the flow rate of the process fluid will dilute the secondary moisture source. As a result, the vapor pressure will be lowered and a lower dew point will be measured.

Note: *Refer to the* Specifications *chapter in this manual for the maximum allowable flow rate for the instrument.*

Contaminants

Industrial gases and liquids often contain fine particulate matter. Particulates of the following types are commonly found in such process fluids:

- carbon particles
- salts
- rust particles
- polymerized substances
- organic liquid droplets
- dust particles
- molecular sieve particles
- alumina dust

For convenience, the above particulates have been divided into three broad categories. Refer to the appropriate section for a discussion of their affect on the GE Panametrics moisture probe.

Non-Conductive Particulates

Note: *Molecular sieve particles, organic liquid droplets and oil droplets are typical of this category.*

In general, the performance of the moisture probe will not be seriously hindered by the condensation of non-conductive, non-corrosive liquids. However, a slower response to moisture changes will probably be observed, because the contaminating liquid barrier will decrease the rate of transport of the water vapor to the sensor and reduce its response time.

Particulate matter with a high density and/or a high flow rate may cause abrasion or pitting of the sensor surface. This can drastically alter the calibration of the moisture probe and, in extreme cases, cause moisture probe failure. A stainless steel shield is supplied with the moisture probe to minimize this effect, but in severe cases, it is advisable to install a Teflon® or stainless steel filter in the fluid stream.

On rare occasions, non-conductive particulate material may become lodged under the contact arm of the sensor, creating an open circuit. If this condition is suspected, refer to the *Probe Cleaning Procedure* section of this appendix for the recommended cleaning procedure.

Conductive Particulates

Note: *Metallic particles, carbon particles and conductive liquid droplets are typical of this category.*

Since the hygrometer reading is inversely proportional to the impedance of the sensor, a decrease in sensor impedance will cause an increase in the meter reading. Thus, trapped conductive particles across the sensor leads or on the sensor surface, which will decrease the sensor impedance, will cause an erroneously high dew point reading. The most common particulates of this type are carbon (from furnaces), iron scale (from pipe walls) and glycol droplets (from glycol-based dehydrators).

If the system contains conductive particulates, it is advisable to install a Teflon® or stainless steel filter in the fluid stream.

Corrosive Particulates

Note: *Sodium chloride and sodium hydroxide particulates are typical of this category.*

Since the active sensor element is constructed of aluminum, any material that corrodes aluminum will deleteriously affect the operation of the moisture probe. Furthermore, a combination of this type of particulate with water will cause pitting or severe corrosion of the sensor element. In such instances, the sensor cannot be cleaned or repaired and the probe must be replaced.

Obviously, the standard moisture probe can not be used in such applications unless the complete removal of such part by adequate filtration is assured.

Aluminum Oxide Probe Maintenance

Other than periodic calibration checks, little or no routine moisture probe maintenance is required. However, as discussed in the previous section, any electrically conductive contaminant trapped on the aluminum oxide sensor will cause inaccurate moisture measurements. If such a situation develops, return of the moisture probe to the factory for analysis and recalibration is recommended. However, in an emergency, cleaning of the moisture probe in accordance with the following procedure may be attempted by a qualified technician or chemist.

IMPORTANT: *Moisture probes must be handled carefully and cannot be cleaned in any fluid which will attack its components. The probe's materials of construction are Al, Al_2O_3, nichrome, gold, stainless steel, glass and Viton® A. Also, the sensor's aluminum sheet is very fragile and can be easily bent or distorted. Do not permit anything to touch it!*

The following items will be needed to properly complete the moisture probe cleaning procedure:

- approximately 300 ml of reagent grade hexane or toluene
- approximately 300 ml of distilled (not deionized) water
- two glass containers to hold above liquids (metal containers should not be used).

To clean the moisture probe, complete the following steps:

1. Record the dew point of the ambient air.
2. Making sure not to touch the sensor, carefully remove the protective shield from the sensor.
3. Soak the sensor in the distilled water for ten (10) minutes. Be sure to avoid contact with the bottom and the walls of the container!
4. Remove the sensor from the distilled water and soak it in the clean container of hexane or toluene for ten (10) minutes. Again, avoid all contact with the bottom and the walls of the container!
5. Remove the sensor from the hexane or toluene, and place it face up in a low temperature oven set at 50°C ±2°C (122°F ±4°F) for 24 hours.

Aluminum Oxide Probe Maintenance (cont.)

6. Repeat steps 3-5 for the protective shield. During this process, swirl the shield in the solvents to ensure the removal of any contaminants that may have become embedded in the porous walls of the shield.

7. Carefully replace probe's protective shield, making sure not to touch the sensor.

8. Connect the probe cable to the probe, and record the dew point of the ambient air, as in step 1. Compare the two recorded dew point readings to determine if the reading after cleaning is a more accurate value for the dew point of the ambient atmosphere.

9. If the sensor is in proper calibration (±2°C accuracy), reinstall the probe in the sample cell and proceed with normal operation of the hygrometer.

10. If the sensor is not in proper calibration, repeat steps 1-9, using time intervals 5 times those used in the previous cleaning cycle. Repeat this procedure until the sensor is in proper calibration.

A trained laboratory technician should determine if all electrically conductive compounds have been removed from the aluminum oxide sensor and that the probe is properly calibrated. Probes which are not in proper calibration must be recalibrated. It is recommended that all moisture probes be recalibrated by GE Panametrics approximately once a year, regardless of the probe's condition.

Corrosive Gases And Liquids

GE Panametrics M Series Aluminum Oxide Moisture Sensors have been designed to minimize the affect of corrosive gases and liquids. As indicated in the *Materials of Construction* section of this appendix, no copper, solder or epoxy is used in the construction of these sensors. The moisture content of corrosive gases such as H_2S, SO_2, cyanide containing gases, acetic acid vapors, etc. can be measured directly.

Note: *Since the active sensor is aluminum, any fluid which corrodes aluminum will affect the sensor's performance.*

By observing the following precautions, the moisture probe may be used successfully and economically:

1. The moisture content of the corrosive fluid must be 10 PPMv or less at 1 atmosphere, or the concentration of the corrosive fluid must be 10 PPMv or less at 1 atmosphere.
2. The sample system must be pre-dried with a dry inert gas, such as nitrogen or argon, prior to introduction of the fluid stream. Any adsorbed atmospheric moisture on the sensor will react with the corrosive fluid to cause pitting or corrosion of the sensor.
3. The sample system must be purged with a dry inert gas, such as nitrogen or argon, prior to removal of the moisture probe. Any adsorbed corrosive fluid on the sensor will react with ambient moisture to cause pitting or corrosion of the sensor.
4. Operate the sample system at the lowest possible gas pressure.

Using the precautions listed above, the hygrometer has been used to successfully measure the moisture content in such fluids as hydrochloric acid, sulfur dioxide, chlorine and bromine.

Materials of Construction

M1 and M2 Sensors:

Sensor Element:	99.99% aluminum, aluminum oxide, gold, Nichrome, A6
Back Wire:	316 stainless steel
Contact Wire:	gold, 304 stainless steel
Front Wire:	316 stainless steel
Support:	Glass (Corning 9010)

Electrical Connector:

Pins:	Al 152 Alloy (52% Ni)
Glass:	Corning 9010
Shell:	304L stainless steel
O-Ring:	silicone rubber
Threaded Fitting:	304 stainless steel
O-Ring:	Viton® A
Cage:	308 stainless steel
Shield:	304 stainless steel

Calculations and Useful Formulas in Gas Applications

A knowledge of the dew point of a system enables one to calculate all other moisture measurement parameters. The most important fact to recognize is that *for a particular dew point there is one and only one equivalent vapor pressure*.

Note: *The calibration of GE Panametrics moisture probes is based on the vapor pressure of liquid water above 0°C and frost below 0°C. GE Panametrics moisture probes are never calibrated with supercooled water.*

Caution is advised when comparing dew points measured with a GE Panametrics hygrometer to those measured with a mirror type hygrometer, since such instruments may provide the dew points of supercooled water.

As stated above, the dew/frost point of a system defines a unique partial pressure of water vapor in the gas. Table A-1 on page A-15, which lists water vapor pressure as a function of dew point, can be used to find either the saturation water vapor pressure at a known temperature or the water vapor pressure at a specified dew point. In addition, all definitions involving *humidity* can then be expressed in terms of the water vapor pressure.

Nomenclature

The following symbols and units are used in the equations that are presented in the next few sections:

- RH = relative humidity
- T_K = temperature (°K = °C + 273)
- T_R = temperature (°R = °F + 460)
- PPM_v = parts per million by volume
- PPM_w = parts per million by weight
- M_w = molecular weight of water (18)
- M_T = molecular weight of carrier gas
- P_S = saturation vapor pressure of water at the prevailing temperature (mm of Hg)
- P_W = water vapor pressure at the measured dew point (mm of Hg)
- P_T = total system pressure (mm of Hg)

Parts per Million by Volume

The water concentration in a system, in parts per million by volume, is proportional to the ratio of the water vapor partial pressure to the total system pressure:

$$PPM_V = \frac{P_W}{P_T} \times 10^6 \qquad (0\text{-}1)$$

In a closed system, increasing the total pressure of the gas will proportionally increase the partial pressures of the various components. The relationship between dew point, total pressure and PPM_V is provided in nomographic form in Figure A-1 on page A-20.

Note: *The nomograph shown in Figure A-1 on page A-20 is applicable only to gases. Do not apply it to liquids.*

To compute the moisture content for any ideal gas at a given pressure, refer to Figure A-1 on page A-20. Using a straightedge, connect the dew point (as measured with the GE Panametrics' Hygrometer) with the known system pressure. Read the moisture content in PPM_V where the straightedge crosses the moisture content scale.

Typical Problems

1. Find the water content in a nitrogen gas stream, if a dew point of -20°C is measured and the pressure is 60 psig.

Solution: In Figure A-1 on page A-20, connect 60 psig on the Pressure scale with -20°C on the Dew/Frost Point scale. Read **200 PPM_V**, on the Moisture Content scale.

2. Find the expected dew/frost point for a helium gas stream having a measured moisture content of 1000 PPM_V and a system pressure of 0.52 atm.

Solution: In Figure A-1 on page A-20, connect 1000 PPM_V on the Moisture Content scale with 0.52 atm on the Pressure scale. Read the expected frost point of **–27°C** on the Dew/Frost Point scale.

Parts per Million by Weight

The water concentration in the gas phase of a system, in parts per million by weight, can be calculated directly from the PPM_V and the ratio of the molecular weight of water to that of the carrier gas as follows:

$$PPM_W = PPM_V \times \frac{M_W}{M_T} \tag{0-2}$$

Relative Humidity

Relative humidity is defined as the ratio of the actual water vapor pressure to the saturation water vapor pressure at the prevailing ambient temperature, expressed as a percentage.

$$RH = \frac{P_W}{P_S} \times 100 \tag{0-3}$$

1. Find the relative humidity in a system, if the measured dew point is 0°C and the ambient temperature is +20°C.

Solution: From Table A-1 on page A-20, the water vapor pressure at a dew point of 0°C is 4.579 mm of Hg and the saturation water vapor pressure at an ambient temperature of +20°C is 17.535 mm of Hg. Therefore, the relative humidity of the system is 100 x 4.579/17.535 = **26.1%**.

Weight of Water per Unit Volume of Carrier Gas

Three units of measure are commonly used in the gas industry to express the weight of water per unit volume of carrier gas. They all represent a vapor density and are derivable from the vapor pressure of water and the Perfect Gas Laws. Referenced to a temperature of 60°F and a pressure of 14.7 psia, the following equations may be used to calculate these units:

$$\frac{\text{mg of water}}{\text{liter of gas}} = 289 \times \frac{P_W}{T_K} \tag{0-4}$$

$$\frac{\text{lb of water}}{\text{ft}^3 \text{ of gas}} = 0.0324 \times \frac{P_W}{T_R} \tag{0-5}$$

$$\frac{\text{lb of water}}{\text{MMSCF of gas}} = \frac{PPM_V}{21.1} = \frac{10^6 \times P_W}{21.1 \times P_T} \tag{0-6}$$

Note: *MMSCF is an abbreviation for a “million standard cubic feet” of carrier gas.*

Weight of Water per Unit Weight of Carrier Gas

Occasionally, the moisture content of a gas is expressed in terms of the weight of water per unit weight of carrier gas. In such a case, the unit of measure defined by the following equation is the most commonly used:

$$\frac{\text{grains of water}}{\text{lb of gas}} = 7000 \times \frac{M_W \times P_W}{M_T \times P_T} \qquad (0\text{-}7)$$

For <u>ambient air at 1 atm of pressure</u>, the above equation reduces to the following:

$$\frac{\text{grains of water}}{\text{lb of gas}} = 5.72 \times P_W \qquad (0\text{-}8)$$

Table A-1: Vapor Pressure of Water

Note: *If the dew/frost point is known, the table will yield the partial water vapor pressure (P_W) in mm of Hg. If the ambient or actual gas temperature is known, the table will yield the saturated water vapor pressure (P_S) in mm of Hg.*

Water Vapor Pressure Over Ice

Temp.°C	0	2	4	6	8
-90	0.000070	0.000048	0.000033	0.000022	0.000015
-80	0.00040	0.00029	0.00020	0.00014	0.00010
-70	0.00194	0.00143	0.00105	0.00077	0.00056
-60	0.00808	0.00614	0.00464	0.00349	0.00261
-50	0.02955	0.0230	0.0178	0.0138	0.0106
-40	0.0966	0.0768	0.0609	0.0481	0.0378
-30	0.2859	0.2318	0.1873	0.1507	0.1209

Temp.°C	0.0	0.2	0.4	0.6	0.8
-29	0.317	0.311	0.304	0.298	0.292
-28	0.351	0.344	0.337	0.330	0.324
-27	0.389	0.381	0.374	0.366	0.359
-26	0.430	0.422	0.414	0.405	0.397
-25	0.476	0.467	0.457	0.448	0.439
-24	0.526	0.515	0.505	0.495	0.486
-23	0.580	0.569	0.558	0.547	0.536
-22	0.640	0.627	0.615	0.603	0.592
-21	0.705	0.691	0.678	0.665	0.652
-20	0.776	0.761	0.747	0.733	0.719
-19	0.854	0.838	0.822	0.806	0.791
-18	0.939	0.921	0.904	0.887	0.870
-17	1.031	1.012	0.993	0.975	0.956
-16	1.132	1.111	1.091	1.070	1.051
-15	1.241	1.219	1.196	1.175	1.153
-14	1.361	1.336	1.312	1.288	1.264
-13	1.490	1.464	1.437	1.411	1.386
-12	1.632	1.602	1.574	1.546	1.518
-11	1.785	1.753	1.722	1.691	1.661
-10	1.950	1.916	1.883	1.849	1.817
-9	2.131	2.093	2.057	2.021	1.985
-8	2.326	2.285	2.246	2.207	2.168
-7	2.537	2.493	2.450	2.408	2.367
-6	2.765	2.718	2.672	2.626	2.581
-5	3.013	2.962	2.912	2.862	2.813
-4	3.280	3.225	3.171	3.117	3.065
-3	3.568	3.509	3.451	3.393	3.336
-2	3.880	3.816	3.753	3.691	3.630
-1	4.217	4.147	4.079	4.012	3.946
0	4.579	4.504	4.431	4.359	4.287

Table A-1: Vapor Pressure of Water (Continued)

Aqueous Vapor Pressure Over Water

Temp.°C	0.0	0.2	0.4	0.6	0.8
0	4.579	4.647	4.715	4.785	4.855
1	4.926	4.998	5.070	5.144	5.219
2	5.294	5.370	5.447	5.525	5.605
3	5.685	5.766	5.848	5.931	6.015
4	6.101	6.187	6.274	6.363	6.453
5	6.543	6.635	6.728	6.822	6.917
6	7.013	7.111	7.209	7.309	7.411
7	7.513	7.617	7.722	7.828	7.936
8	8.045	8.155	8.267	8.380	8.494
9	8.609	8.727	8.845	8.965	9.086
10	9.209	9.333	9.458	9.585	9.714
11	9.844	9.976	10.109	10.244	10.380
12	10.518	10.658	10.799	10.941	11.085
13	11.231	11.379	11.528	11.680	11.833
14	11.987	12.144	12.302	12.462	12.624
15	12.788	12.953	13.121	13.290	13.461
16	13.634	13.809	13.987	14.166	14.347
17	14.530	14.715	14.903	15.092	15.284
18	15.477	15.673	15.871	16.071	16.272
19	16.477	16.685	16.894	17.105	17.319
20	17.535	17.753	17.974	18.197	18.422
21	18.650	18.880	19.113	19.349	19.587
22	19.827	20.070	20.316	20.565	20.815
23	21.068	21.324	21.583	21.845	22.110
24	22.377	22.648	22.922	23.198	23.476
25	23.756	24.039	24.326	24.617	24.912
26	25.209	25.509	25.812	26.117	26.426
27	26.739	27.055	27.374	27.696	28.021
28	28.349	28.680	29.015	29.354	29.697
29	30.043	30.392	30.745	31.102	31.461
30	31.824	32.191	32.561	32.934	33.312
31	33.695	34.082	34.471	34.864	35.261
32	35.663	36.068	36.477	36.891	37.308
33	37.729	38.155	38.584	39.018	39.457
34	39.898	40.344	40.796	41.251	41.710
35	42.175	42.644	43.117	43.595	44.078
36	44.563	45.054	45.549	46.050	46.556
37	47.067	47.582	48.102	48.627	49.157
38	49.692	50.231	50.774	51.323	51.879
39	52.442	53.009	53.580	54.156	54.737
40	55.324	55.910	56.510	57.110	57.720
41	58.340	58.960	59.580	60.220	60.860

Table A-1: Vapor Pressure of Water (Continued)

Aqueous Vapor Pressure Over Water (cont.)

Temp.°C	0.0	0.2	0.4	0.6	0.8
42	61.500	62.140	62.800	63.460	64.120
43	64.800	65.480	66.160	66.860	67.560
44	68.260	68.970	69.690	70.410	71.140
45	71.880	72.620	73.360	74.120	74.880
46	75.650	76.430	77.210	78.000	78.800
47	79.600	80.410	81.230	82.050	82.870
48	83.710	84.560	85.420	86.280	87.140
49	88.020	88.900	89.790	90.690	91.590
50	92.51	93.50	94.40	95.30	96.30
51	97.20	98.20	99.10	100.10	101.10
52	102.09	103.10	104.10	105.10	106.20
53	107.20	108.20	109.30	110.40	111.40
54	112.51	113.60	114.70	115.80	116.90
55	118.04	119.10	120.30	121.50	122.60
56	123.80	125.00	126.20	127.40	128.60
57	129.82	131.00	132.30	133.50	134.70
58	136.08	137.30	138.50	139.90	141.20
59	142.60	143.90	145.20	146.60	148.00
60	149.38	150.70	152.10	153.50	155.00
61	156.43	157.80	159.30	160.80	162.30
62	163.77	165.20	166.80	168.30	169.80
63	171.38	172.90	174.50	176.10	177.70
64	179.31	180.90	182.50	184.20	185.80
65	187.54	189.20	190.90	192.60	194.30
66	196.09	197.80	199.50	201.30	203.10
67	204.96	206.80	208.60	210.50	212.30
68	214.17	216.00	218.00	219.90	221.80
69	223.73	225.70	227.70	229.70	231.70
70	233.70	235.70	237.70	239.70	241.80
71	243.90	246.00	248.20	250.30	252.40
72	254.60	256.80	259.00	261.20	263.40
73	265.70	268.00	270.20	272.60	274.80
74	277.20	279.40	281.80	284.20	286.60
75	289.10	291.50	294.00	296.40	298.80
76	301.40	303.80	306.40	308.90	311.40
77	314.10	316.60	319.20	322.00	324.60
78	327.30	330.00	332.80	335.60	338.20
79	341.00	343.80	346.60	349.40	352.20
80	355.10	358.00	361.00	363.80	366.80
81	369.70	372.60	375.60	378.80	381.80
82	384.90	388.00	391.20	394.40	397.40
83	400.60	403.80	407.00	410.20	413.60

Table A-1: Vapor Pressure of Water (Continued)

Aqueous Vapor Pressure Over Water (cont.)

Temp.°C	0.0	0.2	0.4	0.6	0.8
84	416.80	420.20	423.60	426.80	430.20
85	433.60	437.00	440.40	444.00	447.50
86	450.90	454.40	458.00	461.60	465.20
87	468.70	472.40	476.00	479.80	483.40
88	487.10	491.00	494.70	498.50	502.20
89	506.10	510.00	513.90	517.80	521.80
90	525.76	529.77	533.80	537.86	541.95
91	546.05	550.18	554.35	558.53	562.75
92	566.99	571.26	575.55	579.87	584.22
93	588.60	593.00	597.43	601.89	606.38
94	610.90	615.44	620.01	624.61	629.24
95	633.90	638.59	643.30	648.05	652.82
96	657.62	662.45	667.31	672.20	677.12
97	682.07	687.04	692.05	697.10	702.17
98	707.27	712.40	717.56	722.75	727.98
99	733.24	738.53	743.85	749.20	754.58
100	760.00	765.45	770.93	776.44	782.00
101	787.57	793.18	798.82	804.50	810.21

Table A-2: Maximum Gas Flow Rates

Based on the physical characteristics of air at a temperature of 77°F and a pressure of 1 atm, the following flow rates will produce the maximum allowable gas stream linear velocity of 10,000 cm/sec in the corresponding pipe sizes.

Inside Pipe Diameter (in.)	Gas Flow Rate (cfm)
0.25	7
0.50	27
0.75	60
1.0	107
2.0	429
3.0	966
4.0	1,718
5.0	2,684
6.0	3,865
7.0	5,261
8.0	6,871
9.0	8,697
10.0	10,737
11.0	12,991
12.0	15,461

Table A-3: Maximum Liquid Flow Rates

Based on the physical characteristics of benzene at a temperature of 77°F, the following flow rates will produce the maximum allowable fluid linear velocity of 10 cm/sec in the corresponding pipe sizes.

Inside Pipe Diameter (in.)	Flow Rate (gal/hr)	Flow Rate (l/hr)
0.25	3	11
0.50	12	46
0.75	27	103
1.0	48	182
2.0	193	730
3.0	434	1,642
4.0	771	2,919
5.0	1,205	4,561
6.0	1,735	6,567
7.0	2,361	8,939
8.0	3,084	11,675
9.0	3,903	14,776
10.0	4,819	18,243
11.0	5,831	22,074
12.0	6,939	26,269

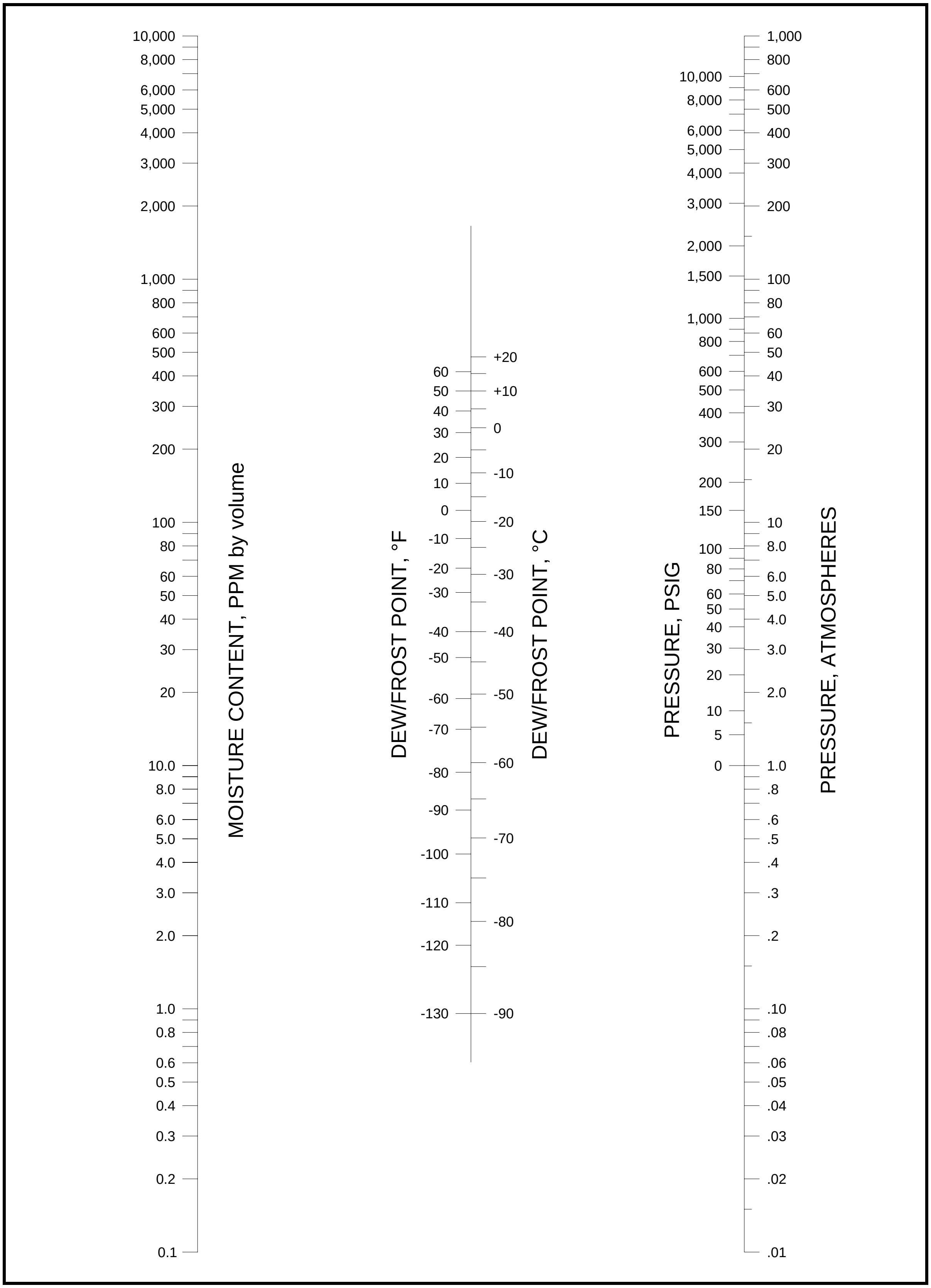

Figure A-1: Moisture Content Nomograph for Gases

Comparison of PPM_V Calculations

There are three basic methods for determining the moisture content of a gas in PPM_V:

- the calculations described in this appendix
- calculations performed with the slide rule device that is provided with each GE Panametrics hygrometer
- values determined from tabulated vapor pressures

For comparison purposes, examples of all three procedures are listed in Table A-4 below.

Table A-4: Comparative PPM_V Values

Dew Point (°C)	Pressure (psig)	Calculation Method		
		Slide Rule	Appendix A	Vapor Pressure
-80	0	0.5	0.55	0.526
	100	0.065	N.A.	0.0675
	800	0.009	N.A.	0.0095
	1500	0.005	N.A.	0.0051
-50	0	37	40	38.88
	100	4.8	5.2	4.98
	800	0.65	0.8	0.7016
	1500	0.36	0.35	0.3773
+20	0	N.A.	20,000	23,072.36
	100	3000	3000	2956.9
	800	420	400	416.3105
	1500	220	200	223.9

Liquid Applications

Theory of Operation

The direct measurement of water vapor pressure in organic liquids is accomplished easily and effectively with GE Panametrics' Aluminum Oxide Moisture Sensors. Since the moisture probe pore openings are small in relation to the size of most organic molecules, admission into the sensor cavity is limited to much smaller molecules, such as water. Thus, the surface of the aluminum oxide sensor, which acts as a semi-permeable membrane, permits the measurement of water vapor pressure in organic liquids just as easily as it does in gaseous media.

In fact, an accurate sensor electrical output will be registered whether the sensor is directly immersed in the organic liquid or it is placed in the gas space above the liquid surface. As with gases, the electrical output of the aluminum oxide sensor is a function of the measured water vapor pressure.

Moisture Content Measurement in Organic Liquids

Henry's Law Type Analysis

When using the aluminum oxide sensor in non-polar liquids having water concentrations ≤1% by weight, *Henry's Law* is generally applicable. Henry's Law states that, at constant temperature, *the mass of a gas dissolved in a given volume of liquid is proportional to the partial pressure of the gas in the system*. Stated in terms pertinent to this discussion, it can be said that the PPM_W of water in hydrocarbon liquids is equal to the partial pressure of water vapor in the system times a constant.

As discussed above, a GE Panametrics aluminum oxide sensor can be directly immersed in a hydrocarbon liquid to measure the equivalent dew point. Since the dew point is functionally related to the vapor pressure of the water, a determination of the dew point will allow one to calculate the PPM_W of water in the liquid by a Henry's Law type analysis. A specific example of such an analysis is shown below.

For liquids in which a Henry's Law type analysis is applicable, the parts per million by weight of water in the organic liquid is equal to the partial pressure of water vapor times a constant:

$$PPM_W = K \times P_W \tag{a}$$

where, K is the Henry's Law constant in the appropriate units, and the other variables are as defined on page A-11.

Henry's Law Type Analysis (cont.)

Also, the value of K is determined from the known water saturation concentration of the organic liquid at the measurement temperature:

$$K = \frac{\text{Saturation PPM}_W}{P_S} \qquad \text{(b)}$$

For a mixture of organic liquids, an average saturation value can be calculated from the weight fractions and saturation values of the pure components as follows:

$$\text{Ave. } C_S = \sum_{i=1}^{n} X_i (C_S)_i \qquad \text{(c)}$$

where, X_i is the weight fraction of the i^{th} component, $(C_S)_i$ is the saturation concentration (PPM_W) of the i^{th} component, and n is the total number of components.

In conclusion, the Henry's Law constant (K) is a constant of proportionality between the saturation concentration (C_S) and the saturation vapor pressure (P_S) of water, at the measurement temperature. In the *General Case*, the Henry's Law constant varies with the measurement temperature, but there is a *Special Case* in which the Henry's Law constant does not vary appreciably with the measurement temperature. This special case applies to saturated, straight-chain hydrocarbons such as pentane, hexane, heptane, etc.

A: General Case

Determination of Moisture Content if C_S is Known:

The nomograph for liquids in Figure A-2 on page A-32 can be used to determine the moisture content in an organic liquid, if the following values are known:

- the temperature of the liquid at the time of measurement
- the saturation water concentration at the measurement temperature
- the dew point, as measured with the GE Panametrics hygrometer

A: General Case (cont.)

Complete the following steps to determine the moisture content from the nomograph:

1. Using a straightedge on the two scales on the right of the figure, connect the known saturation concentration (PPM_W) with the measurement temperature (°C).
2. Read the Henry's Law constant (K) on the center scale.
3. Using a straightedge, connect above K value with the dew/frost point, as measured with the GE Panametrics' hygrometer.
4. Read the moisture content (PPM_W) where the straight edge crosses the moisture content scale.

Empirical Determination of K and C_S

If the values of K and C_S are not known, the GE Panametrics hygrometer can be used to determine these values. In fact, only one of the values is required to determine PPM_W from the nomograph in Figure A-2 on page A-32. To perform such an analysis, proceed as follows:

1. Obtain a sample of the test solution with a known water content; or perform a *Karl Fischer* titration on a sample of the test stream to determine the PPM_W of water.

Note: *The Karl Fischer analysis involves titrating the test sample against a special Karl Fischer reagent until an endpoint is reached.*

2. Measure the dew point of the known sample with the GE Panametrics hygrometer.
3. Measure the temperature (°C) of the test solution.
4. Using a straightedge, connect the moisture content (PPM_W) with the measured dew point, and read the K value on the center scale.
5. Using a straightedge, connect the above K value with the measured temperature (°C) of the test solution, and read the saturation concentration (PPM_W).

Note: *Since the values of K and C_S vary with temperature, the hygrometer measurement and the test sample analysis must be done at the same temperature. If the moisture probe temperature is expected to vary, the test should be performed at more than one temperature.*

B: Special Case

As mentioned earlier, saturated straight-chain hydrocarbons represent a special case, where the Henry's Law constant does not vary appreciably with temperature. In such cases, use the nomograph for liquids in Figure A-2 on page A-32 to complete the analysis.

Determination of moisture content if the Henry's Law constant (K) is known.

1. Using a straightedge, connect the known K value on the center scale with the dew/frost point, as measured with the GE Panametrics hygrometer.
2. Read moisture content (PPM_W) where the straightedge crosses the scale on the left.

Typical Problems

1. Find the moisture content in benzene, at an ambient temperature of 30°C, if a dew point of 0°C is measured with the GE Panametrics hygrometer.
   - **a.** From the literature, it is found that C_S for benzene at a temperature of 30°C is **870 PPM_W**.
   - **b.** Using a straightedge on Figure A-2 on page A-32, connect the 870 PPM_W saturation concentration with the 30°C ambient temperature and read the Henry's Law Constant of **27.4** on the center scale.
   - **c.** Using the straightedge, connect the above K value of 27.4 with the measured dew point of 0°C, and read the correct moisture content of **125 PPM_W** where the straightedge crosses the moisture content scale.
2. Find the moisture content in heptane, at an ambient temperature of 50°C, if a dew point of 3°C is measured with the GE Panametrics hygrometer.
   - **a.** From the literature, it is found that C_S for heptane at a temperature of 50°C is **480 PPM_W**.
   - **b.** Using a straightedge on Figure A-2 on page A-32, connect the 480 PPM_W saturation concentration with the 50°C ambient temperature and read the Henry's Law Constant of **5.2** on the center scale.
   - **c.** Using the straightedge, connect the above K value of 5.2 with the measured dew point of 3°C, and read the correct moisture content of **29 PPM_W** where the straightedge crosses the moisture content scale.

B: Special Case (cont.)

Note: *If the saturation concentration at the desired ambient temperature can not be found for any of these special case hydrocarbons, the value at any other temperature may be used, because K is constant over a large temperature range.*

3. Find the moisture content in hexane, at an ambient temperature of 10°C, if a dew point of 0°C is measured with the GE Panametrics hygrometer.

a. From the literature, it is found that C_S for hexane at a temperature of 20°C is **101 PPM_W**.

b. Using a straightedge on Figure A-2 on page A-32, connect the 101 PPM_W saturation concentration with the 20°C ambient temperature and read the Henry's Law Constant of **5.75** on the center scale.

c. Using the straightedge, connect the above K value of 5.75 with the measured dew point of 0°C, and read the correct moisture content of **26 PPM_W** where the straightedge crosses the moisture content scale.

4. Find the moisture content in an unknown organic liquid, at an ambient temperature of 50°C, if a dew point of 10°C is measured with the GE Panametrics hygrometer.

a. Either perform a Karl Fischer analysis on a sample of the liquid or obtain a dry sample of the liquid.

b. Either use the PPM_W determined by the Karl Fischer analysis or add a known amount of water (i.e. 10 PPM_W) to the dry sample.

c. Measure the dew point of the known test sample with the GE Panametrics hygrometer. For purposes of this example, assume the measured dew point to be -10°C.

d. Using a straightedge on the nomograph in Figure A-2 on page A-32, connect the known 10 PPM_W moisture content with the measured dew point of -10°C, and read a K value of **5.1** on the center scale.

e. Using the straightedge, connect the above K value of 5.1 with the measured 10°C dew point of the original liquid, and read the actual moisture content of **47 PPM_W** on the left scale.

B: Special Case (cont.)

Note: *The saturation value at 50°C for this liquid could also have been determined by connecting the K value of 5.1 with the ambient temperature of 50°C and reading a value of 475 PPM_W on the right scale.*

For many applications, a knowledge of the absolute moisture content of the liquid is not required. Either the dew point of the liquid or its percent saturation is the only value needed. For such applications, the saturation value for the liquid need not be known. The GE Panametrics hygrometer can be used directly to determine the dew point, and then the percent saturation can be calculated from the vapor pressures of water at the measured dew point and at the ambient temperature of the liquid:

$$\%\ \text{Saturation} = \frac{C}{C_S} \times 100 = \frac{P_W}{P_S} \times 100$$

Empirical Calibrations

For those liquids in which a Henry's Law type analysis is not applicable, the absolute moisture content is best determined by empirical calibration. A Henry's Law type analysis is generally not applicable for the following classes of liquids:

- liquids with a high saturation value (2% by weight of water or greater)
- liquids, such as dioxane, that are completely miscible with water
- liquids, such as isopropyl alcohol, that are conductive

For such liquids, measurements of the hygrometer dew point readings for solutions of various known water concentrations must be performed. Such a calibration can be conducted in either of two ways:

- perform a Karl Fischer analysis on several unknown test samples of different water content
- prepare a series of known test samples via the addition of water to a quantity of dry liquid

In the latter case, it is important to be sure that the solutions have reached equilibrium before proceeding with the dew point measurements.

Note: *Karl Fisher analysis is a method for measuring trace quantities of water by titrating the test sample against a special Karl Fischer reagent until a color change from yellow to brown (or a change in potential) indicates that the end point has been reached.*

Either of the empirical calibration techniques described above can be conducted using an apparatus equivalent to that shown in Figure A-3 on page A-33. The apparatus pictured can be used for both the Karl Fischer titrations of unknown test samples and the preparation of test samples with known moisture content. Procedures for both of these techniques are presented below.

A. Instructions for Karl Fischer Analysis

To perform a Karl Fisher analysis, use the apparatus in Figure A-3 on page A-33 and complete the following steps:

1. Fill the glass bottle completely with the sample liquid.

2. Close both valves and turn on the magnetic stirrer.

3. Permit sufficient time for the entire test apparatus and the sample liquid to reach equilibrium with the ambient temperature.

4. Turn on the hygrometer and monitor the dew point reading. When a stable dew point reading indicates that equilibrium has been reached, record the reading.

5. Insert a syringe through the rubber septum and withdraw a fluid sample for Karl Fischer analysis. Record the actual moisture content of the sample.

6. Open the exhaust valve.

7. Open the inlet valve and increase the moisture content of the sample by bubbling wet N_2 through the liquid (or decrease the moisture content by bubbling dry N_2 through the liquid).

8. When the hygrometer reading indicates the approximate moisture content expected, close both valves.

9. Repeat steps 3-8 until samples with several different moisture contents have been analyzed.

B. Instructions for Preparing Known Samples

Note: *This procedure is only for liquids that are highly miscible with water. Excessive equilibrium times would be required with less miscible liquids.*

To prepare samples of known moisture content, use the apparatus in Figure A-3 on page A-33 and complete the following steps:

1. Weigh the dry, empty apparatus.
2. Fill the glass bottle with the sample liquid.
3. Open both valves and turn on the magnetic stirrer.
4. While monitoring the dew point reading with the hygrometer, bubble dry N_2 through the liquid until the dew point stabilizes at some minimum value.
5. Turn off the N_2 supply and close both valves.
6. Weigh the apparatus, including the liquid, and calculate the sample weight by subtracting the step 1 weight from this weight.
7. Insert a syringe through the rubber septum and add a known weight of H_2O to the sample. Continue stirring until the water is completely dissolved in the liquid.
8. Record the dew point indicated by the hygrometer and calculate the moisture content as follows:

$$PPM_W = \frac{\text{weight of water}}{\text{total weight of liquid}} \times 10^6$$

9. Repeat steps 6-8 until samples with several different moisture contents have been analyzed.

Note: *The accuracy of this technique can be checked at any point by withdrawing a sample and performing a Karl Fischer titration. Be aware that this will change the total liquid weight in calculating the next point.*

C. Additional Notes for Liquid Applications

In addition to the topics already discussed, the following general application notes pertain to the use of GE Panametrics moisture probes in liquid applications:

1. All M Series Aluminum Oxide Moisture Sensors can be used in either the gas phase or the liquid phase. However, for the detection of trace amounts of water in conductive liquids (for which an empirical calibration is required), the M2 Sensor is recommended. Since a background signal is caused by the conductivity of the liquid between the sensor lead wires, use of the M2 Sensor (which has the shortest lead wires) will result in the best sensitivity.

2. The calibration data supplied with GE Panametrics Moisture Probes is applicable to both liquid phase (for those liquids in which a Henry's Law analysis is applicable) and gas phase applications.

3. As indicated in Table A-3 on page A-19, the flow rate of the liquid is limited to a maximum of 10 cm/sec.

4. Possible probe malfunctions and their remedies are discussed in the *Troubleshooting* chapter of this manual.

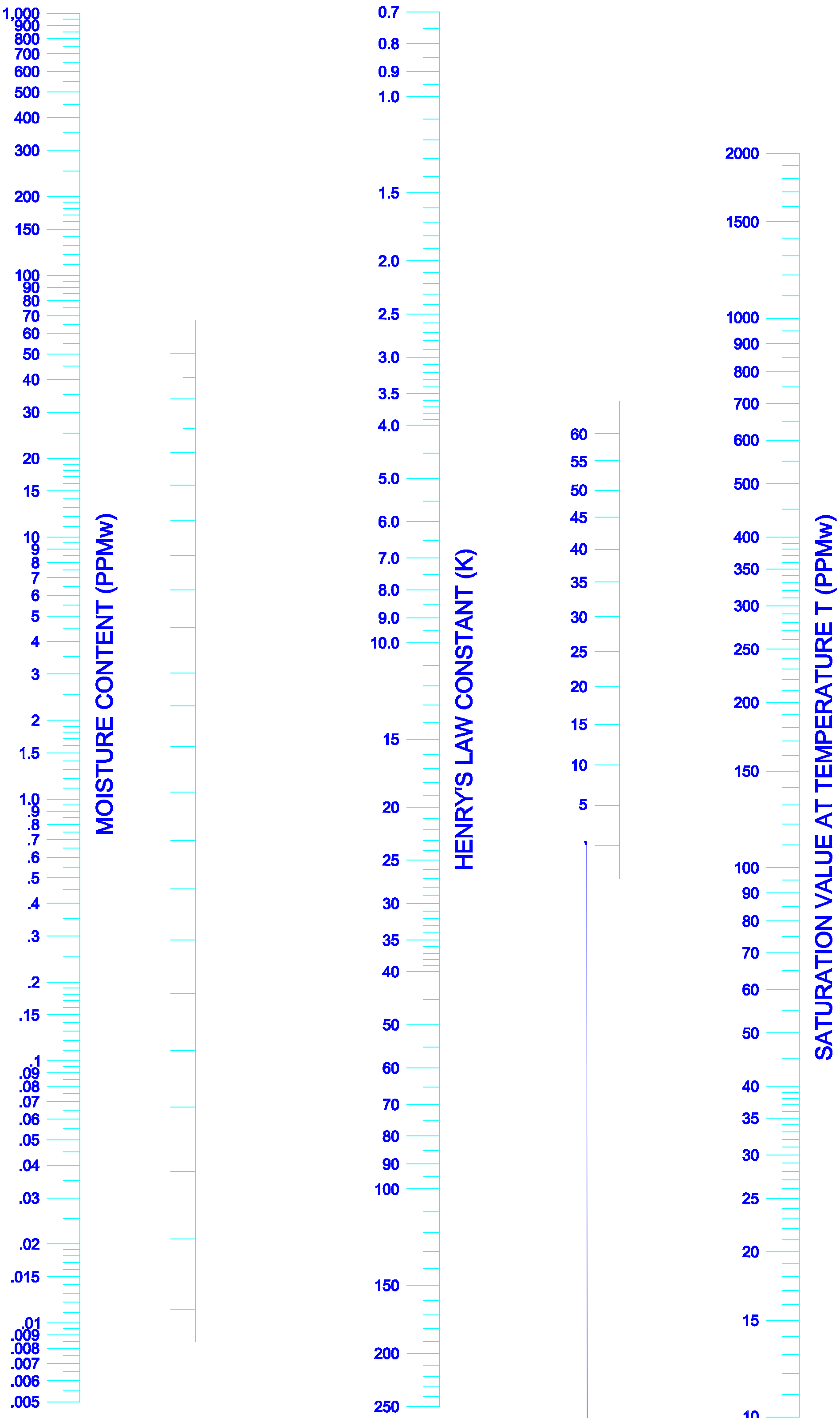

Figure A-2: Moisture Content Nomograph for Liquids

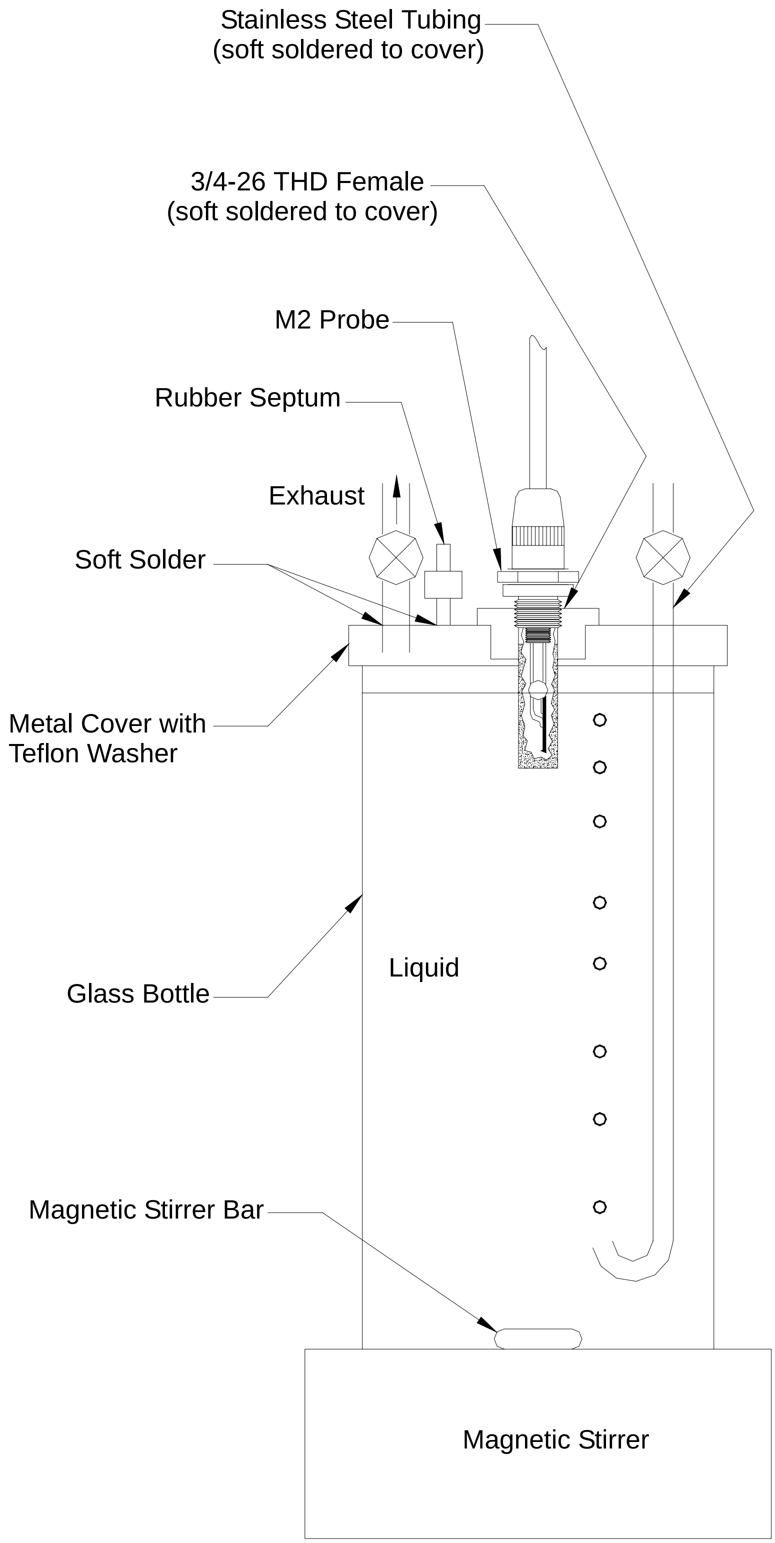

Figure A-3: Moisture Content Test Apparatus

Solids Applications

A. In-Line Measurements

GE Panametrics moisture probes may be installed in-line to continuously monitor the drying process of a solid. Install one sensor at the process system inlet to monitor the moisture content of the drying gas and install a second sensor at the process system outlet to monitor the moisture content of the discharged gas. When the two sensors read the same (or close to the same) dew point, the drying process is complete. For example, a system of this type has been used successfully to monitor the drying of photographic film.

If one wishes to measure the absolute moisture content of the solid at any time during such a process, then an empirical calibration is required:

1. At a particular set of operating conditions (i.e. flow rate, temperature and pressure), the hygrometer dew point reading can be calibrated against solids samples with known moisture contents.

2. Assuming the operating conditions are relatively constant, the hygrometer dew point reading can be noted and a solids sample withdrawn for laboratory analysis.

3. Repeat this procedure until a calibration curve over the desired moisture content range has been developed.

Once such a curve has been developed, the hygrometer can then be used to continuously monitor the moisture content of the solid (as long as operating conditions are relatively constant).

B. Laboratory Procedures

If in-line measurements are not practical, then there are two possible laboratory procedures:

1. The unique ability of the GE Panametrics sensor to determine the moisture content of a liquid can be used as follows:

a. Using the apparatus shown in Figure A-3 on page A-33, dissolve a known amount of the solids sample in a suitable hydrocarbon liquid.

b. The measured increase in the moisture content of the hydrocarbon liquid can then be used to calculate the moisture content of the sample.

c. For best results, the hydrocarbon liquid used above should be pre-dried to a moisture content that is insignificant compared to the moisture content of the sample.

Note: *Since the addition of the solid may significantly change the saturation value for the solvent, published values should not be used. Instead, an empirical calibration, as discussed in the previous section, should be used.*

d. A dew point of -110°C, which can correspond to a moisture content of 10^{-6} PPM_W or less, represents the lower limit of sensor sensitivity. The maximum measurable moisture content depends to a great extent on the liquid itself. Generally, the sensor becomes insensitive to moisture contents in excess of 1% by weight.

2. An alternative technique involves driving the moisture from the solids sample by heating:

a. The evaporated moisture is directed into a chamber of known volume, which contains a calibrated moisture sensor.

b. Convert the measured dew point of the chamber into a water vapor pressure, as discussed earlier in this appendix. From the known volume of the chamber and the measured vapor pressure (dew point) of the water, the number of moles of water in the chamber can be calculated and related to the percent by weight of water in the test sample.

c. Although this technique is somewhat tedious, it can be used successfully. An empirical calibration of the procedure may be performed by using hydrated solids of known moisture content for test samples.

Appendix B

Outline and Installation Drawings

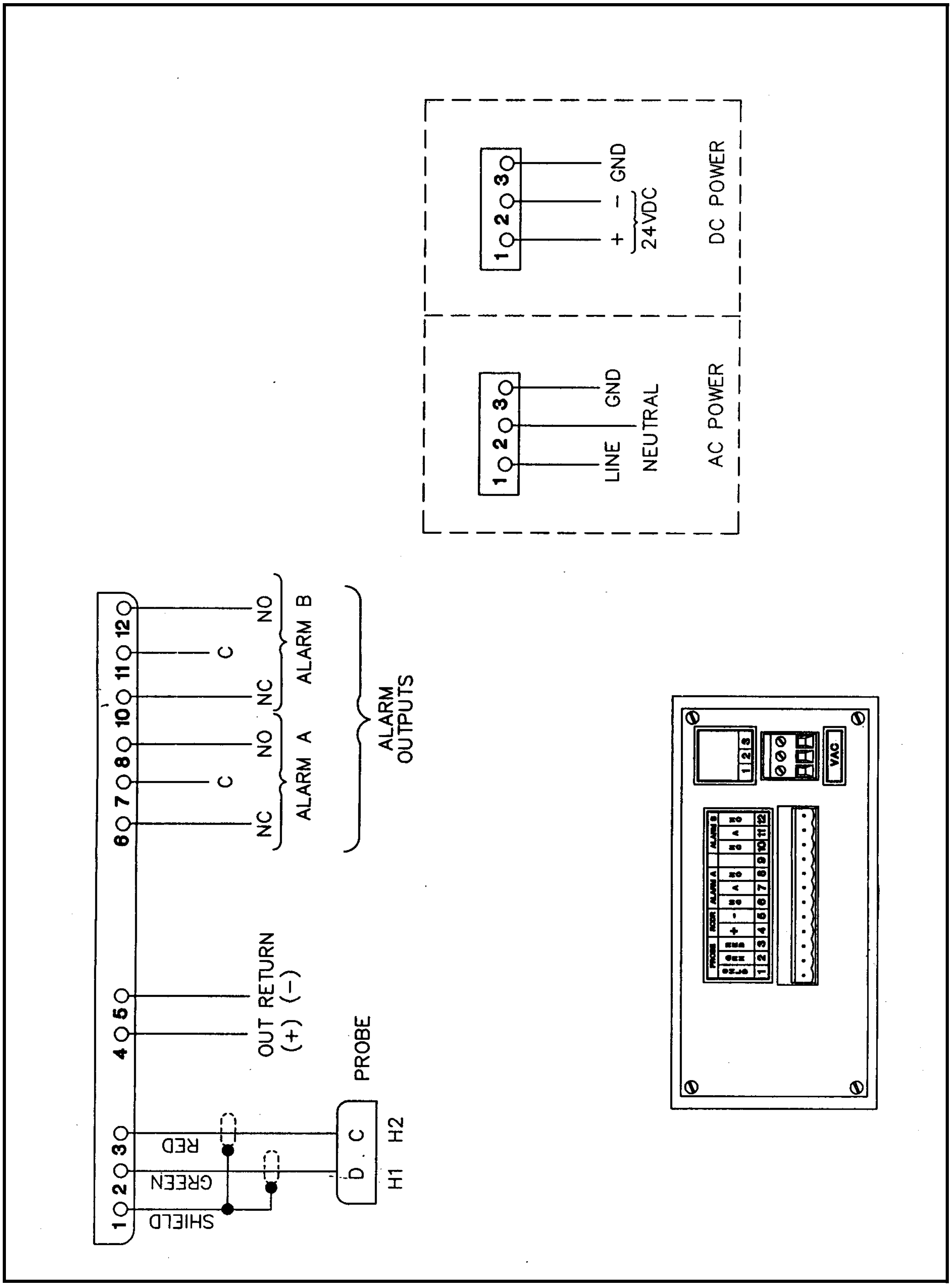

Figure B-1: MTS 4 Interconnection Diagram (dwg. #702-162)

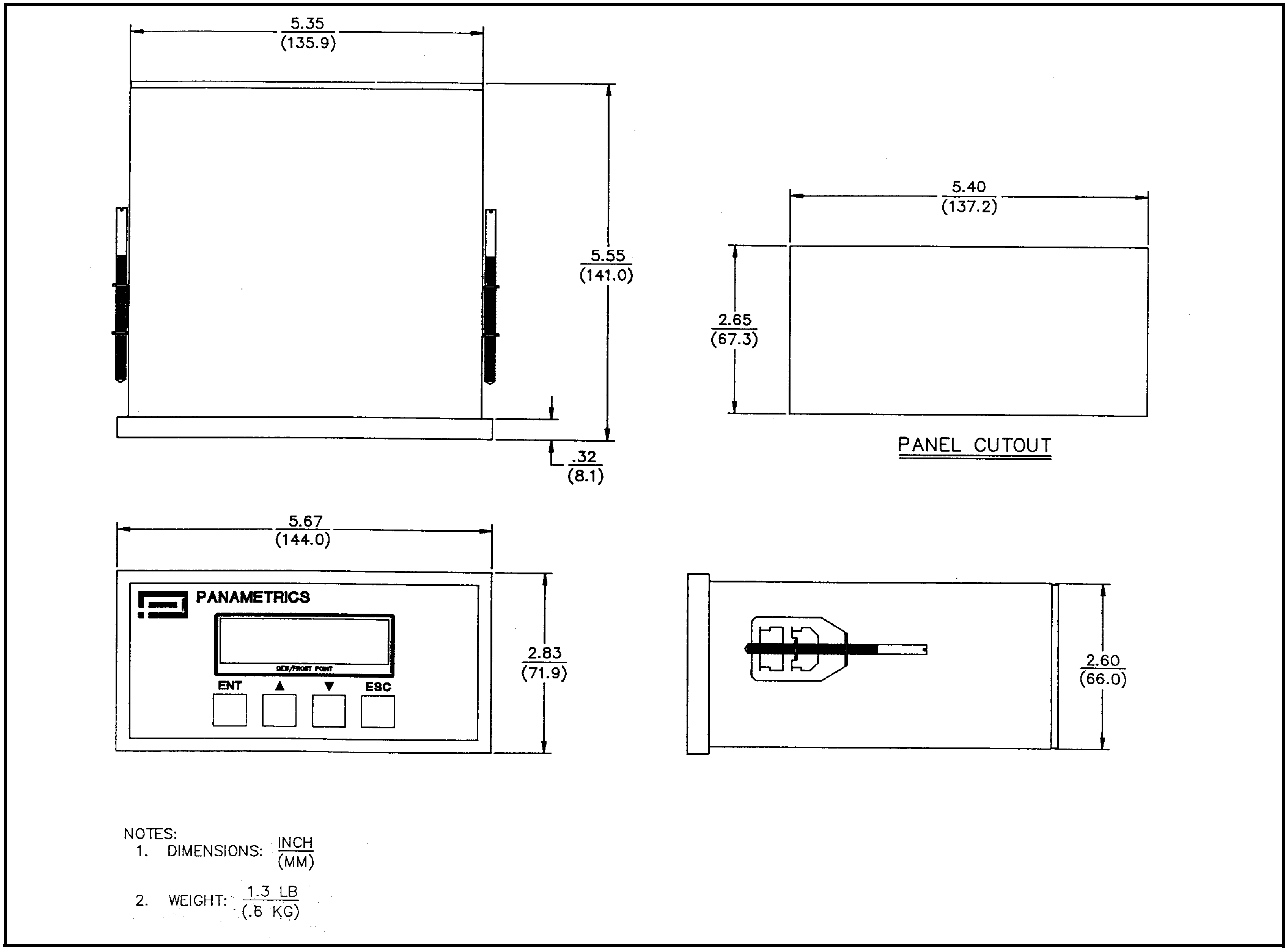

Figure B-2: MTS 4 Outline and Installation Panel Mount (dwg. #712-903)

Appendix C

Series 4 Menu Map

Series 4 Menu Map

The illustration below is a top level diagram of the Series 4 menus. Once you are familiar with how the Series 4 operates, use this diagram as a reference for moving through the user program.

To enter the programming mode, perform the following two steps within five (5) seconds, or the Series 4 will time out and return to the measurement mode (page 3-1).

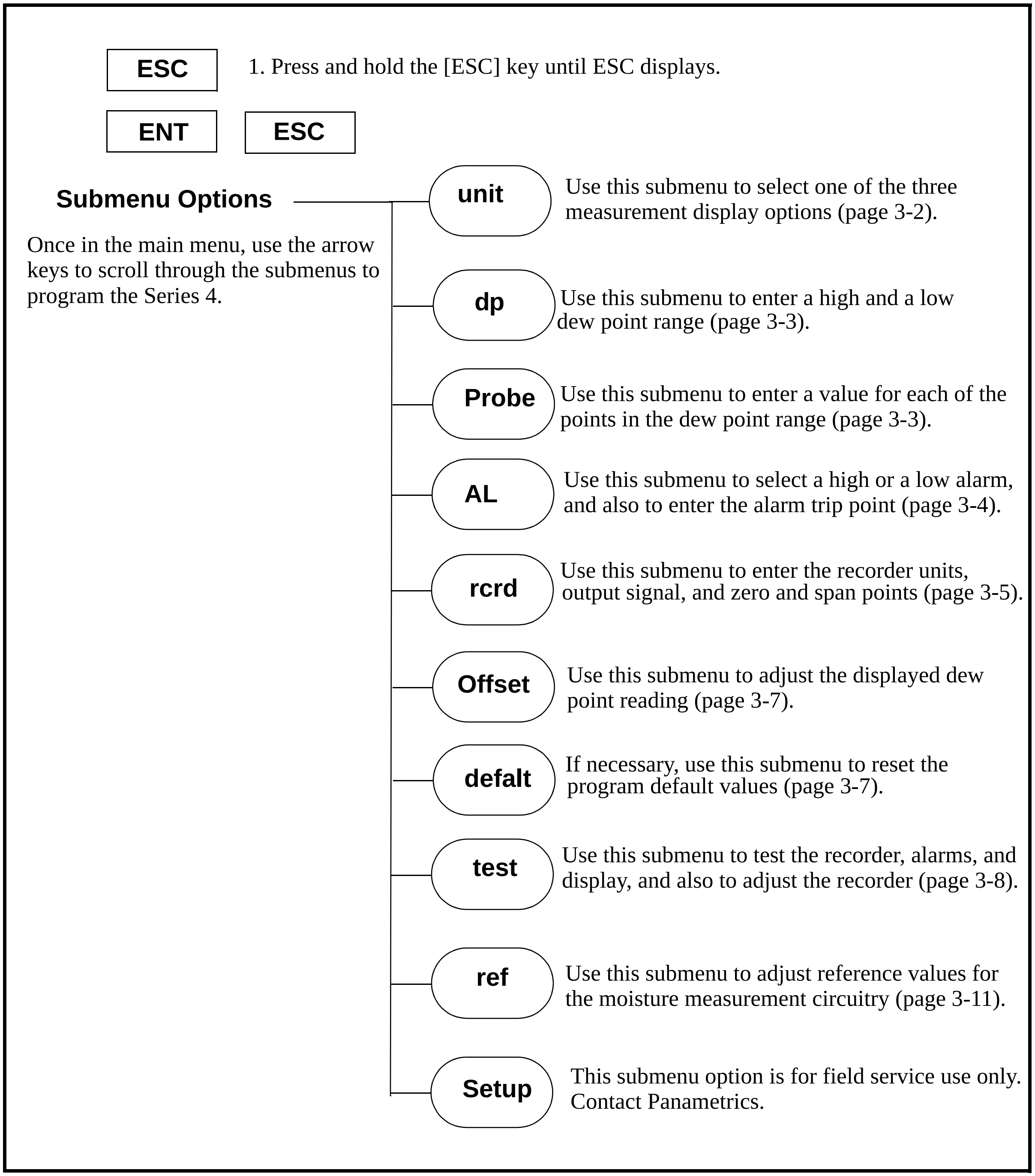

Figure C-1: Series 4 Menu Map

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