System 2 Hygrometer

User's Manual *910-076A*

PANAMETRICS

About Panametrics

During its 29 years specializing in the manufacture of non-destructive testing (NDT) equipment and process control instrumentation, Panametrics, Inc. has earned a reputation for unusual customer-oriented, person-to-person service. We at Panametrics take great pride in continuing our reputation for personalized customer support and service.

Panametrics is easy to reach for assistance. In addition to our headquarters in Waltham, Massachusetts, the telephone, telex and fax numbers of our worldwide offices and agencies are listed at the end of this manual.

Our Waltham, Massachusetts location is staffed with technical specialists—such as engineers, chemists, physicists—with whom you may communicate your technical needs in the language of your field applications. Our satellite companies around the world also have technical specialists, competent in the support of all our product lines.

We offer a wide range of customized service support, including applications engineering, sample system design and fabrication, special-case installation assistance, and the on-site or factory repair of any Panametrics product. In the event, you need assistance beyond the scope of this manual, telephone your nearest Panametrics office for immediate assistance, or telephone our headquarters for additional information.

Panametrics also offers instruction in operation and maintenance of its products, and can provide on-site training upon request.

How to Use This Manual

To save you time and enable you to start operating your System 2 as quickly as possible, we have separated this manual into three parts as follows:

Part 1 - OPERATING INSTRUCTIONS is user-oriented and designed to acquaint you with the System 2 and get you comfortable operating it.

Part 2 - TECHNICAL INSTRUCTIONS deals more with installation issues and technical details.

Part 3 - APPENDICES is where you will find general information about hygrometry and specific information about some of the System 2 options.

You can save time by reading only the information you need (check the chapter summaries that follow). First time users or anyone who needs to familiarize themselves with System 2 operation before installation in a process system should read Part 1 of this book, and perform the moisture measurement example demonstration.

Chapter Summaries

Part 1 - Operating Instructions

Read this part to familiarize yourself with the operation of the System 2, including User Programming.

Chapter 1, *System 2 Basics and Options*, gives an overview of the System 2, including a summary of features and capabilities, package options available, and general operating information.

Chapter 2, *Getting Started*, tells you how to connect and operate a System 2 hygrometer. This section provides a quick introduction to the System 2 by getting you up and running without going into installation details. By the end of this section you will know how to make desktop dew/frost point measurements.

Chapter 3, *Operation*, discusses how to interpret the readings on the display, and includes a detailed description of display updating and error messages. A table of display prefixes and units can also be found in this section.

Chapter Summaries (cont.)

Part 1 - Operating Instructions (continued)

Chapter 4, *User Programming*, gives you an overview of, and introduction to, System 2 user programming. This section provides hands on descriptions of user programming operations with working programming examples and contains the *User Programming Flow Diagram*, a complete overview of the User Program on a single page.

Chapter 5, *Other Measurements*, describes how to make measurements other than dew/frost point temperature. The applicability of this section to your system will depend on what options you have available.

Part 2 - Technical Instructions

Read this part if you are installing or re-configuring a System 2.

Chapter 6, *Installation*, contains information you will need to set up and run a System 2 in actual process environments. Probe mounting and location are discussed as well as how to connect to alarms and recorders.

Chapter 7, *Summary of Connections*, contains a complete synopsis of connection information with tables and illustrations of how and where to make all external connections.

Chapter 8, *Reconfiguring the System 2,* describes how to change hardware controlled default settings such as measuring units (English or metric) and analog output ranges. In this section you will find switch location information and tables showing the options available.

Chapter 9, *Specifications*, details the System 2 physical, electrical and operating specifications.

Chapter 10, *Troubleshooting*, contains a troubleshooting chart and instructions for using the internal diagnostic features of the System 2.

Part 3 - Appendices

Read this part for specific information on the topics covered.

Appendix A, *Applications of the Hygrometer,* is a treatise on Aluminum Oxide Moisture Measurement and how it is implemented in the System 2 hygrometer.

Appendix B, *Reference Calibration*, explains how to recalibrate the internal moisture references. As indicated, this procedure should not be performed without first consulting Panametrics.

Related Documentation

- Schematics and PC Card Mechanicals œ- Special order - contact the sales department at your nearest Panametrics office for availability and price.
- Parts Lists - A PC board level spare parts list is part of the User's Manual. A complete parts list may be available - contact the factory or your nearest Panametrics office for availability.
- Setup and Adjustment Proceduresœ - Under certain circumstances, such as operation in remote or isolated locations, we will provide additional special documentation, diagrams, and special test procedures you may need to repair and maintain this equipment with a minimum of outside support. Contact the factory or the Panametrics office nearest you if you have special requirements in this area.

Conventions Used

Display Messages

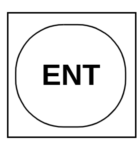
In this manual, when we refer to what is shown on the front panel digital display, we enclose what is actually seen on the display in quotation marks ("..."). For example, you will see:

“SYSTEM 2”

or, the display shows “SYSTEM 2." SYSTEM 2 is what is actually seen on the display.

Keypad References

Many references to pressing keys on the front panel keypad are made by showing a picture of the key. Thus, directions state:

Press the 

key.

We also denote keys within the text with angle brackets. Thus, the text may state: press <ENT>.

Service and Policy

One Year Limited Warranty

Each PANAMETRICS-manufactured instrument is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to servicing or calibrating any instrument returned to the factory for that purpose and to replace any defective parts. 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 have been defective for warranty to be valid. The instrument must be returned with transportation charges prepaid by the owner. This warranty is effective with respect to the following:

- One year for electronic failures
- One year for mechanical failures (shorts or opens) to the sensing probes
- Six months for calibration of the sensing probes

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.

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

1. Notify us, giving full details of the difficulty, and providing the model and serial number for the instrument. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of your shipping instructions, send the instrument, prepaid or as directed to the factory (or to the authorized repair station indicated on the instructions).

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

Maintenance Policy

If you require maintenance or believe you need service for your Panametrics product or Panametrics-based instrumentation system, call your local office as listed on the following page. Our applications and service engineering staff will assist you to determine the best course of action. If you decide to return your equipment for factory service, note that **Panametrics does not require a Return Merchandise Authorization (RMA) number.** However, to avoid unnecessary delays be sure to call the appropriate applications engineering or service department and alert them of your intentions and be sure to use the Service Information Form at the back of this section. (Make a copy of this form and include it with your return shipment.)

Hygrometer Service Form

Use the form at the back of this manual when you return your hygrometer for service. This will help us expedite your service order. Make copies of this form for future use.

If you need additional forms, write to Panametrics Inc., 221 Crescent Street, Waltham MA 02453, Attn: Technical Publications Department and request Hygro Service Form #916-012. The requested number of forms will be mailed to you at no charge.

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Appendix A: Application of the Hygrometer (900-901E)

Chapter 1

System 2 Basics and Options

Features and Capabilities

The System 2 hygrometer is a high precision moisture measuring instrument with a direct reading digital display and analog outputs. The primary measurement parameter is dew point (DP). Optional secondary measurement parameters are temperature (T) and pressure (P). Refer to Table 1-1 below.

The measurement parameters can be used to derive other parameters (the System 2 microprocessor calculates derived parameters in real time). Standard derived measurement parameters include Parts Per Million by Volume (PPM_v), Parts Per Million by Weight (PPM_w), and Relative Humidity (RH).

The System 2 also reads MH, a diagnostic and calibration parameter used in all Panametrics hygrometers. These measurement capabilities come with all System 2 hygrometers. Note that there are two special mode selections available (see Table 1-1 below). These two “specials” are additionally derived parameters that Panametrics will supply by special order. One popular “special” is #/MMSCF (Pounds of Water per Million Standard Cubic Feet).

Table 1-1: System 2 Measurement Modes

1.	Dew/Frost Point Temperature
2.	Temperature
3.	Pressure
4.	PPMw
5.	PPMv
6.	RH
7.	MH
8.	Special #1 (optional)
9.	Special #2 (optional)

All parameters can be displayed or output (one output is standard and a second one is optional). Outputs can be any of several different switch-selectable voltage or current ranges (see Chapter 7, *Summary of Connections*). The System 2 can also be equipped with an optional digital output and optional high and low alarms. The optional alarms can be preset to trip anywhere within the output range.

Adjustments to the output functions (such as Zero and Span and alarm trip points) can be made at any time by “User Programming,” a feature that is discussed in detail later in this manual. While User Program setup parameters can be changed,they are kept in the System 2 memory until you change them, so the operating characteristics are always retained.

Features and Capabilities (cont.)

The System 2 is ideal for survey applications since it can be supplied with a battery pack for portable operation. Survey application is also facilitated by the availability of up to six “channels” of setup parameters. Thus, specific data corresponding to as many as six different setup sites may be entered into the System 2 memory, and recalled at any time by pressing a button. This feature is especially useful when moisture probes are permanently mounted in the process system and cannot be moved from site. You may then move the hygrometer, connect the probe cable to another probe, call up the channel containing calibration data for that probe, and immediately make measurements.

System 2 Packages

The basic System 2 electronics hardware package consists of:

1. A base chassis unit with:

- Card cage
- Hinged Front and Rear Panels
- Top Cover

2. A basic set of electronics card/modules which plug into the motherboard consisting of:

- Interface Card
- Computer Card
- Memory Card
- DVM Card
- RC Calibrator Card
- Hygrometer Card
- Regulator Card
- Power Supply Module

Note: *Additional cards are available for special options.*

Refer to Chapter 8 for board locations. Since all of the active electronic circuits are located on these card/modules, the System 2 is easy to service.

System 2 Packages (cont.)

Moisture, temperature and/or pressure probes and a Panametrics probe cable complete the System 2 measurement package.

Note: *System 2 hygrometers can be optionally equipped for Division 2 operating environments.*

System 2 hygrometers are supplied in one of three package styles:

- Rack-mounted (see Figure 1-1 below)
- Bench-mounted (see Figure 1-2 below)
- Panel-mounted (see Figure 1-3 on the next page)

Each package style is built around the base chassis described on the previous page. The three package styles are shown in the following three illustrations.

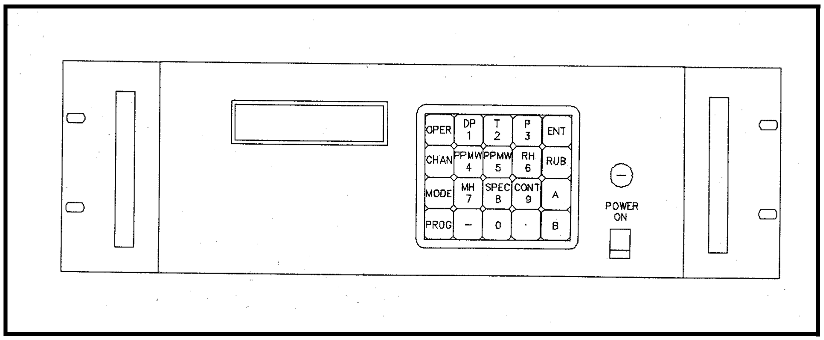


Figure 1-1: Rack Mount Package

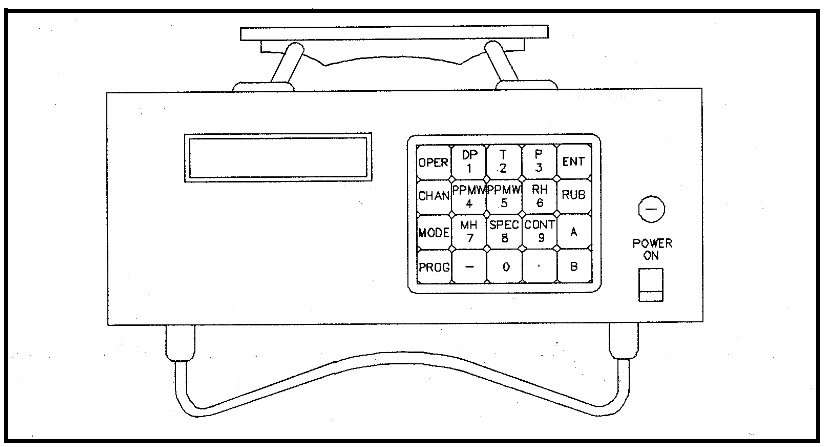


Figure 1-2: Bench Mount Package

System 2 Packages (cont.)

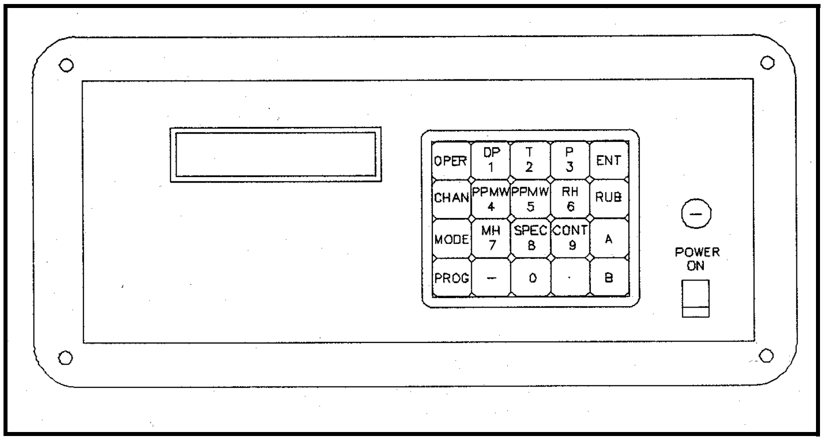


Figure 1-3: Panel Mount Package

What You Need to Operate a System 2 Hygrometer

To make *dew/frost point temperature measurements* with a System 2 hygrometer, you need a Panametrics M-Series moisture probe with probe cable, and a System 2 hygrometer with moisture probe calibration data entered for that probe (see Figure 1-4). New or factory repaired System 2 hygrometers are always shipped with probe calibration data entered and are ready to operate with the probes supplied.

For *ambient temperature measurements*, you need an (optional) MT-Series moisture probe. This is an M-Type moisture probe with a thermistor mounted in close proximity to the moisture sensing element.

Pressure measurements can be made by interfacing the System 2 with any standard 4-20 mA pressure transmitter. Panametrics optionally supplies the type P40 pressure transmitter for standard applications, and the type P40X explosion-proof transmitter for use in hazardous areas.

You can also measure *parts per million moisture by volume* (PPM_v) in gases, *parts per million moisture by weight* (PPM_w) in liquids and *relative humidity.* These calculated parameters are derived from the moisture reading and temperature or pressure readings.

The System 2 microprocessor is programmed to calculate the derived parameters. Formulas showing how these parameters are calculated can be found in Chapter 5, which also provides examples for each type of measurement.

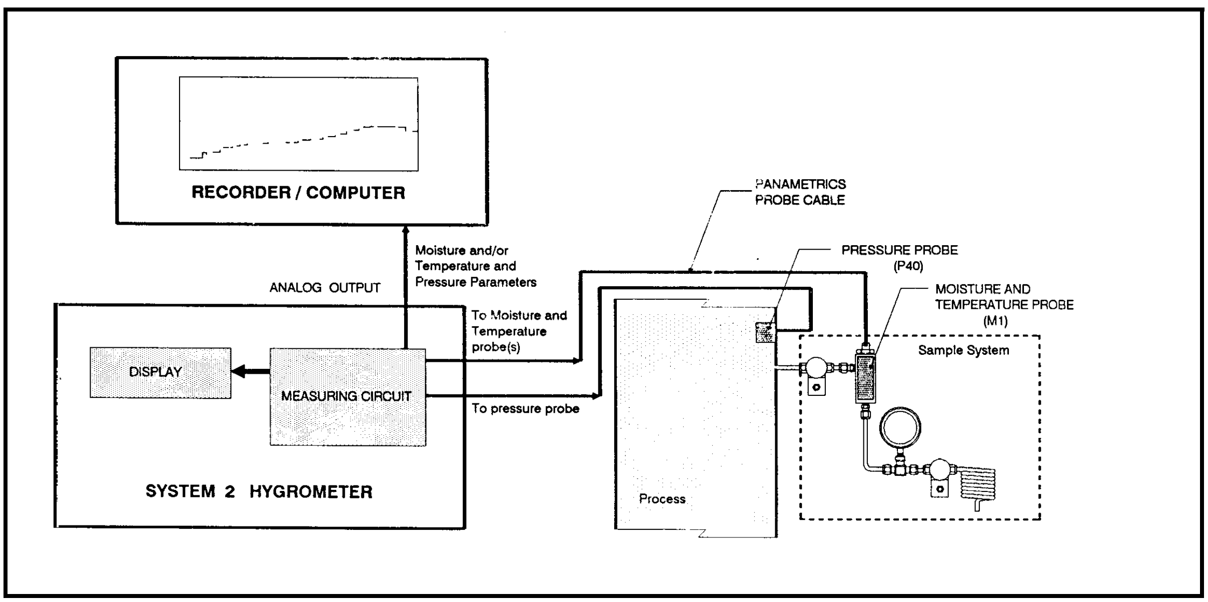


Figure 1-4: Typical System 2 Process Measuring System

System 2 Options

Battery Pack Option

The System 2 can be equipped with an optional rechargeable battery pack. When fully charged, the battery pack supplies eight hours of continuous power. For your convenience, the battery can be charged using two speeds, trickle or fast. A trickle charge is used to keep batteries at a full charge during idle periods. A fast charge is applied when batteries are depleted while the System 2 is in operation. See Chapter 6 for more information on the optional battery pack.

Carrying Case Option

Panametrics offers a soft carrying case for use with the System 2 bench mount unit. The carrying case is ideally suited for battery-operated units, particularly when the unit is used for field-survey applications.

The case consists of a main compartment for the hygrometer and an accessory compartment for such items as a probe case, cables, a small sample system, and the AC adapter (for the battery-operated System 2 hygrometers). It is fitted with a sturdy shoulder strap for portability.

Since the compartments are interconnected, you can set up a complete portable system in the case with the AC adapter permanently attached. To charge the unit, simply open the accessory compartment flap and plug the AC adapter into 110 volts AC.

For portable operation, you can pack the power cord in the accessory compartment and carry the entire system from site to site.

Chapter 2

Getting Started

The Front Panel

On the System 2 front panel you will find a digital display, a keypad, a power ON/OFF switch, and a security keylock (see Figure 2-1 below).

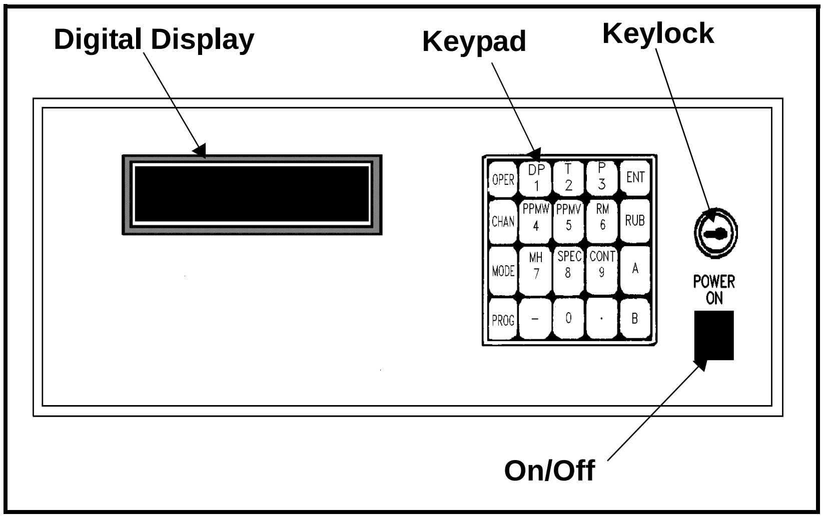


Figure 2-1: Front Panel

Initial Setup

Unless you specify otherwise, System 2 hygrometers are shipped from the factory ready to measure dew/frost point temperature on channel 1, and are calibrated to work with the companion probe. Other channels will generally have no calibration data and will not be accessible unless programmed with calibration data.

In this section, we give an example of how to make a basic dew/frost point temperature measurement. You will have to connect a Panametrics Type M or MT moisture probe and probe cable (supplied) for this example.

Note: *Each moisture probe must be used on the channel where probe calibration data is stored. If you have more than one probe, you can verify which probe is the correct one in several ways. First, you can check the probe calibration data sheet (see Figure 2-7) for the serial number and for the channel of the hygrometer on which that probe was calibrated. If you still are not sure, you can check that the probe serial number programmed into the machine corresponds to the number on the probe. (Refer to the remainder of this section and to Chapter 4 for information on checking probe calibration.)*

Also appearing in this section are examples of how to make each of the other five standard measurements as well as the diagnostic MH reading (see Chapter 5, *Other Measurements*).

Connecting a Moisture Probe

Examine the back of the System 2. The rear cover is secured by a pair of screws on the left-hand side. Remove these screws and the rear cover will swing out on hinges, as shown in Figure 2-2 below.

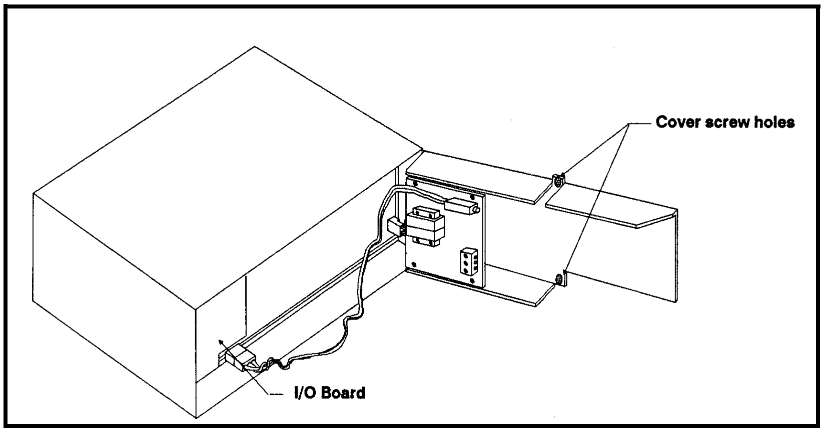


Figure 2-2: System 2 with Rear Cover Open, Showing I/O Board and Location of Cover Screws

On the left side, you will see a small printed circuit board imprinted with the number “19.” This is the I/O board. You will make all external connections—except power—via the connectors on this board (see Figure 2-3 below).

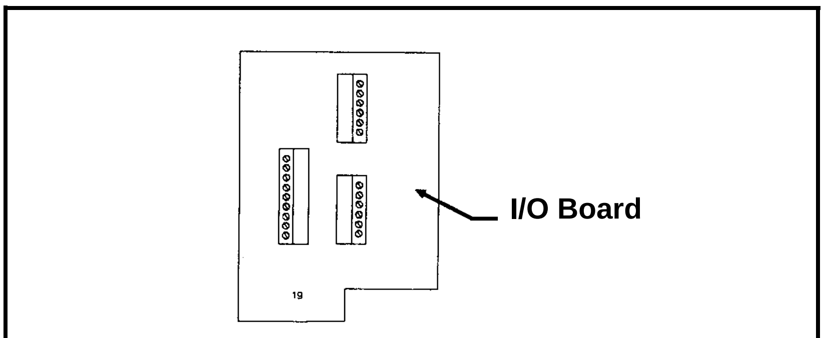


Figure 2-3: System 2 I/O Board Showing Connectors

Locate the moisture probe or probes that came with the hygrometer. Each probe has a serial number engraved on one of the flat surfaces of the hexagonal probe header as shown in Figure 2-4 on the next page. Check that this serial number corresponds to the serial number on the calibration data sheet (see Figure 2-7).

Connecting a Moisture Probe (cont.)

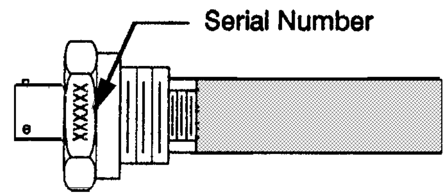


Figure 2-4: Serial Number on M Type Moisture Probe

Connect the probe cable to TB1901 on the I/O board as shown in Figures 2-5 and 2-6 and plug the probe into the cable. Note that leads 4 and 5 are for the optional temperature sensor. This option is discussed in Chapter 5. You should connect these wires now even if you are not planning to use them.

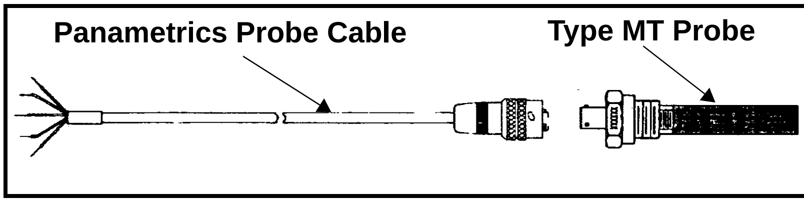


Figure 2-5: Panametrics Probe Cable and Probe for Type M or MT Probes

Note: *Proper moisture cables are critical for instrument accuracy. **If possible, always use Panametrics-supplied cables**. If you must modify cables or use cables other than Panametrics, be sure to follow all guidelines in Chapter 6, "Moisture Cable Considerations." Panametrics guarantees specified moisture measurement accuracy only with Panametrics moisture cables.*

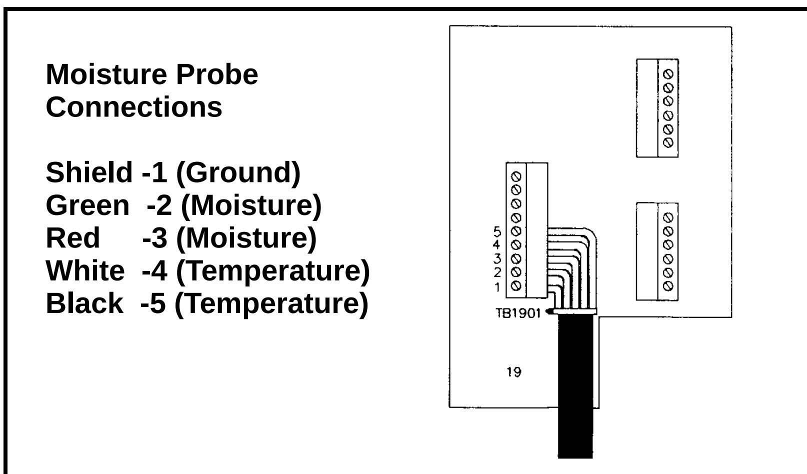


Figure 2-6: Connecting the Moisture Probe Cable

Connecting a Moisture Probe (cont.)

At this time, locate the calibration data sheet. (All moisture probes are shipped with calibration data sheets, one for each probe, packed in the probe case behind the foam packing in the case lid.) An example of a probe calibration data sheet is shown in Figure 2-7 below.

PANAMETRICS INC.
221 Crescent St.
Waltham, MA 02453

Tel: (781) 889-2719 /TLX: 951006/FAX: (781)894-8582

Moisture Sensor Calibration Data Sheet for use with SYSTEM I, II or 250

Probe Serial Number	xxxxxx
Calibrated on	August 09, 1988
Probe Part Number	M2LRTZ
Sales Order Number	PCI 47754-02

For use with Instrument SN ________________
On Channel number ________________

ND Number	Dew Point (Deg C)	MH Reading	Dew Point (Deg F)
	(D)	(M)	(D)
0	-110	0.2632	-166
1	-100	0.2703	-148
2	-90	0.2776	-130
3	-80	0.2851	-112
4	-70	0.2929	-94
5	-60	0.3039	-76
6	-50	0.3153	-58
7	-40	0.3285	-40
8	-30	0.3441	-22
9	-20	0.3673	-4
10	-10	0.4018	14
11	0	0.4778	32
12	10	0.6559	50
13	20	0.9010	68

NOTE: When using this data with Instrument Program 1002A and higher
Program the number of data points 'NDx=' with 14 and use all points listed.

NOTE: When using this data with Instrument Program 1001A through 1001F
Select the 10 most applicable data points. Program the number of data points 'NDx=' with 10.
PLUK14 Version 7.3 January 12, 1988

Figure 2-7: Probe Calibration Sheet

Connecting a Moisture Probe (cont.)

The calibration data sheet tells you which channel the calibration data is stored. In the following discussion, we will assume your probe was set up for channel 1.

Note: *Most System 2 hygrometers are supplied with a single probe set to be used on channel 1. If you plan to use more than one probe with your System 2, please refer to Chapter 3, "Multi-Probe Operation."*

Up and Running

You are now ready to measure dew/frost point temperature. We define dew/frost point temperature as the temperature at which moisture will condense or precipitate on a cooled surface. This parameter is quite useful in that it is the actual condensation temperature of water under the prevailing conditions.

Power up the System 2 by turning on the front panel power switch (if a line cord was not factory-connected, please go to Chapter 6, "AC Power and Grounding," and connect the line cord now).

A few seconds after you turn power on, the following message will appear indicating the instrument program number installed in the System 2:

"RBP.NNN.L"

This will be displayed for 15-20 seconds. The instrument program number is important to know. If you call us for technical assistance, we may ask you for this number. (The instrument program number is displayed each time the hygrometer is powered up and reset.) See Chapter 6 for additional information on the Instrument Program.

After approximately 10 seconds, the message will change to:

"AUTO-CAL"

indicating that the System 2 is going through its auto-calibration function. This also takes approximately 15-20 seconds, followed by the 10 second message:

"SYSTEM 2"

which is followed by a display of a measurement parameter.

The next display message depends on the mode in which the System2 was last used.

If the display is showing "DP1 = XXX°C" or "DP1 = XXX°F" — where XXX is the dew/frost point temperature value—then your hygrometer is reading dew/frost point temperature.

Up and Running (cont.)

If the display shows ERROR or anything other than a dew/frost point temperature reading, press the following keys in the sequence shown in Figure 2-8 below.

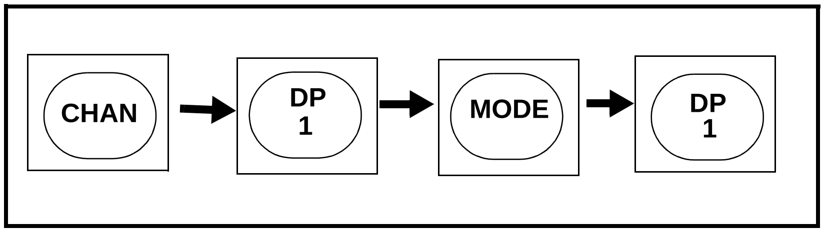


Figure 2-8: Key Sequence to Set Channel 1 for Dew/Frost Point Temperature

The display will show the dew/frost point temperature reading measured by the moisture probe. The display reading should appear as shown in Figure 2-9 below. Of course the value on the display will depend on the actual dew/frost point temperature at the time.

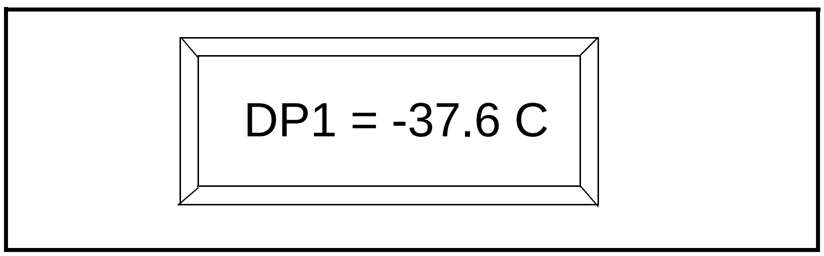


Figure 2-9: Display of Dew/Frost Point Temperature

Note: *If the message shows "NO DATA" is displayed, there is no probe calibration data for that channel. The System 2 must have probe calibration data entered to measure moisture. See Example H in Chapter 4 for information on entering probe calibration data.*

Dew/frost point temperatures in normal atmosphere may range between -20°C (very dry) to +20°C (very humid).

Note: *Probes can easily become saturated if moisture condenses on them. This can occur if the ambient temperature drops below the dew/frost point temperature.Occasionally, new probes will become saturated during shipment. If this happens, the reading will remain at +20°C. No damage occurs to a probe when it is saturated, but it must be dried before it can be used. See Appendix A for a remedy to this problem.*

Making a Moisture Measurement

The System 2 is now reading the room air dew/frost point temperature.

Clasp the entire sensing end of the probe in the palm of your hand and watch the equal sign on the display. Observe that it should blink periodically.

Beginning with the second blink, the display reading is updated and the reading should change. Since you are holding the moisture probe in your hand, you will be increasing the dew/frost point temperature as a result of the moisture adsorbed from your hand. Eventually, the reading will increase to a value between -8°C and +20°C (100% RH).

Note that when you put the probe down, the reading will rapidly decrease.

Chapter 3

Operation

Introduction

In this chapter, we will describe how the display is updated, the six-channel capability of the hygrometer, auto-ranging and the control and interpretation of error conditions.

Display Format

In Figure 3-1, dew/frost point temperature (DP) is used as an example. When you are in the measurement mode, the display shows measured parameters in the following format:

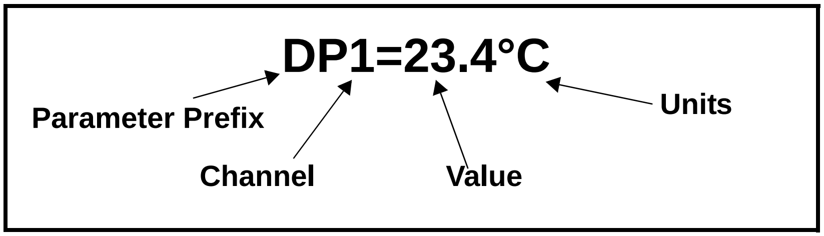


Figure 3-1: Display Format for Measured Parameter

To the left of the equal sign, the parameter prefix identifies the type of parameter being measured followed by the channel number for the measurement.

On the right hand side of the equal sign, the value being measured is displayed followed by the measurement units.

Note that the position of the decimal will vary depending on the parameter and range. The display shows measurement data with up to four decimal places, but it will not show data beyond the accuracy of the particular measurement or calculation, that is data that is not meaningful or accurate is never shown. (Moisture (DP measurements) show a maximum of one decimal place.)

For each measurement mode the display prefix will be different.

Display Format (cont.)

Table 3-1 lists all standard display prefixes, what they stand for, and possible measurement units for each.

Table 3-1: Display Prefixes and Units

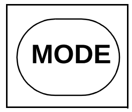
Display Prefix	Parameter Type	Units
DP	Dew/Frost Point Temperature	°C, °F
T	Temperature	°C, °F
P	Pressure	PSIG, BARS
P_w	Parts per Million (by weight)	PPM_w
P_v	Parts per Million (by volume)	PPM_v
RH	Relative Humidity	%

If you have followed the instructions in Chapter 2, then you are now looking at a dew/frost point temperature reading on the display. You may have noticed by now that the equal sign blinks at intervals ranging from several seconds to several minutes). Each blink indicates the completion of a measurement cycle. The time of each measuring cycle depends on how many parameters you choose to measure (see Chapter 4).

Each time the equal sign blinks, the System 2 has finished measuring, and if necessary, calculating data. At this point, it updates the display value and the analog output value and begins the next measurement cycle.

Parameter Displayed

You select the measurement parameter to display by pressing



followed by pressing one of the parameter mode keys. There are nine mode keys which correspond to the nine possible parameter modes (see Figure 3-2 below).

Note: *If no data is entered in programming the message "NO DATA" will appear when a mode is selected.*

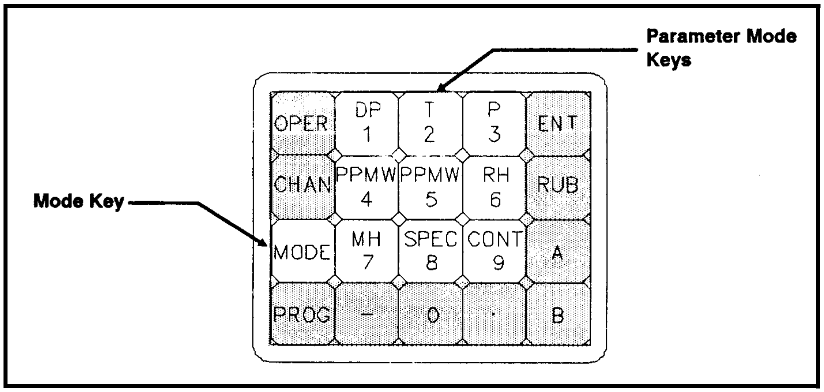


Figure 3-2: Display Mode Selection Keys

Six-Channel Operation

Although the System 2 is a single-channel instrument, it is capable of accepting and storing up to six sets of moisture probe calibration, temperature and pressure data. It can also store recorder zero and span limits, as well as alarm setpoints.

If an application does not require continuous data, you can move the hygrometer from one site to another even if the moisture probe and/or pressure measuring device must remain installed in the system. This is possible because the System 2 allows you to enter a complete new set of operating and calibration parameters for each site.

Each set of data is stored in a "channel" which can be called up with several keystrokes on the System 2 keypad. In this way, the System 2 can be used as a portable device to spot sample at up to six separate locations without the need for reprogramming.

Note: *To eliminate confusion, the moisture probe serial number should be entered under the prompt PNn = XXXXX (see Chapter 2, "Connecting a Moisture Probe," and Chapter 4 on"DWPT?" programming) for each channel of data entered. The probe serial number is displayed for a few seconds whenever the CHAN pushbutton is selected in the operating mode. You can then check the correlation between System 2 data and a particular measurement site by comparing this number with the serial number on the probe. The channel serial number and the probe serial number must match exactly. Otherwise, measured moisture data will be inaccurate.*

Auto-Ranging

The System 2 is capable of auto-ranging in the dew/frost point temperature mode. Auto-ranging can be enabled or disabled in the User Program at the “AUT-R?” prompt. A discussion of how to enable and disable auto-ranging can be found in Chapter 4.

Auto-ranging affects the resolution of the measurement process: however, only one decimal place is displayed (see Chapter 3). What auto-ranging provides is a greater ability to distinguish between small changes in moisture. For example, with auto-ranging on, a measurement update of from 10.7 —-> 10.8 may be possible while, without auto-ranging, the minimum change resolvable might be 10.7 —-> 11.7. The absolute amount of change in resolution varies for different measurement points and for different probes; however, the relative amount is shown in Table 3-2. As you would expect, smaller moisture values (given as MH in the table) get increased resolution (in three steps).

Table 3-2: Auto-Ranging Steps

Range	MH Range	Increase in Resolution
Low	<0.54	×30
Std	>0.54 <4.5	×3
High	>4.5	1

The only disadvantage to having auto-ranging enabled is an increased processing time (between 2 and 14 seconds per measurement). This is usually not a problem in moisture measurements, however, since the process time constant is almost always well in excess of those values. Therefore, auto-ranging is generally enabled.

System 2 Error Processing

Two types of errors are monitored:

- Cal Errors — The system does not successfully complete an Auto-Cal.
- Range Errors — The value to be displayed is out of range or is dependent upon a value that is out of range.

Cal Errors

During auto-cal, if an error is detected (which indicates an electronic error), an error flag will be set. This will cause:

- the display to flash the message “CH=X CAL ERROR” for 20 seconds
- the recorder outputs for this channel to go either high or low (as described below)
- the alarms relays to be activated

The System 2 will then continue calibration, and begin operating as usual, after calibration is completed.

If you attempt to display data on a channel for which a calibration error has occurred, the display will show “MPn=CAL ERR” where MP equals the measurement parameter selected for that channel, and n equals the channel number. (For example, if channel 1 was set for Dew Point, but failed to pass calibration, the display will show “DP1= CAL ERR.”) Note that if no measurement parameter has been programmed for that channel, the display will then show “NO DATA.”

You can also set the sense (high or low) of the recorder outputs upon detection of a calibration error. You can do this in the User Program using the “CONT?” subroutine at the prompt “RECER?”

The default output sense for RECER? is high. If this is acceptable, enter RUB and you will go to the next prompt.

If you wish to change the sense, press ENT and you will see the (sub)prompt “RER=X” where X is 0 or 1. If you select X = 0, the recorder output(s) will go low on a cal error. If you select X=1, the recorder output(s) will go high on a cal error.

For more information about this feature, see Chapter 4, *User Programming* and also review the section on “RECER?”.

Range Errors

Range error detection is provided because calculated values that are outside of the accepted range cannot be determined. Range errors occur only during normal system operation, and may be optionally detected and displayed. They may force the alarms and recorders high or low in accordance with the options outlined below.

On detecting a range error, an error message in the form “ERROR mn” is displayed where m is the mode number and n is 1 or 0 (a 1 indicates the value is above the accepted range and a 0 indicates the value is below the accepted range).

For example, if relative humidity is calculated to be above 100% for channel 1 (obviously high), “RH1=ERROR 61" is displayed. As a second example, if dew/frost point temperature is out of range and PPM_w is being displayed for channel 1, the display will show “PW1=ERROR 11,” indicating that PPM_w could not be calculated correctly because the dew/frost point temperature value is above range.

When more than one error condition applies to a function, the lowest mode number takes priority.

When the appropriate option is selected, the alarms and recorders will respond to range error indications. For example, if error option 2 is selected (see Table 3-3 below) a 0—or below range condition—causes any corresponding recorder output to fall to the minimum value and a corresponding low alarm to be set. A 1—or above range condition—causes any corresponding recorder output to rise to the maximum value and a corresponding high alarm to be set.

Table 3-3: Range Error Options

Option Number	Displayed	Alarms and Recorders
0 (default)	NO	no action on errors
1	YES	no action on errors
2	YES	follow range errors
3	YES	follow range errors low error sets low and high alarms and sets recorders to maximum

Range Errors (cont.)

When a function cannot be calculated because of an out-of-range condition in a related function (to which it is inversely proportional), the recorder and alarm conditions are reversed.

For example, PPM_v is inversely proportional to pressure. If pressure is above-range when displaying PPM_v, the display would be "PV1=ERROR 31." If the recorders and alarms are programmed for PPM_v, and error option 2 is selected, the recorders would fall to the minimum value and the low alarm would be set.

The alarm unaffected by error processing will function as usual.

Range errors are not detected for mode 7, MH. This function is always displayed.

The lower and upper range limits for each of the standard functions are determined as shown in Table 3-4 below.

Table 3-4: Range Error Limits

Mode 1	lowest and highest programmed MH values
Mode 2	-30°C and 70°C
Mode 3	lowest and highest programmed current (mA) values
Mode 4	0.0010 and 99999
Mode 5	0.0010 and 99999
Mode 6	0.0010 and 100%

Error Processing Options

The options are selected in the "CONT?" programming mode (see Chapter 4). Press ENT in response to the "ERROR?" prompt. "ERR=X" will be displayed, where X is the option number selected in the usual manner.

Chapter 4

User Programming

Introduction

The Panametrics System 2 hygrometer is the most sophisticated off-the-shelf moisture measuring instrument on the market. This high level of sophistication is accomplished without a complicated user interface by employing a microcomputer to control functions and instrument operating characteristics. The front panel of the System 2 is therefore simple, consisting of a power switch, panel lock, keypad and display.

As discussed in Chapter 1, a **User Program** controls the operating profile and calibration of the instrument by allowing you to enter system parameters. These parameters are stored in battery-powered random access memory, so they are retained when system power is turned off.

This section gives you an overview of how to access, and if necessary, enter new system parameters through user programming.

Why User Programming?

The user program lets you enter many of the System 2 operating characteristics. Some of the operating characteristics the user program allows you to change are the displayed parameters, the output parameter and setpoint on which alarms will trip. User Programming also allows you to select only the types of probes you need (eliminating unnecessary processing time) and to set the conditions for automatic procedures such as periodic auto-calibration or error handling.

Although you may never need to reprogram the System 2 (we ship all System 2 hygrometers, whether new units or repairs, fully programmed and ready to use), this capability can be extremely useful and is invaluable in troubleshooting.

Accessing the User Program

You can modify the user program directly from the front panel, or, if desired, by remote via a separate computer terminal.

To use a separate computer terminal, you will need an optional (No. 5) UART card. For more information on using a remote terminal or computer with the System 2, see Chapter 6.

The front panel keypad and display allows access and reprogramming of any available function. However, since changes to the User Program can affect the operation and/or the calibration of the hygrometer, a lockout switch prevents unauthorized access to this feature.

How to Program the System 2

First, turn off the programming lockout switch. (You cannot enter the user program unless the programming lockout switch is off.)

The programming lockout switch is located on the rear side of the front panel. To gain access to the switch, unlock the keylock and swing the front panel open (the panel is hinged on the left hand side) so that you are looking at the rear of the panel as shown in Figure 4-1.

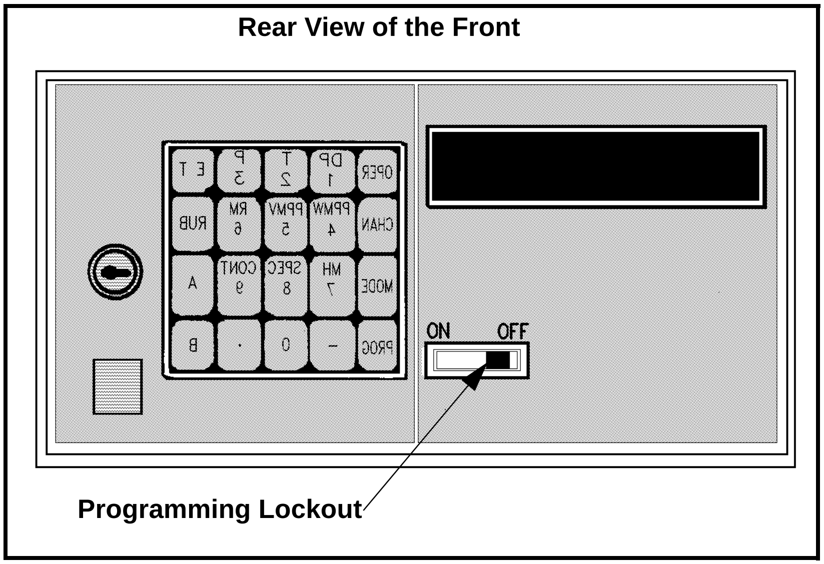
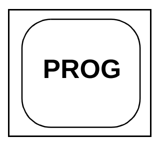


Figure 4-1: Locating the Programming Lockout Switch

To enter the User Program press 

You will see: **"CODE?"** on the display.

At the prompt "CODE?" enter the key sequence shown in Figure 4-2 below.

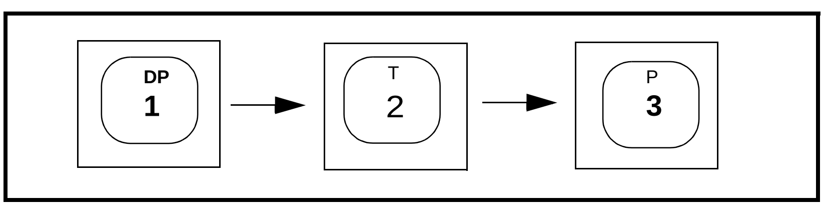


Figure 4-2: Key Sequence to Enter the User Programming Mode

How to Program the System 2 (cont.)

The display will show:

“PROG?”

You are now at the top level of the user program.

The top level of the User Program actually consists of four major sub-programs or subroutines. At the top level, you are asked which subroutine you wish to enter.

The choices are:

“PROG” (Program) i.e., Set-up units of measure, recorder outputs, etc.
“CALIB” (Calibrate) i.e., Enter calibration data and other input information.
“TEST” (Test) i.e., Check operation, test outputs, and troubleshooting.
“CONT” (Control) i.e., Set error checking, battery charge indicator, etc.

You enter a particular subroutine by pressing **ENT**

You bypass a particular subroutine by pressing **RUB**

How to Program the System 2 (cont.)

Let us step through each of these prompts without actually entering the subroutines.

At the prompt **“PROG”** press: **RUB**

The display will change to **“CALIB?”**.

Press **RUB** again.

The display will change to **“TEST?”**.

Press **RUB** again.

The display will change to **“CONT?”**.

You have stepped through all the programming choices at this level.

Press **RUB** again.

The display will change to “RET?”. You are being asked if you would like to return to the operating mode.

Press **ENT**

The System 2 will perform an initialization exactly as if it were just turned on, and will then resume operation in the mode in which it was last operating.

How to Program the System 2 (cont.)

The top level programming sequence is illustrated in Figure 4-3 below. Within the four subroutines there are a series of selections. To sequence from one subroutine to another press <RUB>.When the desired subroutine prompt appears, press <ENT>. Using the appropriate keys, enter data. Please note that once you enter a subroutine, you can only go forward. In order to correct incorrectly entered data you must repeat the subroutine. The subroutine is completed when the prompt "DONE?" appears, at which point you may exit by pressing <ENT> or repeat the sequence by pressing <RUB>.

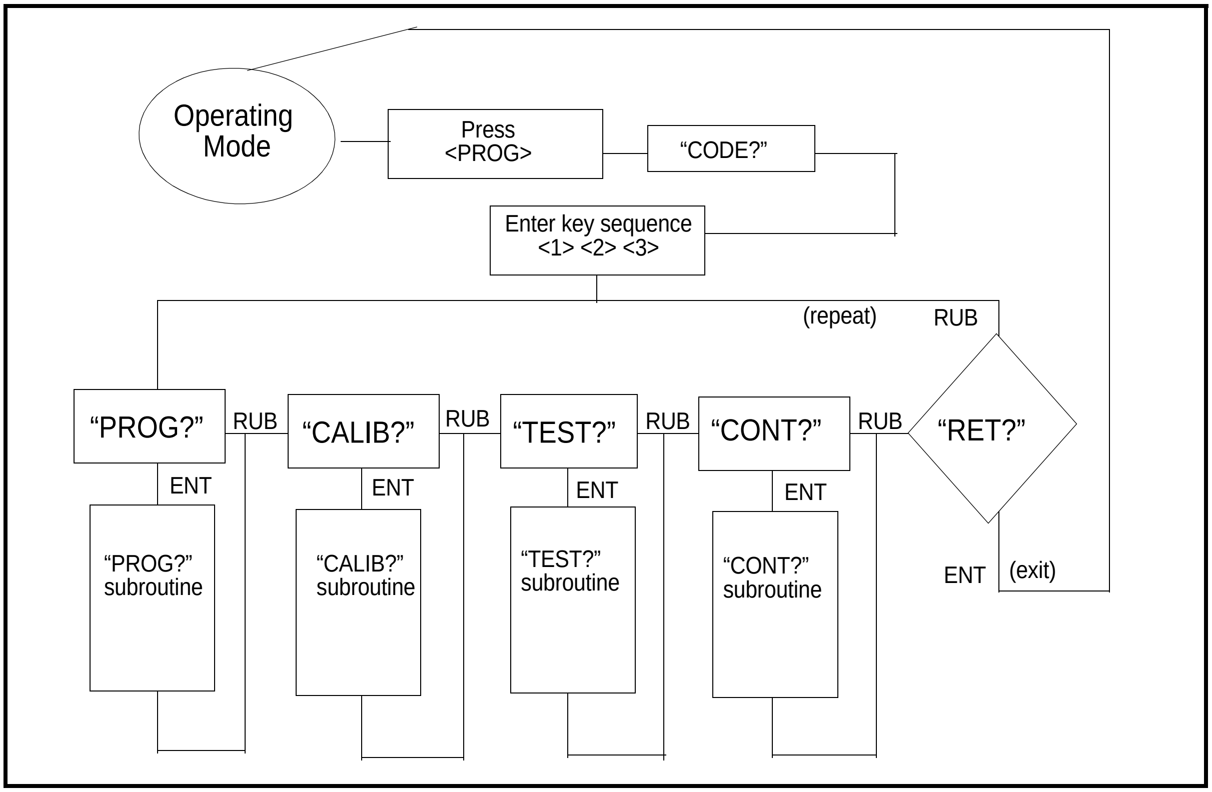


Figure 4-3: User Programming Flow Diagram - Top Level

Program setup and calibration prompts are of the form Pn=X, where

- P = name of a setup or calibration parameter
- n = channel
- X = current value.

To change the "X" (current) value, you must "rub" (erase) the present value by pressing <RUB>. Then, key in a new value from the keypad followed by <ENT> <ENT> (press ENT twice). (If you choose NOT to change the value, DO NOT press <RUB>.) Simply press <ENT><ENT> when you see that the present value is correct. If you change (by pressing <RUB> key) a correct value by mistake, simply re-enter it.

How to Program the System 2 (cont.)

A system reset is automatically performed when you exit programming mode and return to normal operation—UNLESS YOU CHOOSE TO BYPASS THE RE-START (the bypass— “BYP” option is available in the "CONT?" subroutine).

The following sections are an overview of each subroutine with a brief discussion of each selection therein. At the end of the chapter you will also find a complete User Programming Flow diagram, Figure 4-19 on page 4-45, showing all the steps in the user program in summary form.

Note: *Several subroutines contain the prompt “CHAN?” (channel?), which refers to a “channel” of probe setup information, as discussed in Chapter 1.*

The “PROG?” Subroutine

In the “PROG?” subroutine, you can set the basicoperating characteristics for each “channel.”

Once you enter the "PROG?" subroutine, you must step through the entire menu; however, you can do a rapid step-through without changing anything by pressing <RUB> at each prompt.

The "PROG?" subroutine contains the following selections:
"CHAN?"
“MODE?”
“REC-A?”
“REC-B?”
“ALARM?”
“CS?” or "KPPMV?" (appears if Major Mode 4 or 5 is selected)
"DONE?"

Note: *If you press <ENT> by mistake, you will be prompted to make changes to the user program as explained below. To avoid making changes if this happens, continue to press <ENT> until you get back to one of the prompts on the list.*

"CHAN?"

At the prompt "CHAN?", you can check or change the "channel" number to be programmed by pressing <ENT> (see Chapter 1). The display changes to "CHN=n" where "n" is a number from 1 to 6 that represents the current "channel" number. You can accept the current channel value by pressing <ENT><ENT>. To change the value, press <RUB> followed by the new "channel" number followed by <ENT><ENT>.

"MODE?"

The prompt "MODE?" (sometimes referred to as "the Major Mode") is the parameter that the System 2 will display. Note that this can be any one of seven standard and two special measurement modes, as indicated in Table 4-1 below.

Table 4-1: Mode Selections

1-Dew/Frost Point Temperature	6-RH
2-Temperature	7-MH
3-Pressure	8-Special (optional)
4-PPMw	9-Special (optional)
5-PPMv	

To select a particular mode, enter the item number which corresponds to that item at the prompt MDn=X.

Note that when you choose a "Major Mode" for one parameter, you may still set the analog output (discussed below) to any other modes. An example of how to set the "Mode" can be found in Figure 4-4 on page 4-20.

"REC-A?"

At the prompt "REC-A?", you can check or change the Operating Mode selected for Recorder A analog output and check or change its operating range (see Table 4-1 above for mode selections). Every time a new calculation is made for the Operating Mode selected for Recorder A, the output will be updated with this value.

Once you have chosen the desired operating mode, the display changes to "ALn=XXXXX" ("n" represents the present channel selected) which is the first prompt for checking or changing the present 0% of full scale value for Recorder A output. The display then changes to "AHn=XXX", the high end or 100% of full scale. Refer to Examples B-1 and B-2 on page 4-21 and page 4-23 to set up REC-A output.

The "REC-B?" prompt will be available whether you have the optional REC-B output installed or not but will not be relevant without it. The "REC-B?" prompt is the same as the REC-A?" prompt except it sets up the optional REC-B output. Note that you can select yet another mode for REC-B (or you may select the same mode as REC-A). You can also set a different range and different output voltage or current (see Chapter 7 for changing the outputs). Several voltage and current output ranges are allowable).

"ALARM?"

At the prompt "ALARM?" you can set up the optional alarms. You can have a HIGH ALARM and a LOW ALARM for each channel. You can program the alarms to trip on pre-set values in any mode listed in Table 4-1 above. This setting is independent of the setting for analog output mode described above.

"ALARM?" (cont.)

The high alarm should be set to a high value within the set output range for which you want the high alarm relay to trip. The low alarm should be set to a low value within the set output range for which you want the low alarm relay to trip.

More information about using and connecting the alarm relays can be found in Chapter 6, “Using Optional Alarms” and “Summary of I/O Connections.” Also refer to Example C on page 4-25.

The following two selections are for PPM_w and PPM_v, respectively. If you did not select either of these as the MODE for the current channel, these selections will not be available and you will be asked if you are "DONE?"

"Cs"

If you selected Mode 4, PPM_w, the next prompt will be "CS?" You must know the values for Saturation Constant C_s.

We derive PPM_w according to the formula:

$PPM_w = (P_w/P_s)*C_s$,

where P_w= partial pressure of water vapor (measured by the moisture probe)
P_s = the saturation pressure of water at temperature of measurement (T)
C_s = the Saturation Constant that is usually given as a function of temperature.

The "PROG?" subroutine enables entry of 2 to 6 data points, representing a curve of Cs versus temperature. For example, using the Saturation Constant for Hexane, the data entry is 3 points and the values are listed in Table 4.2.

Table 4-2: C_s Values for Hexane

CTn	CSn
20°C (CT0)	101 PPM_w (CS0)
30°C (CT1)	179 PPM_w (CS1)
40°C (CT2)	317 PPMw (CS2)

Enter these values at the "CS?" prompt as shown in Example D on page 4-27.

"KPPMv"

If mode 5 had been selected, prompt "KPPMV?" will display. The instrument program for calculating PPM_v contains a constant multiplier as follows:

$$PPM_v = (P_w/P_t)*K*10^6$$

where P_w = partial pressure of water
P_t = total pressure,
K = a constant multiplier, normally set to 1.000 for PPM_v

The value for K can range for 500 max. to 0.0001 min. You set the value of K at the prompt "KVn=XXXXX." If you do not set this value, it defaults to 1.000.

A typical example for the use of K other than 1.000 is in the Ideal Gas Law calculation of Pounds of Water per Million Standard Cubic Feet. If the value of K is set to 0.0474, then the value displayed for "PVn" will be Pounds of Water per Million Standard Cubic Feet on an IDEAL GAS basis.

Note: *The optional #/MMSCF program does not calculate the value on an ideal gas basis. Rather, it uses empirical data that was developed by the natural gas industry.*

"DONE?"

The final prompt in the "PROG?" subroutine is "DONE?" If you wish to review your entries or make any changes, press <RUB> and you will be back to the first prompt in "PROG?" which is "CHAN?"

If you do not need to go back and check your entries or make any changes, press <ENT> and you will be asked if you wish to enter the next subroutine, "CALIB?"

You can find examples of setting up each "PROG?" subroutine selection option in the “List of Programming Examples” starting on page 4-18.

The "CALIB?" Subroutine

In "CALIB?" you can examine and, if necessary, modify specific probe calibration data for moisture, temperature and pressure probes. A prompt is also included to permit the selection or disabling of the auto-range feature.

Once you enter the "CALIB?" subroutine, you must step through the entire menu; however, you can do a rapid step-through without changing anything by pressing <RUB> at each prompt.

The "CALIB?" subroutine contains the following selections:

"CHAN?"
"PROBE?"
"AUT-R?"
"DEW-PT?"
"TEMP?"
"PRESS?"
"DONE?"

Note: *If you press <ENT> by mistake, you will be prompted to make changes to the user program as explained below. To avoid making changes if this happens, continue to press <ENT> until you get back to one of the prompts on the list.*

"CHAN?"

At the prompt "CHAN?", you can check or change the "channel" number to be calibrated by pressing <ENT> (see Chapter 1). The display changes to "CHN=n" where "n" is a number from 1 to 6 that represents the current "channel" number. You can accept the current channel value by pressing <ENT><ENT>. To change the value, press <RUB> followed by the new "channel" number, followed by <ENT><ENT>.

"PROBE?"

The "PROBE?" prompt allows you to choose which probes (including pressure transmitters) the hygrometer will use. You may select one probe or you may select a combination of probes, as shown in Table 4-3. At the prompt PRn=X, enter one of the following numbers for X (see Table 4-3):

Table 4-3: Probe Setup Options

1	Moisture
2	Temperature
3	Moisture and Temperature
4	Pressure
5	Moisture and Pressure
6	Temperature and Pressure
7	Moisture, Temperature and Pressure

"PROBE?" (cont.)

The probe setup option you select will determine which measurement parameters you will be able to display. The System 2 will not allow you to select a display parameter unless all of the probes needed to measure that parameter are selected (see Chapter 3).

You may select any mode for which the necessary probe setup is available; however, you cannot select measurement modes for which the probe setup is not consistent.

Table 4-4 below shows which parameter modes you can display as a function of the User Program probe setup variable PRn.

Table 4-4: Parameter Displayed Versus Probe Setup

Parameter Displayed	Probe Parameter "PRn"
Dewpoint	1,3,5 or 7
Temp	2,3,6 or 7
Press	4,5,6 or 7
PPMw	3 or 7
PPMv	5 or 7
RH	3 or 7
MH	1,3,5 or 7

Probe setup is a function of User Programming and is discussed at length in "PROBE?" on page 4-10.

You should carefully select the probe, on the basis that (1) you must select a probe or combination of probes necessary to make the measurement or measurements you choose in the "PROG?" subroutine, and (2) the more probes you choose, the longer the overall measuring time for each cycle. Thus, while PRn=7 (which gives you "all probes") will work in all cases, it may be inefficient and cause unnecessarily long measurement times.

An example of setting probes can be found in Example F on page 4-31. Note that in the example, we instruct you to set PRn=7. This is a common procedure during troubleshooting and is also useful for performing the examples earlier in the book.

Note: *When you are through with the examples, be certain to reset PRn to its previous value.*

"AUT-R?"

The third prompt in "CALIB?" is "AUT-R?" which stands for Auto-range. You may choose to set auto-ranging ON (AUn=1) or to set auto-ranging OFF (AUn=0). Auto-ranging was previously discussed in Chapter 3).

"DEWPT?"

The next prompt, "DEWPT?", is for entering calibration data for a moisture probe to be used with the selected probe "channel." Calibration data must be entered here for the moisture probe to give valid data. Moisture probe data is supplied with each new moisture probe on a calibration data sheet (see Chapter 2). If a probe is supplied along with a new or repaired System 2 hygrometer, the data will have been entered for you at the factory.

There are normally 14 calibration points supplied with a standard Panametrics M series probe. However, you may enter any number of points (greater than two, up to twenty). The more calibration points you use (up to 14), the more accurate the calibration.

You can find an illustration showing a set of probe calibration data in Chapter 2, and an example of how to examine and/or change calibration values in Example H on page 4-35.

"TEMP?"

With this selection, you may choose to get temperature data by either:

- using an MT type probe, or
- setting temperature equal to a constant.

If you are measuring temperature as a process variable, you should choose to use a temperature probe for input; however, for other measurements, it may be sufficient or expedient to simply set temperature to a constant. You will find an example of how to set temperature to a constant in Example I on page 4-37.

"PRESS?"

At the next prompt, "PRESS?", you are asked to enter two data points for the pressure transmitter.

You may use any linear 4-20 mA pressure transmitter with the System 2. Panametrics recommends that you purchase our pressure transmitter with the hygrometer since we will then be able to test it for you at the factory. The calibration factors will also be installed for you.

If you do not use a factory-supplied pressure transmitter, or choose to add one later, you will have to enter pressure transmitter calibration data first. To enter pressure transmitter calibration data at the prompt "PRESS?" enter P0, a low-scale pressure value, and then enter a precise (4-digit) value for the loop current (PH0) at that pressure. Then enter P1, a high-scale pressure value, and the equivalentcurrent (PH1) at that pressure. The pressure readings will then be accurate to four places within the linearity limits of the device.

You can also enter pressure as a constant. An example of setting pressure to a constant can be found in Example J on page 4-39.

"DONE?"

The final prompt in the "CALIB?" subroutine is "DONE?" If you wish to review your entries or make any changes, press <RUB> and you will be back to the first prompt in "CALIB?" (which is "CHAN?").

If you do not need to go back and check your entries or make any changes, press <ENT> and you will be asked if you wish to enter the next subroutine ("TEST?").

You can find examples of setting up each selection option in the "CALIB?" subroutine in “Fast Response Option” on page 4-42.

The "TEST?" Subroutine

Selections in the "TEST?" subroutine allow you to perform certain diagnostic tests. While we will cover these steps in the following paragraphs, we recommend you contact Panametrics if you need to do diagnostic troubleshooting requiring the use of the TEST subroutine. Our technical personnel will then talk you through the procedures.

The TEST subroutine contains the following selections:

“CHAN?”
“REC-A?”
“REC-B?”
“ALA-RM?”
“DVM?”
“DONE?”

"CHAN?"

At the prompt "CHAN?", you can check or change the "channel" number to be tested by pressing <ENT> (see Chapter 1). The display changes to "CHN=n" where "n" is a number from 1 to 6 that represents the current "channel" number. You can accept the current channel value by pressing <ENT><ENT>. To change the value, press <RUB> followed by the new "channel" number followed by <ENT><ENT>.

"REC-A?"/"REC-B?"

The second prompt, "REC-A?", allows you to test the analog output and any devices (such as a recorder) connected to it by placing a constant output voltage or a loop current (depending upon which output you have set up) on the output. Select any percent full-scale output value by entering this number at the prompt ARn.

When you make the entry and go to the next prompt, output A will go to this voltage or current.

Note: *When you enter the normal operating mode, the outputs will automatically change to their newly calculated levels.*

The same is true for "REC-B?" if you have an optional REC-B output.

"ALARM?"

The third selection "ALARM?" allows you to turn the high and low alarms on and off. Enter 1 for KLn to activate the low alarm relay, and enter 0 to turn it off. Enter 1 for KHn to activate the high alarm relay, and enter 0 to turn it off.

When you make the entry (<ENT> <ENT>) and go to the next prompt, the alarm relays will change state.

Note: *When you enter the normal operating mode, the outputs will automatically change to their newly calculated states.*

"DVM?"

The final prompt, "DVM?", is used for a factory test. This option is used in conjunction with service and maintenance.

"DONE?"

The last prompt in the "TEST?" subroutine is "DONE?" If you wish to review your entries or make any changes, press <RUB> and you will be back to the first prompt in "TEST?" (which is "CHAN?").

If you do not need to go back and check your entries or make any changes, press <ENT> and you will be asked if you wish to enter the next subroutine ("CONT?").

The "CONT?" Subroutine

Selections in the "CONT?" subroutine allow you to set certain system parameters and to perform certain global or local instrument control operations.

The CONT?" subroutine contains the following selections:

"HLREF?"
"BATT?"
"ERROR?"
"REC-ER?"
"RBT?"
"BYPAS?"
"DONE?"

"HLREF?"

The first selection, "HLREF?", allows you to change the basic electronic reference calibration values for the moisture measuring circuitry.

Caution!
Do not change these values unless you are certain that the new values are correct.

"BATT?"

"BATT?" allows you to fast charge the main battery pack in optional battery-powered units. You can also check the remaining time in a charge cycle. For more information on using this optional feature please refer to Chapter 6, “Optional Battery Pack.”

"ERROR?"

The next selection is "ERROR?" The System 2 allows you to choose several options for dealing with range errors (values that are out of range). You choose from up to four actions the hygrometer will take if a range error is detected. More information on error processing can be found in Chapter 3.

"RECER?"

The next selection, "RECER?", is an additional error condition option. The "RECER?" option allows you to choose a distinct output condition on the analog outputs REC-A and REC-B, should any error occur.

Enter the "RECER?" option and select RER=0 if you wish to have analog outputs go to zero on error. Select RER=1 if you wish to have analog outputs go to full scale on error.

"BYPAS?"

The prompt "BYPAS?" enables you to bypass the auto-calibration procedure. The System 2 automatically performs auto-calibration when you leave the programming mode and return to the operating mode. Since auto-calibration procedure takes a minimum of 14 seconds, there are times you may want to bypass it. To do this, at the prompt "BYPASS?", press <ENT>. The display changes to "BYP=0" (the "0" indicates no bypass). Press <RUB> and enter 1 (the "1" activates bypass). Press <ENT><ENT>. The display changes to "DONE?".

Note: *"BYPASS?" automatically defaults back to "0" after you return to the operating mode. This enables auto-calibration to normally occur whenever you exit any of the routines in the programming mode. Bypassing auto-calibration may degrade the accuracy of some of the channel measurements and also may bypass the updating of some of the operator programmed variables. Whenever in doubt, allow the System 2 to go through the auto-calibration routine. An easy way to initiate an auto-calibration is to press the Master Reset Switch on the RC Calibrator Card (CS1.8A), while BYP=0.*

The last prompt in the "CONT?" subroutine is "DONE?" If you wish to review your entries or make any changes, press <RUB> and you will be back to the first prompt in "CONT?" (which is "HLREF?").

If you do not need to go back and check your entries or make any changes, press <ENT> and you will be asked if you wish to return ("RET?") to the operating mode.

"RET?"

To return to the operating mode, press <ENT> at the prompt "RET?"

If you do not wish to return to the operate mode, but would rather stay in the programming mode, press RUB at the "RET?" prompt. This will return you to the "PROG?" prompt (see Figure 4-3 on page 4-5).

Programming Examples

Examples are provided for each option of the "PROG?" and "CALIB?" subroutines.

We recommend that you perform these examples to gain familiarity with the user programming feature of the System 2 hygrometer.

For the following examples, you are instructed to use "channel" 6. This probe setup channel is generally not used, so entering or changing existing values on channel 6 will not affect the operation of your hygrometer. You can leave the setup examples in the hygrometer, and recall them at any later time.

Note: *Do not change data already entered on "channel" 1. Use channel 6 for all examples.*

Caution!

You cannot damage the hygrometer by altering the user program; however, changing values will affect the operating characteristics of the hygrometer. Before you change any previously programmed parameters, we recommend you make a note of the original value or values. Re-enter the previously programmed parameters after you have completed the examples.

List of Programming Examples

- A. Setting the "Major" Mode to Dew/Frost Point Temperature
- B-1. Setting Analog Output Zero and Span
- B-2. Setting Analog Output to 4 - 20 mA
- C. Setting the Alarm Trip Points
- D. Entering Cs Values for PPMw
- E. Entering KVn for PPMv
- F. Making Probe Setup "ALL PROBES"
- G. Enabling Auto-range
- H. Entering Dew/Frost Point Temperature Probe Calibration
- I. Setting Temperature to a Constant
- J. Setting Pressure to a Constant

Example A. Setting the Major Mode to Dew/Frost Point Temperature

The "Major Mode" governs the parameter for alarm mode 0. In this example, you will set the major mode for channel 6 to 1 (dew/frost point).

Set the "Major Mode" to dew/frost point by entering the option MD1=1 in the "PROG?" subroutine.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameter will take effect as soon as you return to the operating mode.

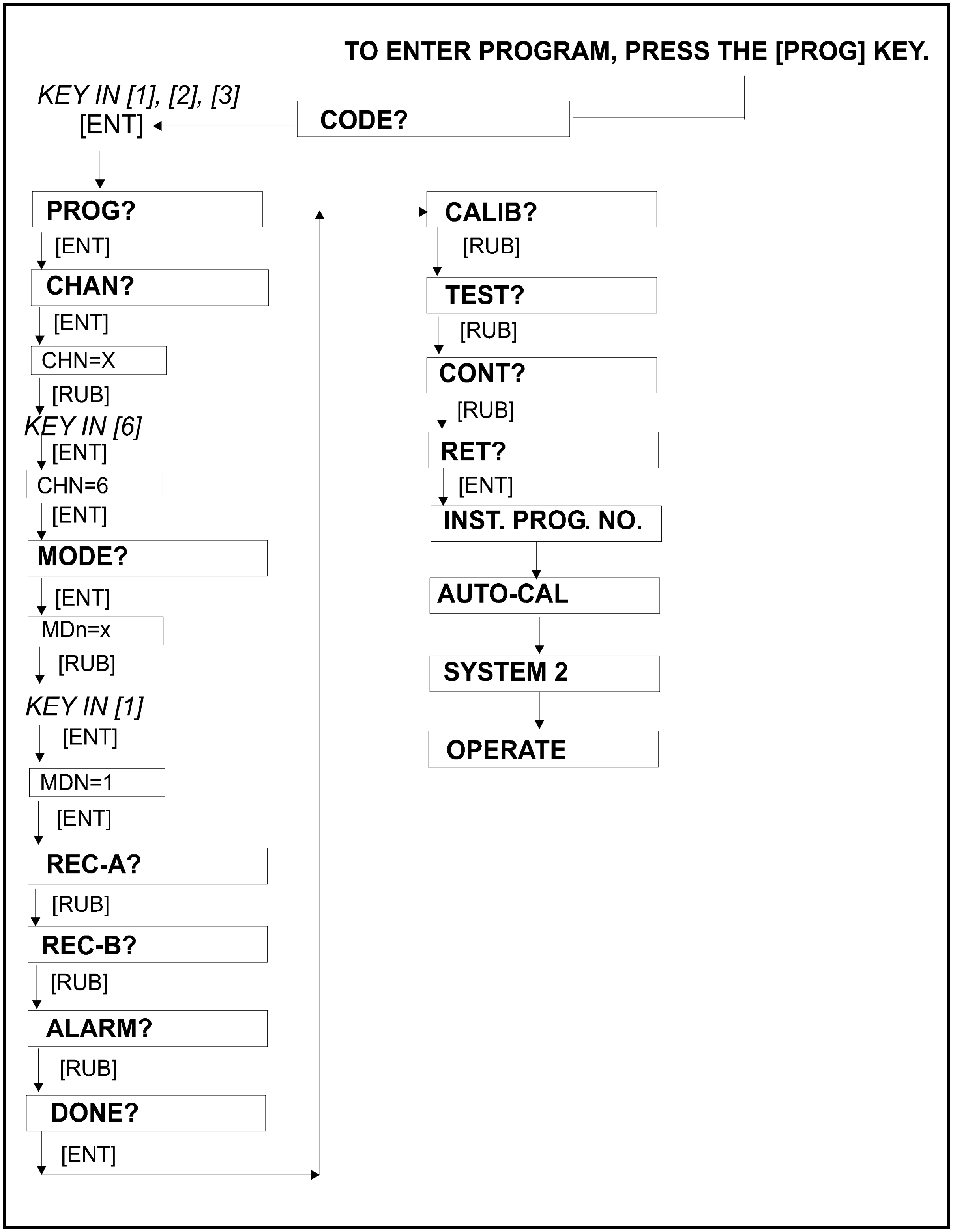


Figure 4-4: Example A: Setting the Major Mode

Example B-1: Setting Analog Output Zero and Span

In this example, we will set the analog recorder output zero to -110° and span to 20°C dew point.

Note: *If a 0 to 2-Volt recorder is used, the recorder will show a 0V output when the dew point is -110°C and gives 2V reading when the dew point reaches 20°C.*

Zero and span are set in the "PROG?" subroutine (see page 4-6) at the option "REC-A" (and "REC-B" for optional output B).

As in all of our examples we first select CHN=6. Next, we select the "REC-A?" option and at the prompt AM6=X, press <RUB> to erase the current value and enter a "1" for moisture. Then at the AL6, press <RUB> to erase the current value and enter -110.

At the next prompt, AH6, press <RUB> to erase the present value and enter 20.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameters will take effect as soon as you return to the operate mode.

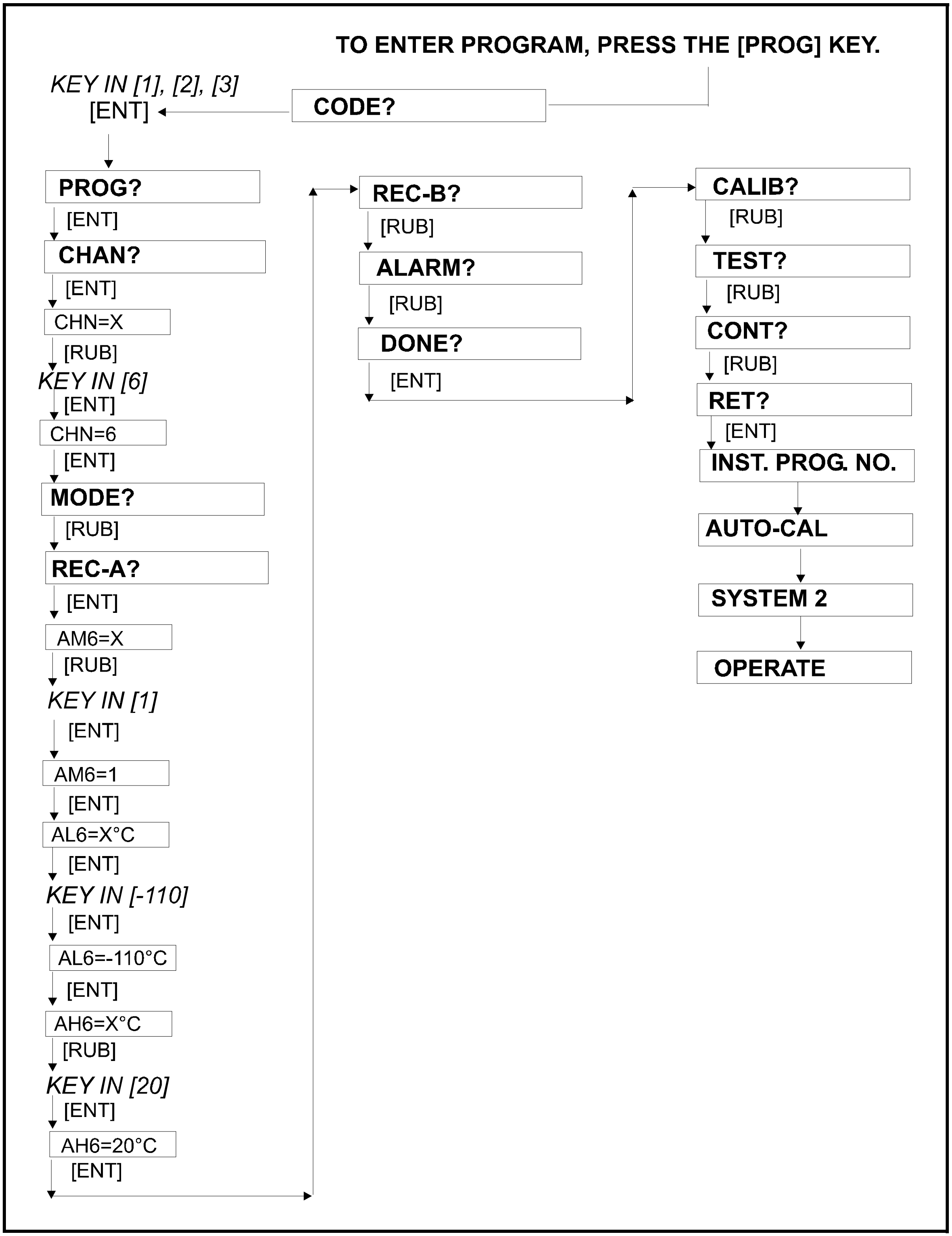


Figure 4-5: Example B-1: Setting Analog Output Zero and Span

Example B-2: Setting Analog Output to 4-20 mA

For this example, we would like to set the output range of -110°C to +20°C to correspond to an output of 4-20 mA. This is a special case of setting Analog Output zero and span (previous example).

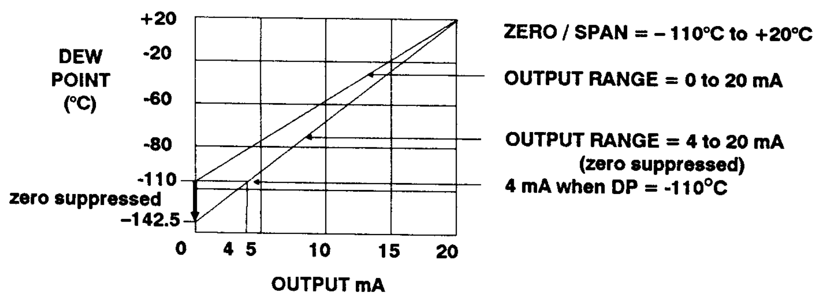
To set zero and span, we enter the values we desire for zero and span at the prompts ALn=X (zero) and AHn = X (span). In the previous example, the desired zero is -110°C and the desired span is +20°C. Since we are programming “channel” 6, this translates to:

AL6 = -110
AH6 = +20

Depending on the setting of the output range switch (see Chapter 8), this zero and span correspond to either 0-2 V, 0-100 mV, or 0-20 mA. If we assume the output switch is set for 0 - 20 mA, then:

AL6 = -110 = 0 mA
AH6 = +20 = 20 mA

We desire to suppress the zero value so that, at -110°C, the current will be 4 mA instead of 0. This is shown in graphic form below.



As the graph indicates, this will be the case if the zero current value (ALn) is -142.5. Therefore, we enter -142.5 for AL6 for the following results:

AL6 = -142.5 = 0 mA

$$\left.\begin{array}{l} -110 = 4\text{ mA} \\ \text{AH6} = +20 = 20\text{ mA} \end{array}\right\} \text{desired range}$$

For a 4-20 mA application, you can calculate the suppressed value for ALn as follows:

$$\text{ALn} = \frac{(5 \times \text{L}) - \text{AHn}}{4}$$

ex: $$\text{ALn} = \frac{(5 \times -110) - (20)}{4}$$

WHERE:
L=the desired dew point value at 4 mA
AHn = the dew point value at 20 mA

$$\frac{(-550 - 20)}{4} = \frac{-570}{4} = -142.5$$

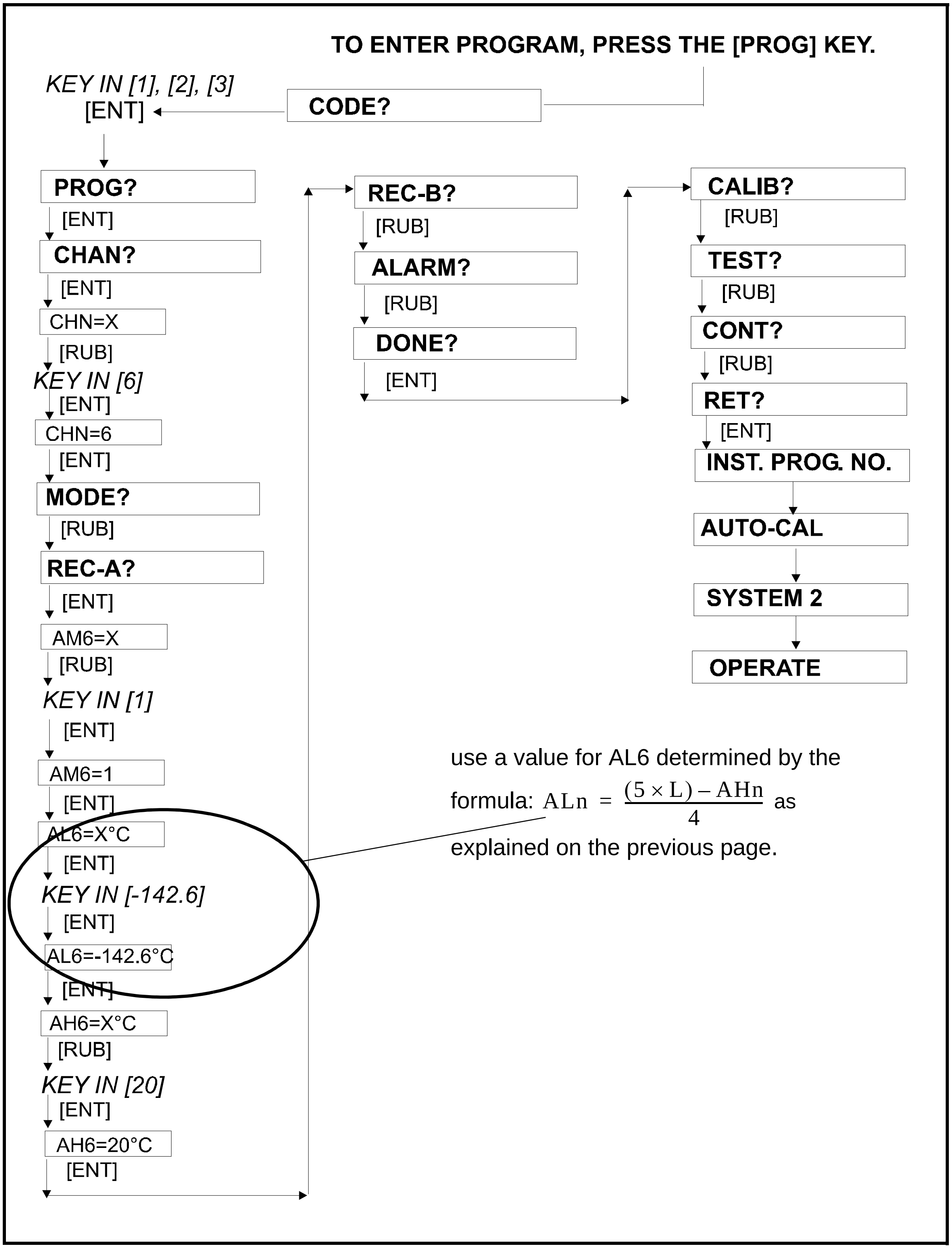


Figure 4-6: Setting Analog Output to 4-20 mA

Example C. Setting the Alarm Trip Points

In this example, we will set the alarms to trip at a high and a low moisture value.

For this example, we will set the low alarm to trip at -4.75°C and the high alarm to trip at +4.75°C.

The alarm trip points are set in the "PROG?" subroutine under the option "ALARMS?" as discussed on page 4-17.

Select the "ALARMS?" option and, at each prompt, erase the present values by pressing <ENT> and enter the values shown:

Set JL6 = 1

Set KL6 = -4.75

Set JH6 = 1

Set KH6 = 4.75

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameters will take effect as soon as you return to the operating mode.

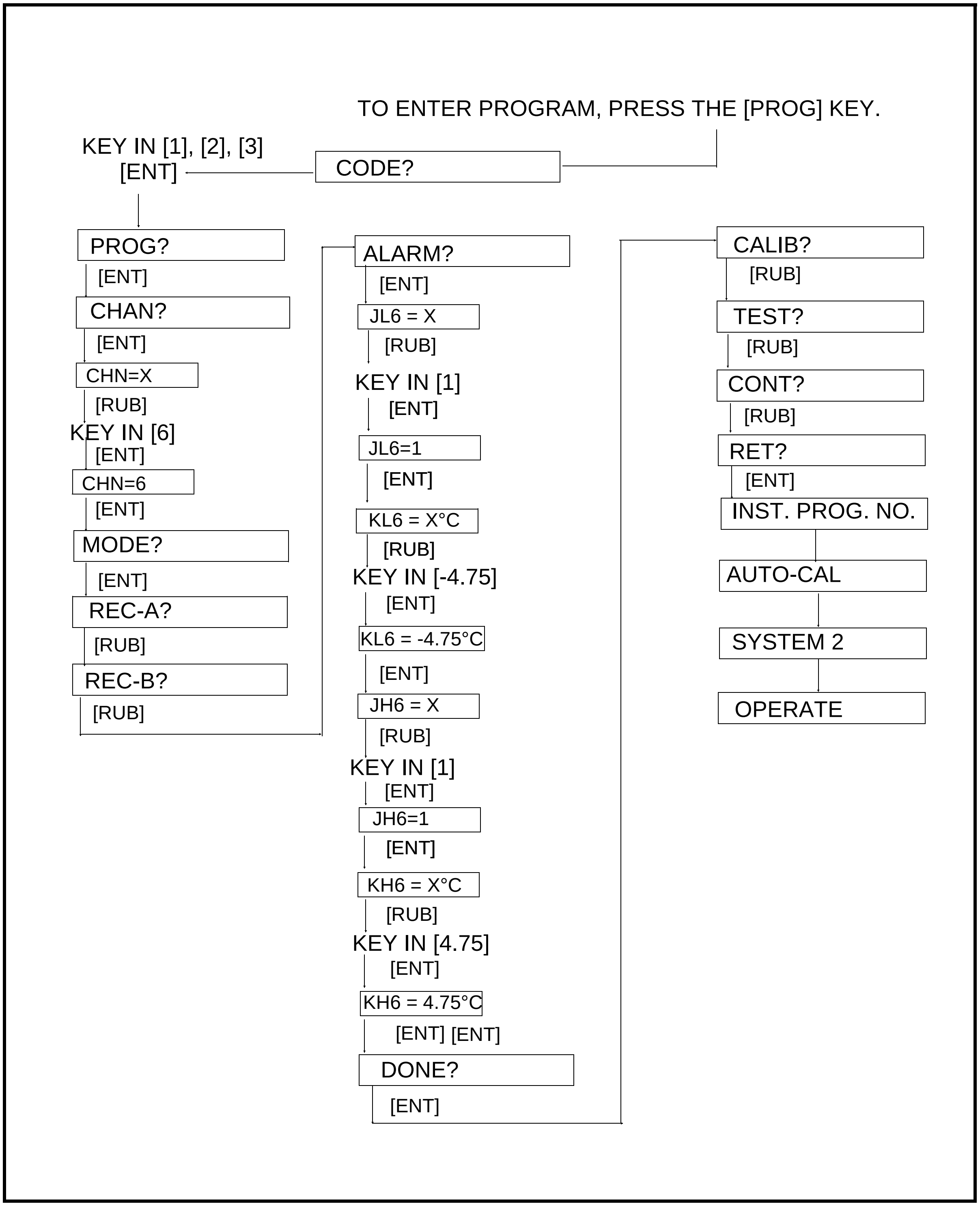


Figure 4-7: Example C: Setting the Alarm Trip Points

Example D: Entering Cs Values for PPMw

To measure PPM_w (in liquids), you must know at least one value of the saturation constant, C_s. In this example, you will enter the three values tabulated earlier on page 4-8 (Table 4-2) for hexane.

In the "PROG?" subroutine, select the "CHAN?" option and, at the prompt CHn, erase the current value by pressing <RUB> and enter 6. Proceed to the "MODE?" option and at the prompt MDN, rub and enter the value 4. Then, proceed to the "CS?" option of the "PROG?" subroutine and enter NC1=3.

You will subsequently get three sets of prompts beginning with CT0=X. Enter temperature values for CT prompts and equivalent saturation values for CS.

Prompt	Temperature	Prompt	CS Values
CT0	20°C	CS0	101
CT1	30°C	CS1	179
CT2	40°C	CS2	317

The new parameters will take effect as soon as you return to the operating mode.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

Note: *You will not get the "CS?" option unless you have chosen mode 4 for "MODE?"*

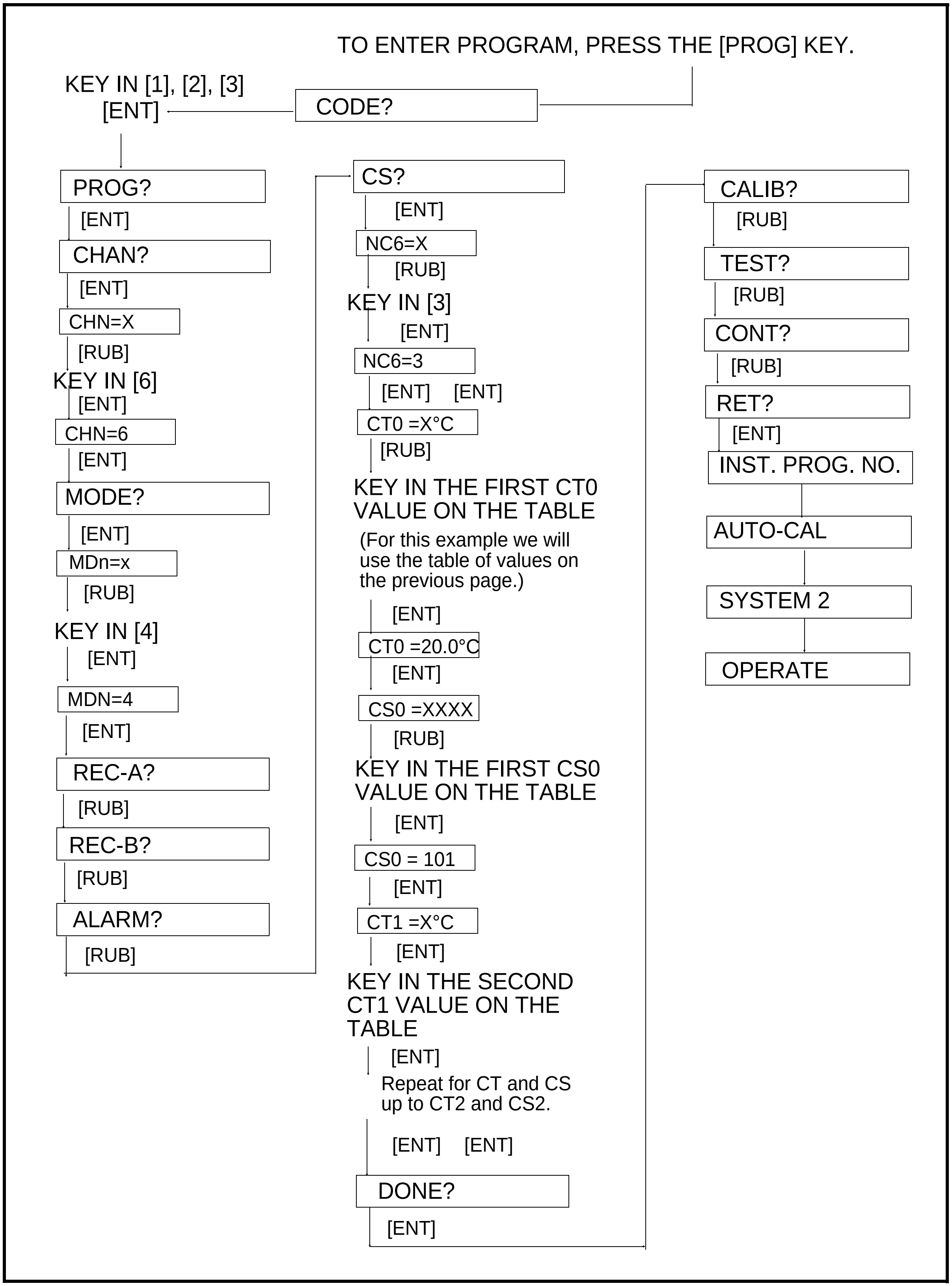


Figure 4-8: Example D: Entering C_S Values for PPM_V

Example E: Entering KVn for PPM_V

KVn is a constant multiplier that applies to PPM_V measurements, as described on page 4-9.

In most cases, KVn is 1.000.

In this example, you will set KVn equal to 1.000.

In the "PROG?" subroutine, select the "CHAN?" option and at the prompt CHn, erase the current value, by pressing <RUB>, and enter 6. Proceed to the "MODE?" option and at the prompt MDN, rub and enter the value 5. Now, continue stepping through the "PROG?" subroutine until you reach the option "KPPMV?" Enter this option and at the prompt KVn, rub and enter the value 1.000.

The new parameters will take effect as soon as you return to the operating mode.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

Note: *You will not get the "KPPMV?" option unless you have chosen mode 5 for "MODE?"*

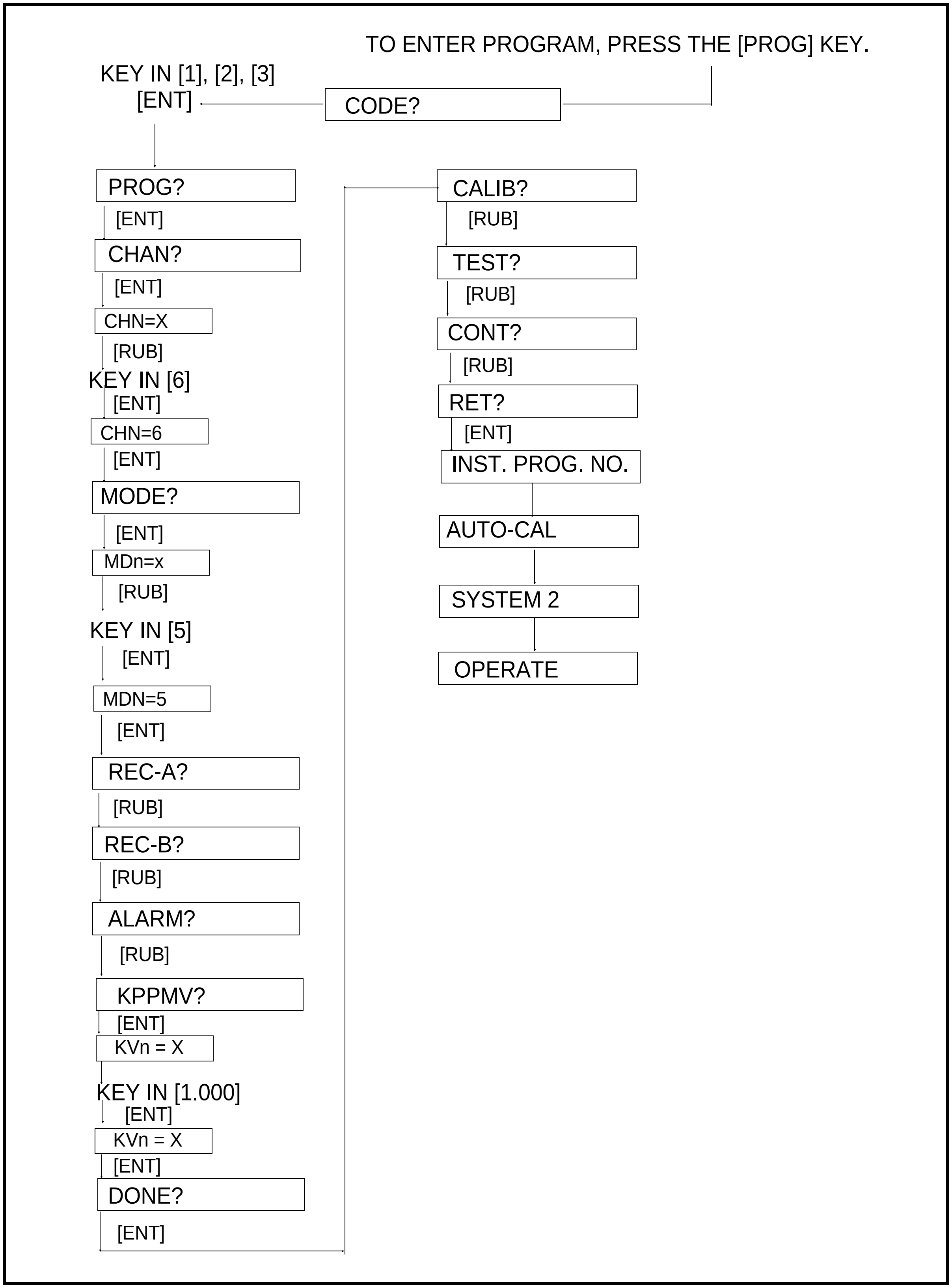


Figure 4-9: Example E: Entering KVn for PPM_V

Example F: Making Probe Setup "ALL PROBES"

The selection of the probe setup "ALL PROBES" is useful if you are exercising all of the measurement options as, for example, you would do if you were doing all of the examples in this section.

Probe setup was discussed earlier on page 4-10.

In this example you will set up channel 6 with an "ALL PROBES" configuration.

Note: *Setting "ALL PROBES" enables all available modes, but may cause total measurements to be more time consuming.*

In the "CALIB?" subroutine select the "CHAN?" option and at the prompt CHn, rub and enter 6. Proceed to the "PROBE?" option and at the prompt PRn, enter 7.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameter will take effect as soon as you return to the operating mode.

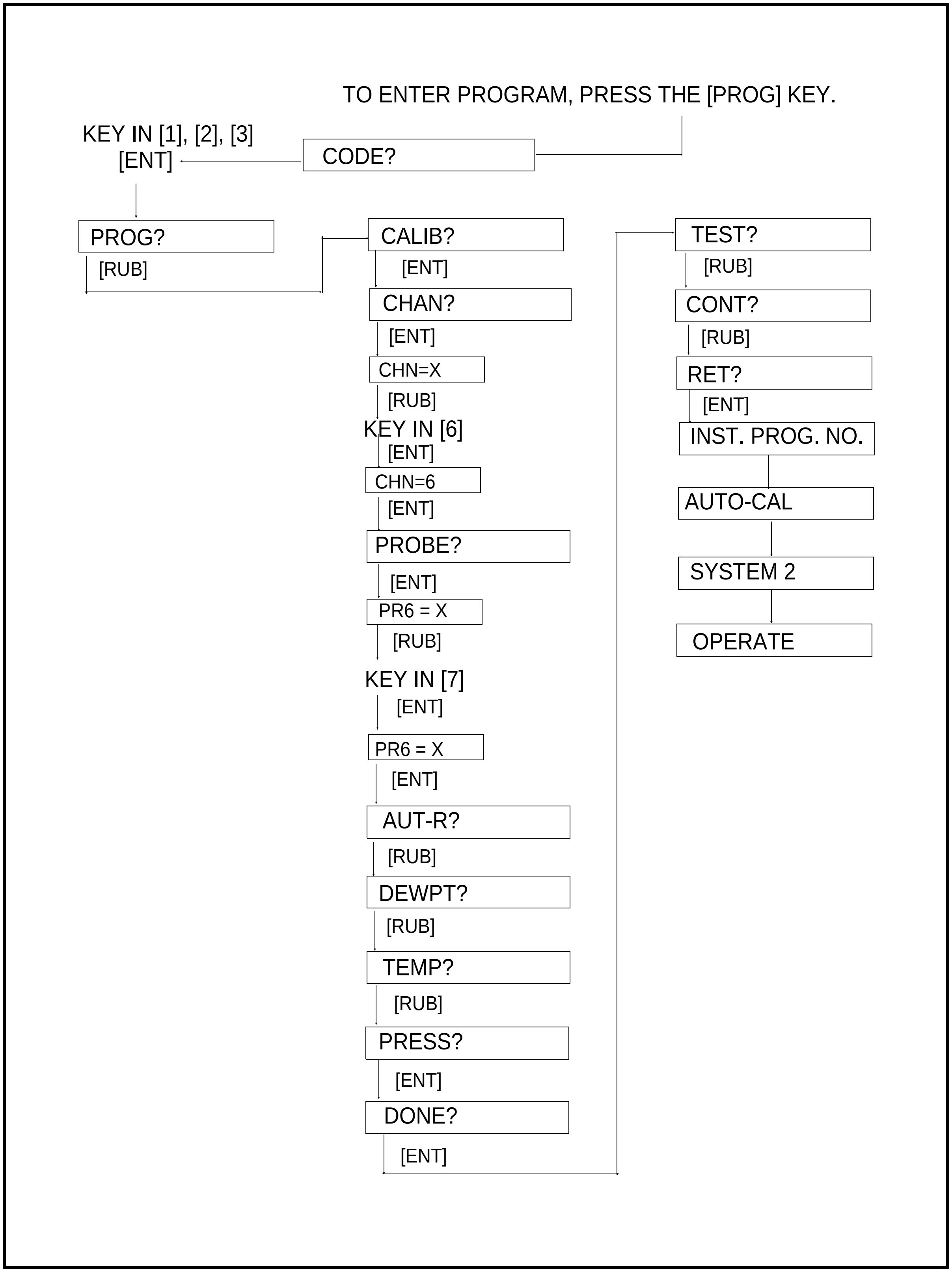


Figure 4-10: Example F: Making Probe Setup "ALL PROBES"

Example G: Enabling Auto-ranging

You may turn auto-ranging on or off for each channel. In this example, we will assume auto-ranging was off and will turn it on (refer to page 3-5 for more information on auto-ranging).

In the "CALIB?" subroutine, select the "CHAN?" option and at the prompt CHn, erase the current value by pressing <RUB> and enter 6. Then, proceed to the "AUT-R?" option and at the prompt AU6=X, enter 1.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameter will take effect as soon as you return to the operating mode.

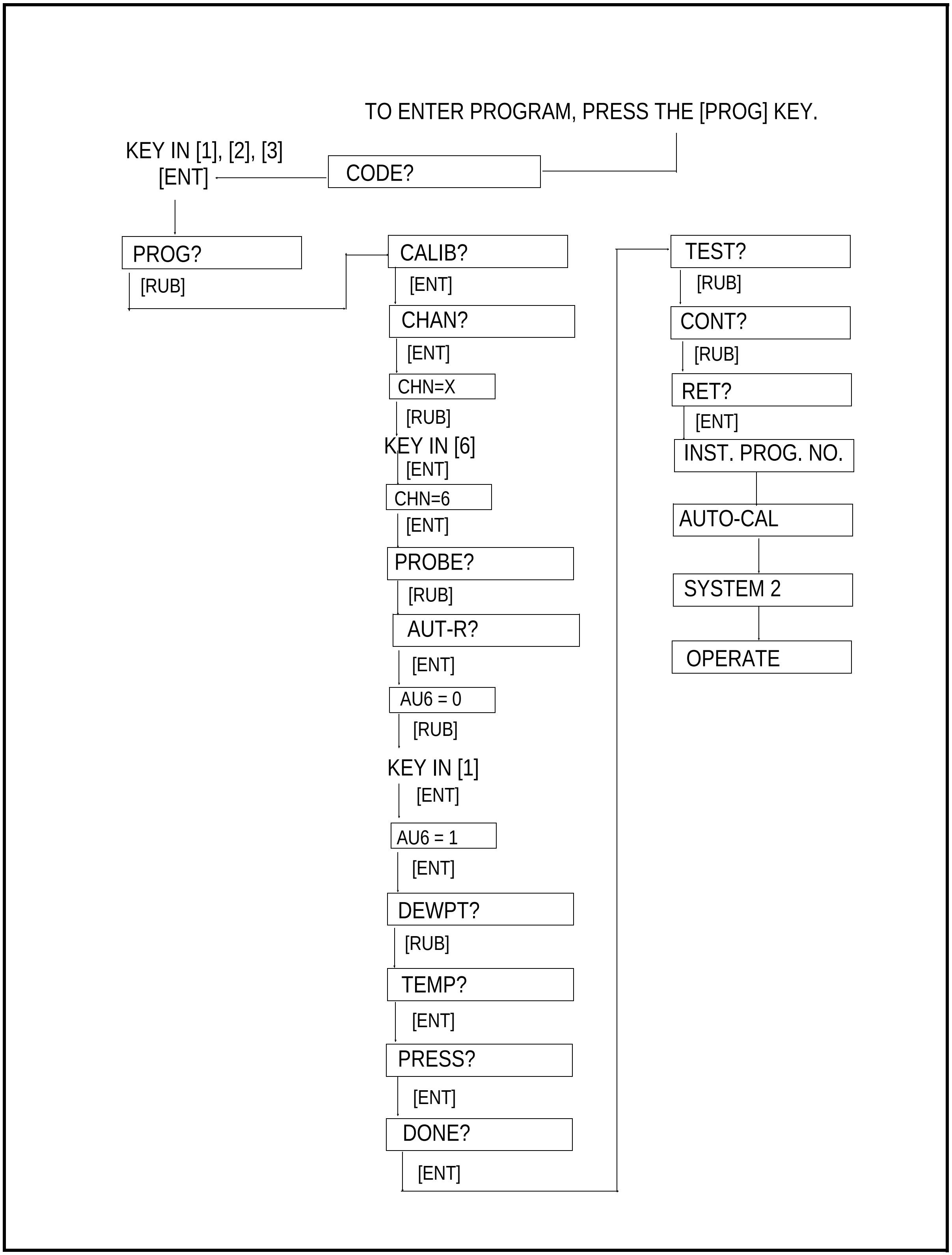


Figure 4-11: Example G: Enabling Auto-Ranging

Example H: Entering Dew/Frost Point Temperature Probe Calibration Data

The Dew/Frost point temperature probe calibration values are supplied for every probe on a calibration sheet. A typical Panametrics probe calibration sheet lists 14 dew/frost point temperatures within the range of the probe and gives a calibration value (MH) associated with each point (see Figure 2-7 on page 2-4).

In this example we will enter calibration data for a standard type M moisture probe on channel 6. You should use data for a probe you already have. You will then be able to use that probe on channel 6.

In the "CALIB?" subroutine, select the "CHAN?" option and, at the prompt CHn, press <RUB> and enter 6. Proceed to the "DEWPT?" option and, at the "PH6=XXXXXX" prompt, enter the probe serial number from the calibration data sheet (in this case, we are using the example data sheet in Figure 2-7 as our source). Next, tell the System 2 how many calibration points there are (ND6=14). Then, enter each point as it appears on the calibration sheet.

D00 = -110°C	M00 = XXXX (from data sheet)
.	Continue
.	until all
.	data points
.	are entered.
M13 = 20°C	D13 = ZZZZ (from data sheet)

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameters will take effect as soon as you return to the operating mode.

Caution!

You cannot damage the hygrometer by changing the user program; however, changing values will affect the hygrometer operating characteristics.

Before you change any previously programmed parameters, we recommend you make a note of the original value or values. Re-enter the previously programmed parameters after you have completed the examples.

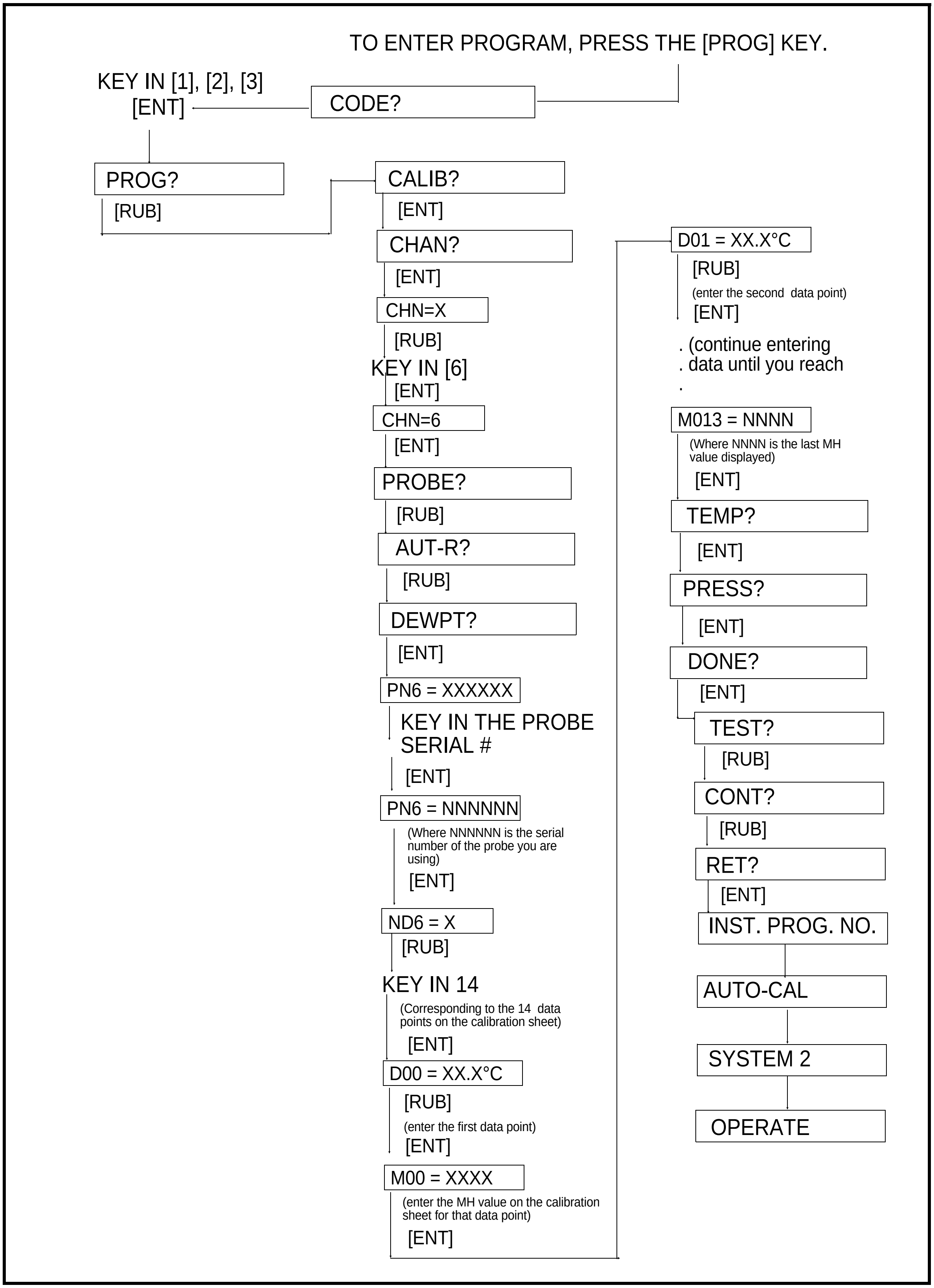


Figure 4-12: Example H: Moisture Probe Calibration

Example I: Setting Temperature to a Constant

In this example, we will set the temperature to -10°C. Setting temperature to a constant is done instead of using a temperature probe.

In the "CALIB?" subroutine, select the "CHAN?" option and, at the prompt CHn, erase the current value, by pressing <RUB> and enter 6. Proceed to the "TEMP?" option and at the prompt KT6, enter 1. Then, at the TP6 prompt, enter -10.

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameter will take effect as soon as you return to the operating mode.

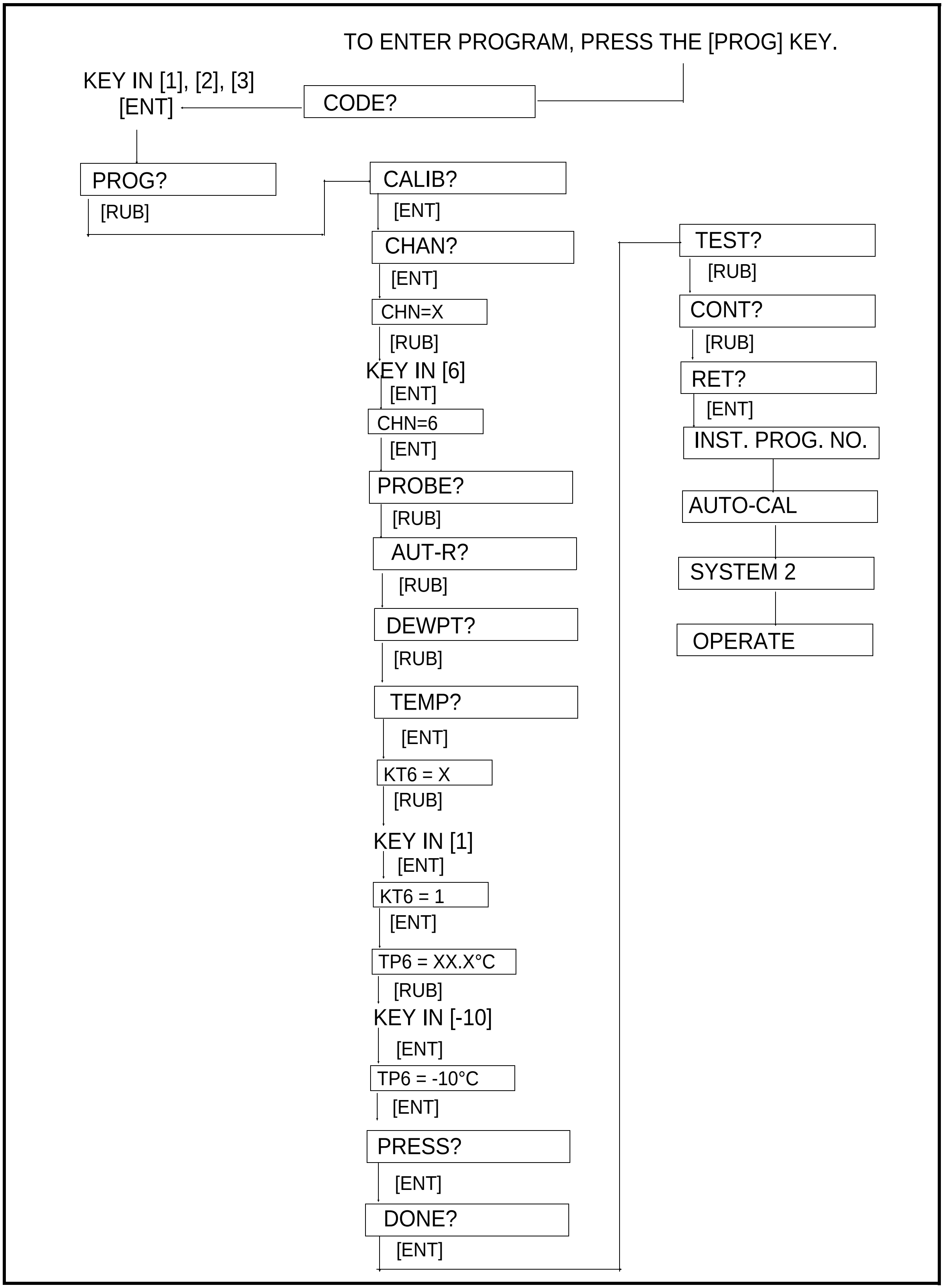


Figure 4-13: Example I: Setting Temperature to a Constant

Example J: Setting Pressure to a Constant

Normally, when using a pressure transmitter, you will enter calibration values for two pressure points on the transmitter pressure curve. For each pressure, you are prompted to enter two loop current values.

You can also program the System 2 for pressure equal to a constant. You do this by entering the same value for pressure in both cases (same value for P0 and P1).

Note: *The System 2 will use the value of pressure you entered for calculations.*

In this example, you will program pressure to be constant at 14.6 PSIG (this assumes your pressure readings are in PSIG; if not, use appropriate values in BARS).

Pressure calibration is done in the "CALIB?" subroutine.

In the "CALIB?" subroutine, select the "CHAN?" option and at the prompt CHn, rub and enter 6. Proceed to the "PRESS?" option and, at the prompt P0, enter 14.6.

Then: set PH0=.0000

set P1=14.6

set PH1=20.00

The programming example described above is shown as a flow diagram on the next page. Please follow these steps exactly as they are given in the flow diagram.

The new parameters will take effect as soon as you return to the operating mode.

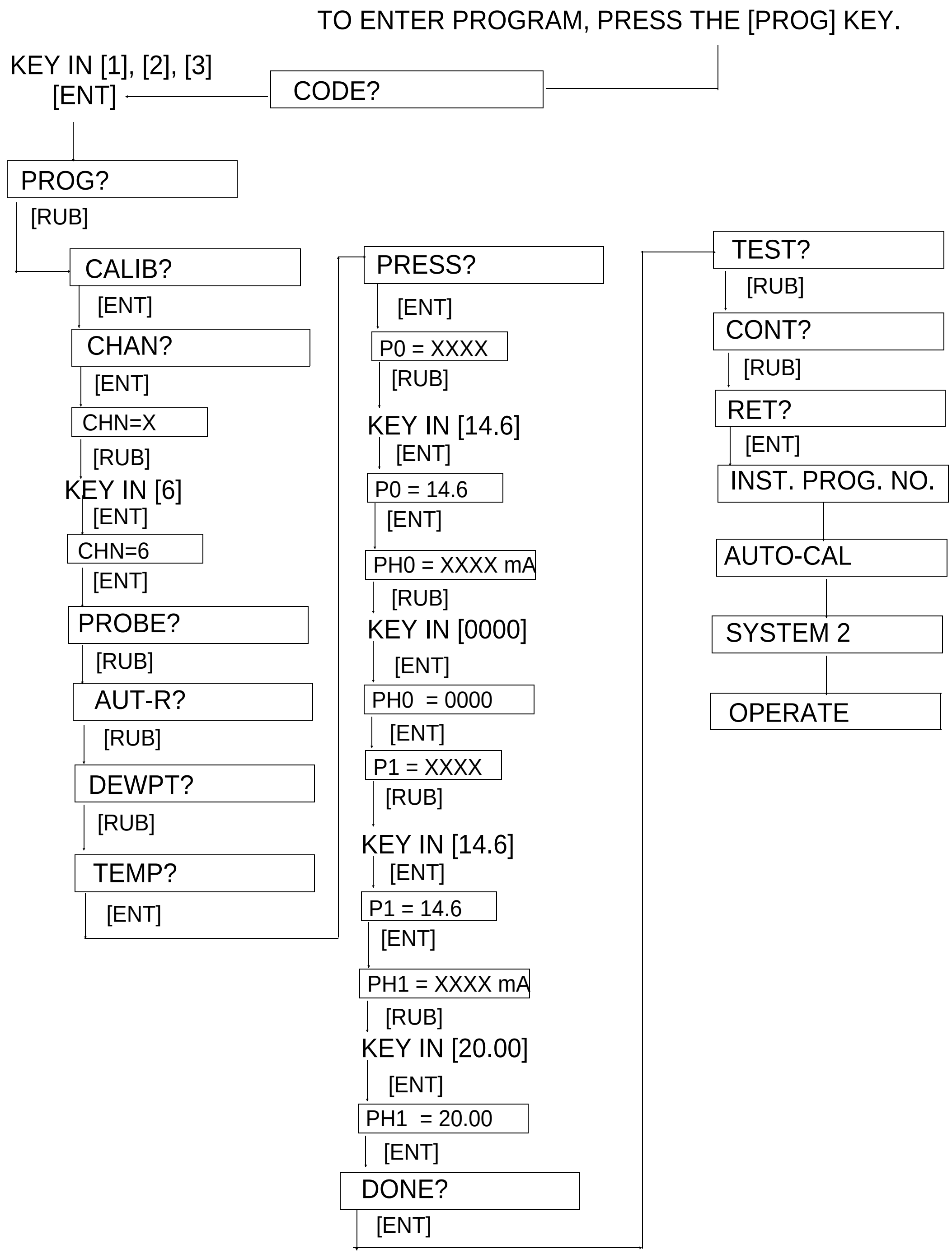


Figure 4-14: Example J: Setting Pressure to a Constant

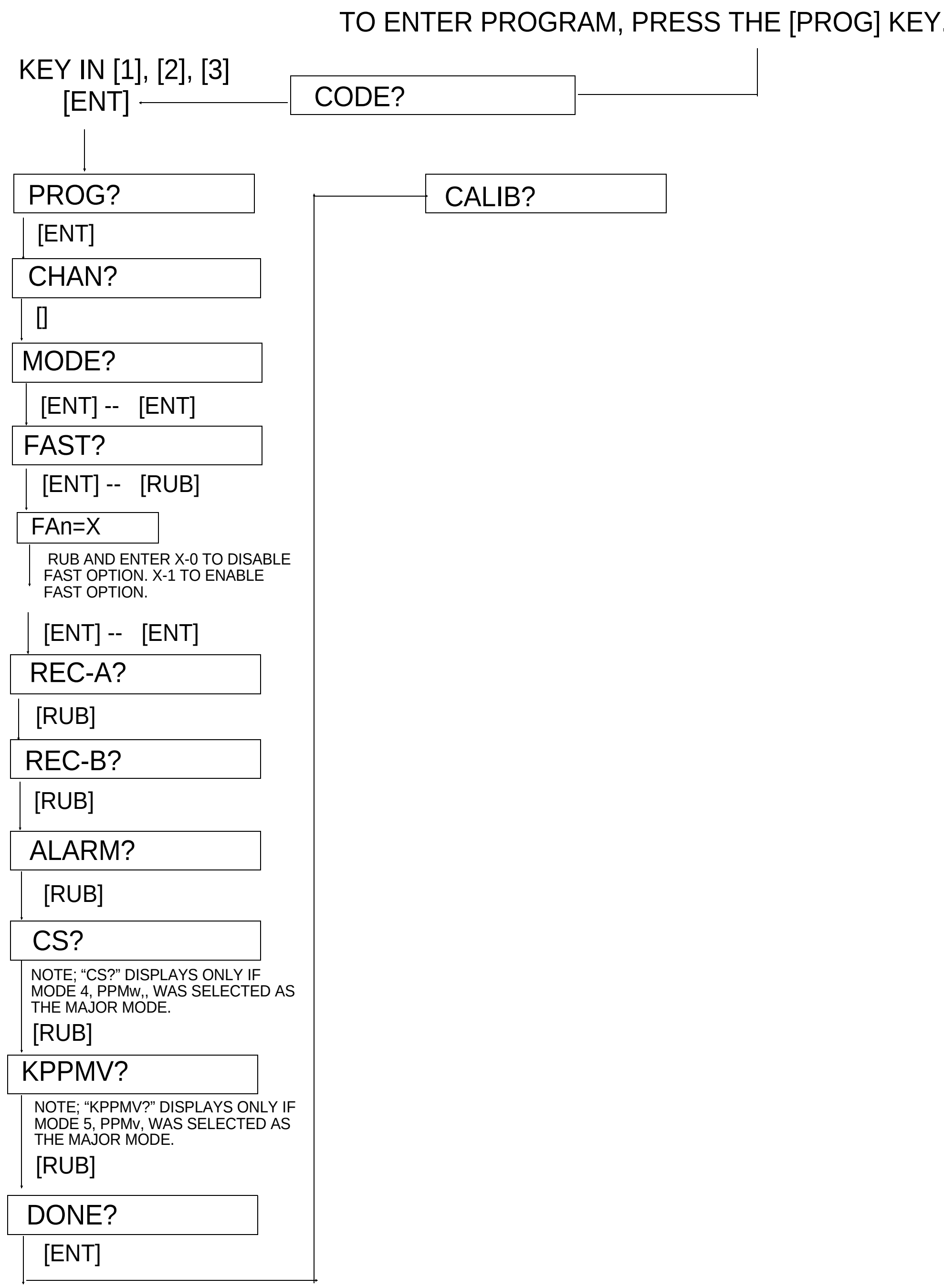


Figure 4-15: Modification to Standard Instrument Program Flow Diagram for Hygrometers with the Fast Response Option

Fast Response Option

If your System 2 is equipped with the fast response option, it will display SYS2.FAST.00X.L, (where X is a revision level and L is a revision letter) when you first power-up. This display will also appear each time you perform a system re-initialization.

System 2 hygrometers with the Fast Response option have the following added features:

1. Mode 8 displays Fast Response dew/frost point temperature.

2. Mode 9 displays Fast Response PPM_v.

3. The $KPPM_v$ multiplier is added to the "PROG" programming section for Mode 9.

4. A new prompt "FAST?" is added to the "PROG" programming section as shown below.

Figure 4-15 on the previous page shows how the standard User Programming Flow diagram (as shown in Figure 4-4) is modified for the Fast Response option.

Mode 9: Fast Response Dew Point

This mode uses a dynamic moisture calibration technique to extrapolate the moisture level to the end point when making measurements in abrupt "dry down" conditions. The system response time depends on the relative change in dew point. For a change from ambient moisture levels to trace levels, the system can respond in as little as two minutes for single-channel operation.

The fast response function must be individually enabled for each channel. At the new prompt "FAST?" key in <ENT>. The display shows "FAn=X", where n is the channel number and X is either 1 or 0. If X=0, fast response is disabled; if X=1, fast response is enabled. The default value is 0 (disabled). To change the setting, type <RUB> at the prompt "FAn=X" and enter the new value for X followed by <ENT>.

The Fast Response dew point has two display modes. While the system is performing preliminary calculations, regular Mode 1 dew point is displayed with the equal sign replaced by the asterisk (Figure 4-16A). When the extrapolated moisture level has been determined, it is displayed and the asterisk is replaced by the equal sign (Figure 4-16B). Thereafter, the system will continue the end point extrapolation at a much faster rate, reflecting small changes in the final dew point value.

FP*-20.1°C	**FP1=-70.1°C**
(A)	**(B)**

Figure 4-16: "Fast" Dew/Frost Point Display

Mode 9: Fast Response Dew Point (cont.)

The system returns to showing an asterisk as the Mode 1 dew point reaches the extrapolation value. A significant change in moisture level will also cause the system to return to the "asterisk" mode and restart the extrapolation calculations.

Accuracy of the extrapolation is within ±2°C dew/frost point temperature of the end point as measured by Mode 1.

Range error limits for Mode 8 are identical to those of Mode 1. Therefore, there are no Mode 8 range errors.

Notes on Operation

1. THE AUTO-RANGE OPTION MUST BE ON. The system will not function properly without automatic range switching.

2. A reasonably constant dew point and flow rate are needed. The minimum flow rate is one standard cubic foot per hour.

3. The lower limit for Mode 8 extrapolation is -85°C.

Note: *The Fast Response Option should only be used in dry down conditions. Up and down fluctuations of moisture content may cause measurement errors in the Fast Response mode.*

Mode 9: Fast Response PPM_v

This mode uses the extrapolated dew point determined in Mode 8 to calculate PPM_v. While the system is performing preliminary calculations, Mode 5 PPM_v is displayed in Mode 9 with the equal sign replaced by the asterisk (Figure 4-17A).

When the extrapolated PPMv has been determined, it is displayed with the asterisk replaced by the equal sign (Figure 4-17B). The other operational considerations for Mode 8 also apply to Mode 9. The $KPPM_v$ multiplier applies to both modes 5 and 9.

The mode 9 range errors are 0.0010 PPM_v and 99999 PPM_v.

Preliminary	**Extrapolated Value**
FD1*2000	**FD1=30**
(A)	**(B)**

Figure 4-17: "Fast" PPM_v Display

Notes on Hardware Changes (See Figure 4-8 below.)

1. System 2 hygrometers ordered with the Fast Response option utilize a 3-EPROM instrument program (instead of two EPROMs). The additional (third) EPROM plugs into XU303 as shown in Figure 4-8 below.

Note: *The instrument program is discussed further in Chapter 6.*

2. An additional (3rd) RAM chip is also required (U307).

The third RAM chip plugs into socket XU307, as shown in Figure 4-18 below.

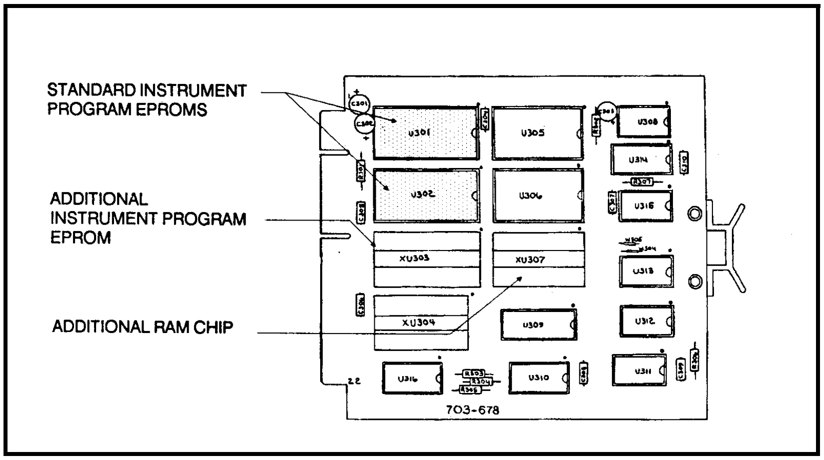
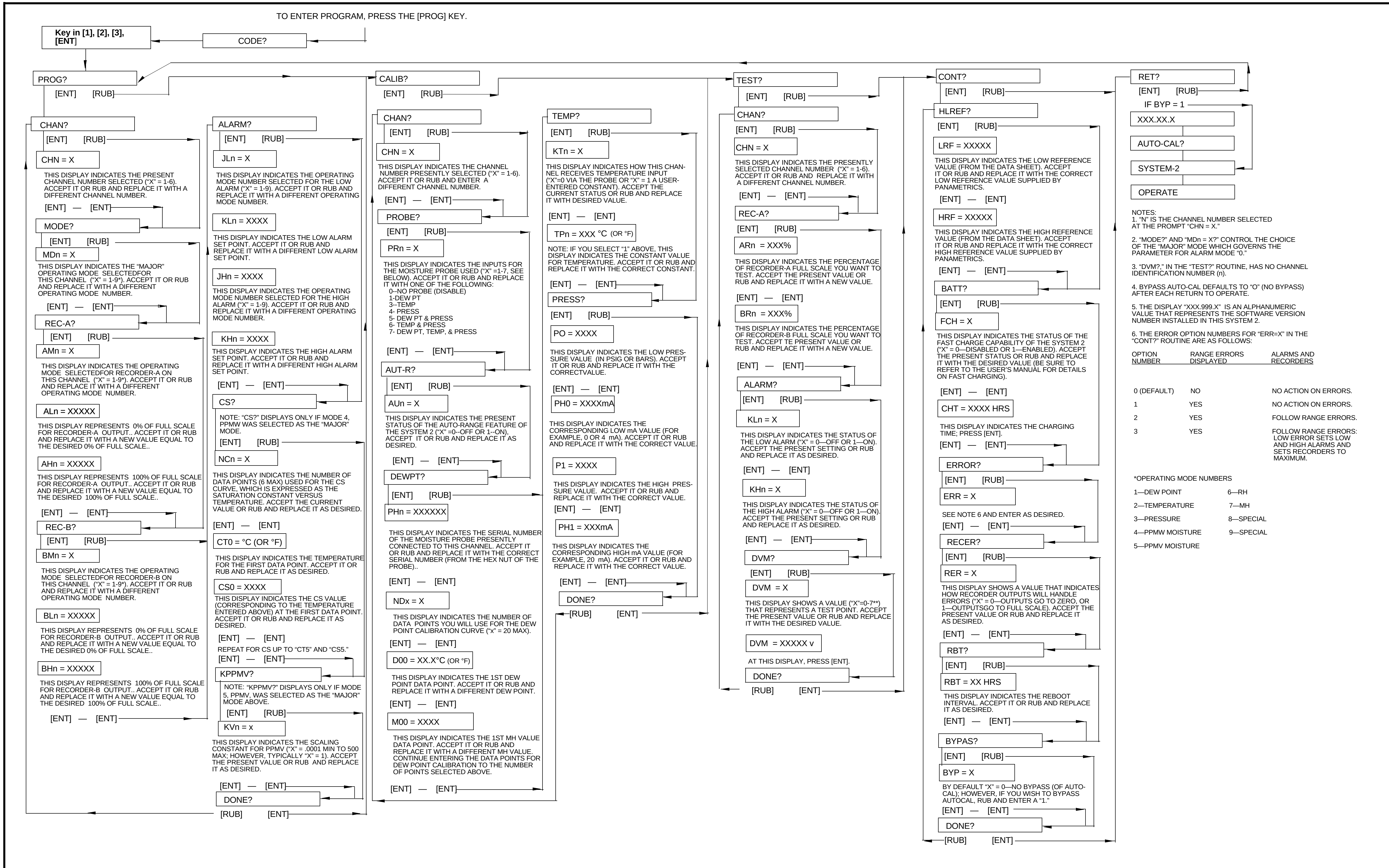


Figure 4-18: Memory Card No. 24 Showing Additional IC Needed for Fast Response Option


TO ENTER PROGRAM, PRESS THE [PROG] KEY.
Key in [1], [2], [3], [ENT]
CODE?
PROG?
[ENT] [RUB]
CHAN?
[ENT] [RUB]
CHN = X
THIS DISPLAY INDICATES THE PRESENT CHANNEL NUMBER SELECTED ("X" = 1-6). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT CHANNEL NUMBER.
[ENT] — [ENT]
MODE?
[ENT] [RUB]
MDn = X
THIS DISPLAY INDICATES THE "MAJOR" OPERATING MODE SELECTEDFOR THIS CHANNEL ("X" = 1-9*). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT OPERATING MODE NUMBER.
[ENT] — [ENT]
REC-A?
[ENT] [RUB]
AMn = X
THIS DISPLAY INDICATES THE OPERATING MODE SELECTEDFOR RECORDER-A ON THIS CHANNEL ("X" = 1-9*). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT OPERATING MODE NUMBER.
ALn = XXXXX
THIS DISPLAY REPRESENTS 0% OF FULL SCALE FOR RECORDER-A OUTPUT.. ACCEPT IT OR RUB AND REPLACE IT WITH A NEW VALUE EQUAL TO THE DESIRED 0% OF FULL SCALE..
AHn = XXXXX
THIS DISPLAY REPRESENTS 100% OF FULL SCALE FOR RECORDER-A OUTPUT.. ACCEPT IT OR RUB AND REPLACE IT WITH A NEW VALUE EQUAL TO THE DESIRED 100% OF FULL SCALE..
[ENT] — [ENT]
REC-B?
[ENT] [RUB]
BMn = X
THIS DISPLAY INDICATES THE OPERATING MODE SELECTEDFOR RECORDER-B ON THIS CHANNEL ("X" = 1-9*). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT OPERATING MODE NUMBER.
BLn = XXXXX
THIS DISPLAY REPRESENTS 0% OF FULL SCALE FOR RECORDER-B OUTPUT.. ACCEPT IT OR RUB AND REPLACE IT WITH A NEW VALUE EQUAL TO THE DESIRED 0% OF FULL SCALE..
BHn = XXXXX
THIS DISPLAY REPRESENTS 100% OF FULL SCALE FOR RECORDER-B OUTPUT.. ACCEPT IT OR RUB AND REPLACE IT WITH A NEW VALUE EQUAL TO THE DESIRED 100% OF FULL SCALE..
[ENT] — [ENT]
ALARM?
[ENT] [RUB]
JLn = X
THIS DISPLAY INDICATES THE OPERATING MODE NUMBER SELECTED FOR THE LOW ALARM ("X" = 1-9). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT OPERATING MODE NUMBER.
KLn = XXXX
THIS DISPLAY INDICATES THE LOW ALARM SET POINT. ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT LOW ALARM SET POINT.
JHn = XXXX
THIS DISPLAY INDICATES THE OPERATING MODE NUMBER SELECTED FOR THE HIGH ALARM ("X" = 1-9). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT OPERATING MODE NUMBER.
KHn = XXXX
THIS DISPLAY INDICATES THE HIGH ALARM SET POINT. ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT HIGH ALARM SET POINT.
[ENT] — [ENT]
CS?
NOTE: "CS?" DISPLAYS ONLY IF MODE 4, PPMW WAS SELECTED AS THE "MAJOR" MODE.
[ENT] [RUB]
NCn = X
THIS DISPLAY INDICATES THE NUMBER OF DATA POINTS (6 MAX) USED FOR THE CS CURVE, WHICH IS EXPRESSED AS THE SATURATION CONSTANT VERSUS TEMPERATURE. ACCEPT THE CURRENT VALUE OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
CT0 = °C (OR °F)
THIS DISPLAY INDICATES THE TEMPERATURE FOR THE FIRST DATA POINT. ACCEPT IT OR RUB AND REPLACE IT AS DESIRED.
CS0 = XXXX
THIS DISPLAY INDICATES THE CS VALUE (CORRESPONDING TO THE TEMPERATURE ENTERED ABOVE) AT THE FIRST DATA POINT. ACCEPT IT OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
REPEAT FOR CS UP TO "CT5" AND "CS5."
[ENT] — [ENT]
KPPMV?
NOTE: "KPPMV?" DISPLAYS ONLY IF MODE 5, PPMV, WAS SELECTED AS THE "MAJOR" MODE ABOVE.
[ENT] [RUB]
KVn = x
THIS DISPLAY INDICATES THE SCALING CONSTANT FOR PPMV ("X" = .0001 MIN TO 500 MAX; HOWEVER, TYPICALLY "X" = 1). ACCEPT THE PRESENT VALUE OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
DONE?
[RUB] [ENT]
CALIB?
[ENT] [RUB]
CHAN?
[ENT] [RUB]
CHN = X
THIS DISPLAY INDICATES THE CHANNEL NUMBER PRESENTLY SELECTED ("X" = 1-6). ACCEPT IT OR RUB AND ENTER A DIFFERENT CHANNEL NUMBER.
[ENT] — [ENT]
PROBE?
[ENT] [RUB]
PRn = X
THIS DISPLAY INDICATES THE INPUTS FOR THE MOISTURE PROBE USED ("X" =1-7, SEE BELOW). ACCEPT IT OR RUB AND REPLACE IT WITH ONE OF THE FOLLOWING:
0--NO PROBE (DISABLE)
1-DEW PT
3--TEMP
4- PRESS
5- DEW PT & PRESS
6- TEMP & PRESS
7- DEW PT, TEMP, & PRESS
[ENT] — [ENT]
AUT-R?
[ENT] [RUB]
AUn = X
THIS DISPLAY INDICATES THE PRESENT STATUS OF THE AUTO-RANGE FEATURE OF THE SYSTEM 2 ("X" =0--OFF OR 1--ON). ACCEPT IT OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
DEWPT?
[ENT] [RUB]
PHn = XXXXXX
THIS DISPLAY INDICATES THE SERIAL NUMBER OF THE MOISTURE PROBE PRESENTLY CONNECTED TO THIS CHANNEL. ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT SERIAL NUMBER (FROM THE HEX NUT OF THE PROBE)..
[ENT] — [ENT]
NDx = X
THIS DISPLAY INDICATES THE NUMBER OF DATA POINTS YOU WILL USE FOR THE DEW POINT CALIBRATION CURVE ("x" = 20 MAX).
[ENT] — [ENT]
D00 = XX.X°C (OR °F)
THIS DISPLAY INDICATES THE 1ST DEW POINT DATA POINT. ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT DEW POINT.
[ENT] — [ENT]
M00 = XXXX
THIS DISPLAY INDICATES THE 1ST MH VALUE DATA POINT. ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT MH VALUE. CONTINUE ENTERING THE DATA POINTS FOR DEW POINT CALIBRATION TO THE NUMBER OF POINTS SELECTED ABOVE.
[ENT] — [ENT]
TEMP?
[ENT] [RUB]
KTn = X
THIS DISPLAY INDICATES HOW THIS CHANNEL RECEIVES TEMPERATURE INPUT ("X"=0 VIA THE PROBE OR "X" = 1 A USER-ENTERED CONSTANT). ACCEPT IT OR RUB AND REPLACE IT WITH DESIRED VALUE.
[ENT] — [ENT]
TPn = XXX °C (OR °F)
NOTE: IF YOU SELECT "1" ABOVE, THIS DISPLAY INDICATES THE CONSTANT VALUE FOR TEMPERATURE. ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT CONSTANT.
[ENT] — [ENT]
PRESS?
[ENT] [RUB]
PO = XXXX
THIS DISPLAY INDICATES THE LOW PRESSURE VALUE (IN PSIG OR BARS). ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECTVALUE.
[ENT] — [ENT]
PH0 = XXXXmA
THIS DISPLAY INDICATES THE CORRESPONDING LOW mA VALUE (FOR EXAMPLE, 0 OR 4 mA). ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT VALUE.
P1 = XXXX
THIS DISPLAY INDICATES THE HIGH PRESSURE VALUE. ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT VALUE.
[ENT] — [ENT]
PH1 = XXXmA
THIS DISPLAY INDICATES THE CORRESPONDING HIGH mA VALUE (FOR EXAMPLE, 20 mA). ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT VALUE.
[ENT] — [ENT]
DONE?
[RUB] [ENT]
TEST?
[ENT] [RUB]
CHAN?
[ENT] [RUB]
CHN = X
THIS DISPLAY INDICATES THE PRESENTLY SELECTED CHANNEL NUMBER ("X" = 1-6). ACCEPT IT OR RUB AND REPLACE IT WITH A DIFFERENT CHANNEL NUMBER.
[ENT] — [ENT]
REC-A?
[ENT] [RUB]
ARn = XXX%
THIS DISPLAY INDICATES THE PERCENTAGE OF RECORDER-A FULL SCALE YOU WANT TO TEST. ACCEPT THE PRESENT VALUE OR RUB AND REPLACE IT WITH A NEW VALUE.
[ENT] — [ENT]
BRn = XXX%
THIS DISPLAY INDICATES THE PERCENTAGE OF RECORDER-B FULL SCALE YOU WANT TO TEST. ACCEPT TE PRESENT VALUE OR RUB AND REPLACE IT WITH A NEW VALUE.
[ENT] — [ENT]
ALARM?
[ENT] [RUB]
KLn = X
THIS DISPLAY INDICATES THE STATUS OF THE LOW ALARM ("X" = 0—OFF OR 1—ON). ACCEPT THE PRESENT SETTING OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
KHn = X
THIS DISPLAY INDICATES THE STATUS OF THE HIGH ALARM ("X" = 0—OFF OR 1—ON). ACCEPT THE PRESENT SETTING OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
DVM?
[ENT] [RUB]
DVM = X
THIS DISPLAY SHOWS A VALUE ("X"=0-7**) THAT REPRESENTS A TEST POINT. ACCEPT THE PRESENT VALUE OR RUB AND REPLACE IT WITH THE DESIRED VALUE.
DVM = XXXXX v
AT THIS DISPLAY, PRESS [ENT].
DONE?
[RUB] [ENT]
CONT?
[ENT] [RUB]
HLREF?
[ENT] [RUB]
LRF = XXXXX
THIS DISPLAY INDICATES THE LOW REFERENCE VALUE (FROM THE DATA SHEET). ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT LOW REFERENCE VALUE SUPPLIED BY PANAMETRICS.
[ENT] — [ENT]
HRF = XXXXX
THIS DISPLAY INDICATES THE HIGH REFERENCE VALUE (FROM THE DATA SHEET). ACCEPT IT OR RUB AND REPLACE IT WITH THE CORRECT HIGH REFERENCE VALUE SUPPLIED BY PANAMETRICS.
[ENT] — [ENT]
BATT?
[ENT] [RUB]
FCH = X
THIS DISPLAY INDICATES THE STATUS OF THE FAST CHARGE CAPABILITY OF THE SYSTEM 2 ("X" = 0—DISABLED OR 1—ENABLED). ACCEPT THE PRESENT STATUS OR RUB AND REPLACE IT WITH THE DESIRED VALUE (BE SURE TO REFER TO THE USER'S MANUAL FOR DETAILS ON FAST CHARGING).
[ENT] — [ENT]
CHT = XXXX HRS
THIS DISPLAY INDICATES THE CHARGING TIME; PRESS [ENT].
[ENT] — [ENT]
ERROR?
[ENT] [RUB]
ERR = X
SEE NOTE 6 AND ENTER AS DESIRED.
[ENT] — [ENT]
RECER?
[ENT] [RUB]
RER = X
THIS DISPLAY SHOWS A VALUE THAT INDICATES HOW RECORDER OUTPUTS WILL HANDLE ERRORS ("X" = 0—OUTPUTS GO TO ZERO, OR 1—OUTPUTSGO TO FULL SCALE). ACCEPT THE PRESENT VALUE OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
RBT?
[ENT] [RUB]
RBT = XX HRS
THIS DISPLAY INDICATES THE REBOOT INTERVAL. ACCEPT IT OR RUB AND REPLACE IT AS DESIRED.
[ENT] — [ENT]
BYPAS?
[ENT] [RUB]
BYP = X
BY DEFAULT "X" = 0—NO BYPASS (OF AUTO-CAL); HOWEVER, IF YOU WISH TO BYPASS AUTOCAL, RUB AND ENTER A "1."
[ENT] — [ENT]
DONE?
[RUB] [ENT]
RET?
[ENT] [RUB]
IF BYP = 1
XXX.XX.X
AUTO-CAL?
SYSTEM-2
OPERATE
NOTES:
1. "N" IS THE CHANNEL NUMBER SELECTED AT THE PROMPT "CHN = X."
2. "MODE?" AND "MDn = X?" CONTROL THE CHOICE OF THE "MAJOR" MODE WHICH GOVERNS THE PARAMETER FOR ALARM MODE "0."
3. "DVM?," IN THE "TEST?" ROUTINE, HAS NO CHANNEL IDENTIFICATION NUMBER (n).
4. BYPASS AUTO-CAL DEFAULTS TO "O" (NO BYPASS) AFTER EACH RETURN TO OPERATE.
5. THE DISPLAY "XXX.999.X" IS AN ALPHANUMERIC VALUE THAT REPRESENTS THE SOFTWARE VERSION NUMBER INSTALLED IN THIS SYSTEM 2.
6. THE ERROR OPTION NUMBERS FOR "ERR=X" IN THE "CONT?" ROUTINE ARE AS FOLLOWS:
OPTION NUMBER / RANGE ERRORS DISPLAYED / ALARMS AND RECORDERS
0 (DEFAULT) / NO / NO ACTION ON ERRORS.
1 / YES / NO ACTION ON ERRORS.
2 / YES / FOLLOW RANGE ERRORS.
3 / YES / FOLLOW RANGE ERRORS: LOW ERROR SETS LOW AND HIGH ALARMS AND SETS RECORDERS TO MAXIMUM.
*OPERATING MODE NUMBERS
1—DEW POINT
2—TEMPERATURE
3—PRESSURE
4—PPMW MOISTURE
5—PPMV MOISTURE
6—RH
7—MH
8—SPECIAL
9—SPECIAL

Chapter 5

Other Measurements

Introduction

In addition to dewpoint, the System 2 can measure:

- Temperature
- Pressure
- PPM_V
- PPM_W
- RH
- MH

as well as “special” measurements such as #MMSCF that can be optionally supplied. (The #MMSCF option is covered on page 5-11.)

Note that, except for MH, you will generally need optional temperature or pressure sensors to make these measurements (in special cases, you can set temperature and pressure to a constant which is further explained in this section and demonstrated in examples shown in Chapter 4).

In the following sub-sections, you will find out which sensor probes you need, how to hook them up, and how to make and interpret the readings.

Temperature

Temperature, either as a live input or constant value, is needed for the System 2 to calculate PPM_w or RH. To measure temperature, you will need an optional moisture/temperature type probe. Panametrics manufactures two standard types of moisture/temperature probes, the M1T or M2T. These probes are identical to the basic M1 and M2 moisture probes except for an additional 2-wire temperature sensor mounted adjacent to the moisture sensor.

The probe cable for the M1T and M2T probes is the same as for the standard M1 and M2 moisture probes (four wires with shield). You already connected the optional temperature probe when you installed the dew/frost point probe, as discussed on page 2-2.

If your System 2 is not already programmed to display temperature on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-1 below:

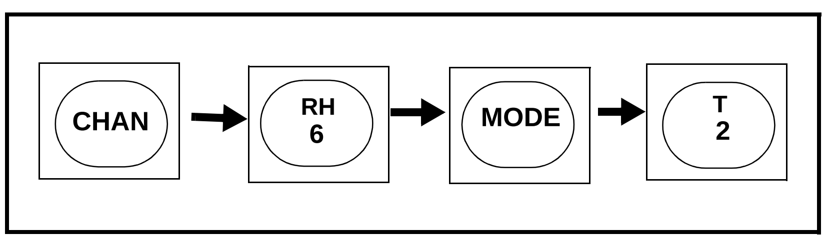


Figure 5-1: Key Sequence to Read Temperature on Channel 6

Temperature (cont.)

The display will then show temperature in the format shown in Figure 5-2 below (the value shown is for illustration purposes; the value you actually see will be different):

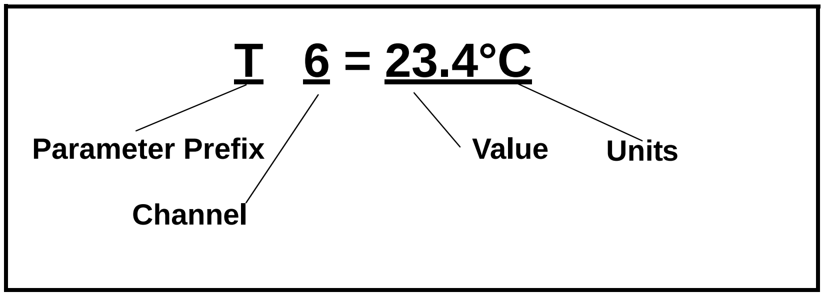


Figure 5-2: Display Format for Temperature

Note: *The choice of °C (CELSIUS) or °F (FAHRENHEIT) measurement units is factory set per your order. If you did not specify the units at time of order, your hygrometer will be set to °C. For information on how to change temperature measurement units, refer to Chapter 8.*

Pressure

Pressure, either as a live input or a constant value, is needed for the System 2 to calculate PPM_v. To make pressure measurements, you need a 4-20 mA pressure transmitter. Panametrics supplies optional pressure transmitters in four standard ranges, and in either standard or explosion-proof styles. Wire the transmitter as shown in Figure 5-3 below. Be sure to observe the loop polarity.

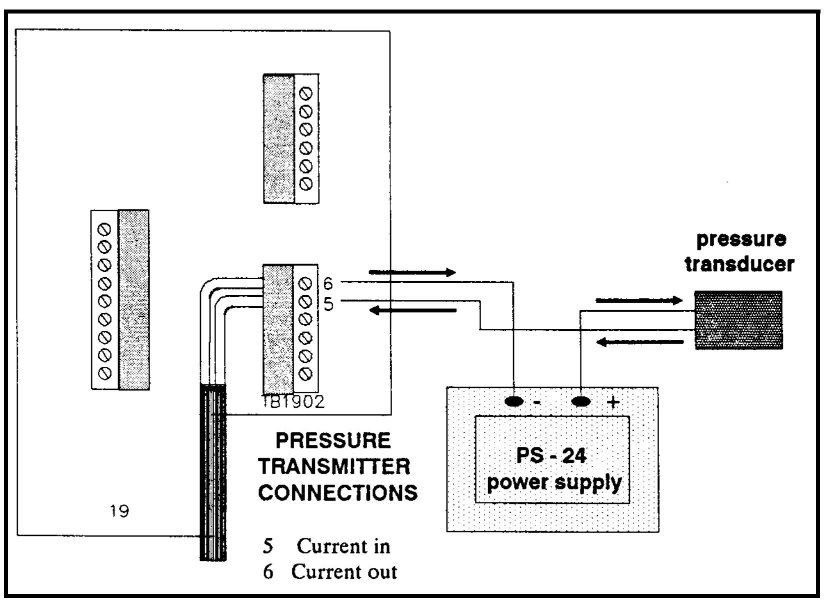


Figure 5-3: Connecting a Pressure Transmitter

Pressure (cont.)

If your System 2 is not already programmed to display pressure on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-4 below:

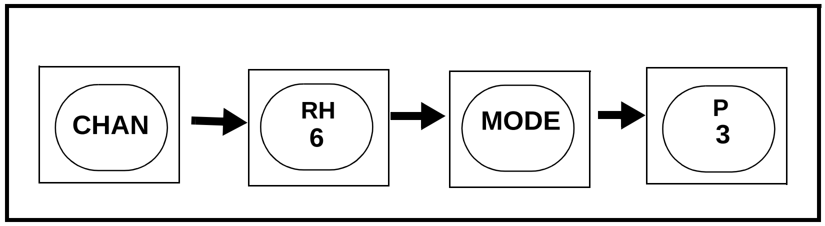


Figure 5-4: Key Sequence to Read Pressure on Channel 6

The display will then show pressure in the format shown in Figure 5-5 below (the value shown is for illustration purposes; the value you actually see will be different):

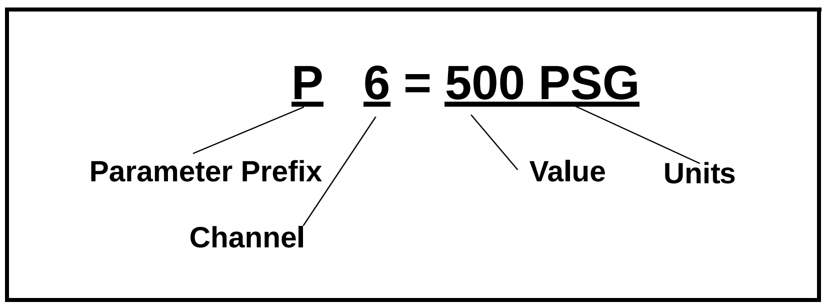


Figure 5-5: Display Format for Pressure

You will then be reading pressure in either PSIG (PSG) or BARS (BAR). The choice of PSIG (PSG) or BARS (BAR) measurement units is factory-set per your order. If you did not specify the units at time of order, your hygrometer will be set to PSIG. For information on how to change pressure measurement units, refer to Chapter 8.

PPM_w

PPM_w is a calculated parameter used for expressing moisture content in liquids. The measurement of PPM_w is not dependent on pressure, but is dependent upon process temperature.

The relationship is:

$$PPM_W = \frac{P_W}{P_S} \times C_S$$

where: P_W = partial pressure of water vapor (measured by the moisture probe)
P_S = the Saturation vapor pressure of water at the temperature of measurement
C_S = the saturation concentration of water in the liquid at the temperature of measurement

To calculate PPM_w, we need a measurement of P_w, and a measurement of process temperature. (We can extrapolate P_s from temperature and C_s input data.)

The System 2 derives P_w directly from Panametrics M type moisture probe signal since the aluminum oxide measurement technique is, in fact, a direct measurement of the partial pressure due to water vapor.

To obtain temperature, you will need a type M1T or M2T probe as described on page 5-1. If temperature is known, and remains stable enough over time to be assumed constant, it can be programmed as a system (calibration) constant. (Setting temperature to a constant is described on page 4-37.)

You will also have to enter at least one value for C_s. Values for C_s are empirical. When you have the C_s data, enter the values as explained on page 4-8 and demonstrated on page 4-27.

Assuming you have a Panametrics type M1T or M2T moisture/ temperature probe connected (or have the temperature value set at a constant), you are ready to measure PPM_w. Turn the power on.

PPM_W (cont.)

If your System 2 is not already programmed to display PPM_w on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-6 below:

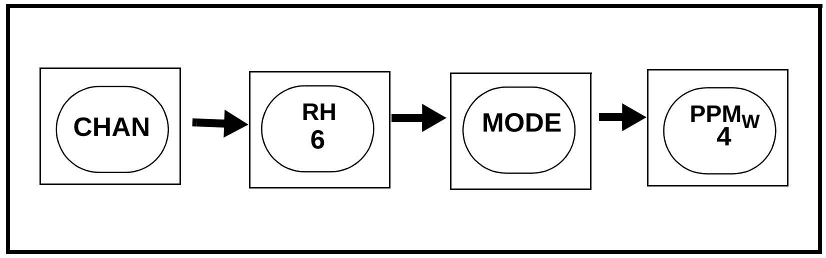


Figure 5-6: Key Sequence to Read PPM_W on Channel 6

The display will then show PPM_w in the format shown in Figure 5-7 below (the value shown is for illustration purposes; the value you see will be different):

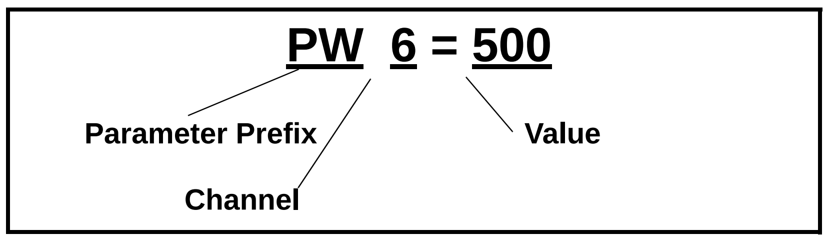


Figure 5-7: Display Format for PPM_W

PPM_v

PPM_V is the ratio of the partial pressure of water vapor to the total pressure of the carrier gas and is calculated as follows:

$$PPM_v = \frac{P_w}{P_t} \times 10^6$$

where $\mathbf{P_w}$ = partial pressure of water vapor (measured by the moisture probe)
and $\mathbf{P_t}$ = the total pressure.

The System 2 derives P_w directly from the Panametrics M type moisture probe signal since the aluminum oxide measurement technique is a direct measurement of the partial pressure due to water vapor.

$\mathbf{P_t}$**,** the total pressure, can be supplied by a separate pressure sensor (i.e., a pressure transmitter, such as described on page 5-2) or, if known, and sufficiently non-varying, it can be programmed as a constant.

Assuming you have a Panametrics moisture probe connected, and a pressure transmitter such as the Panametrics P40 or P40X also connected (or have the pressure value set at a constant), you are ready to measure moisture in PPM_v.

Turn the power on.

If your System 2 is not already programmed to display PPM_v on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-8 below:

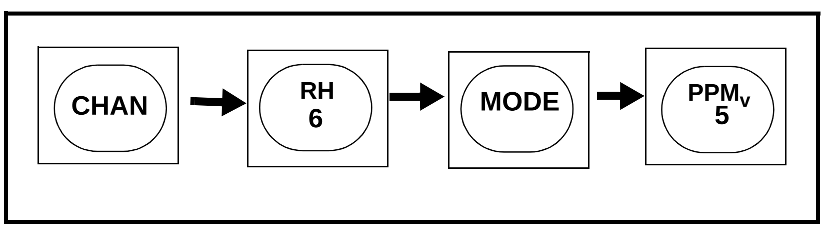


Figure 5-8: Key Sequence to Read PPM_v on Channel 6

PPM_V (cont.)

The display will then show PPM_v in the format shown in Figure 5-9 below (the value shown is for illustration purposes; the value you see will be different):

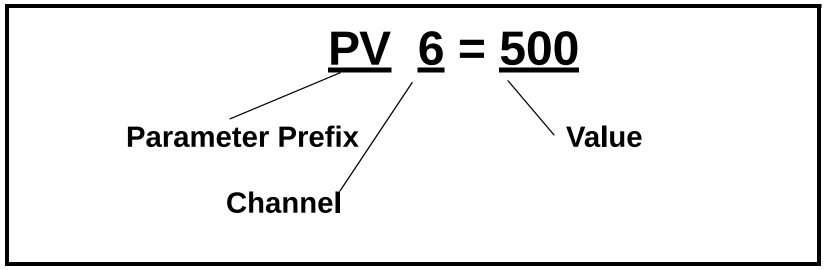


Figure 5-9: Display Format for PPM_v

RH

RH is calculated according to the following relationship:

$$\%RH = \frac{P_w}{P_s} \times 100$$

where:

P_w = partial pressure of water vapor (measured by the moisture probe)
P_s = the saturation vapor pressure of water at the temperature of measurement

Two direct measurement parameters are required to derive RH.

The System 2 derives P_w directly from Panametrics M type moisture probe signal, since the aluminum oxide measurement technique is a direct measurement of the partial pressure due to water vapor.

P_s is calculated as a function of temperature. To obtain temperature, you will need a type M1T or M2T probe as described on page 5-1 or, if temperature is known, and is sufficiently non-varying to be assumed constant, it can be programmed as a system (calibration) constant.

To enter a constant temperature, follow the programming example I on page 4-37.

Assuming you have a Panametrics type M1T or M2T moisture/ temperature probe connected (or have the temperature value set at a constant), you are ready to measure RH. Turn the power on.

If your System 2 is not already programmed to display RH on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-10 below:

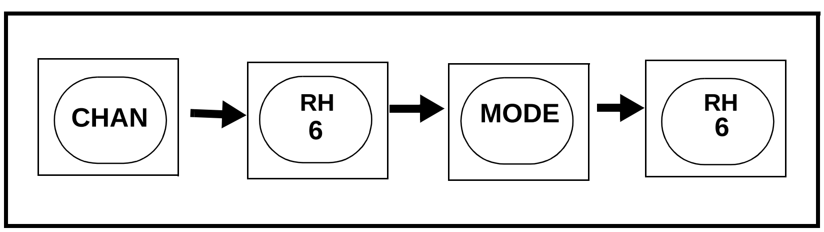


Figure 5-10: Key Sequence to Read RH on Channel 6

RH (cont.)

The display will then show RH in the format shown in Figure 5-11 below (the value shown is for illustration purposes; the value you see will be different):

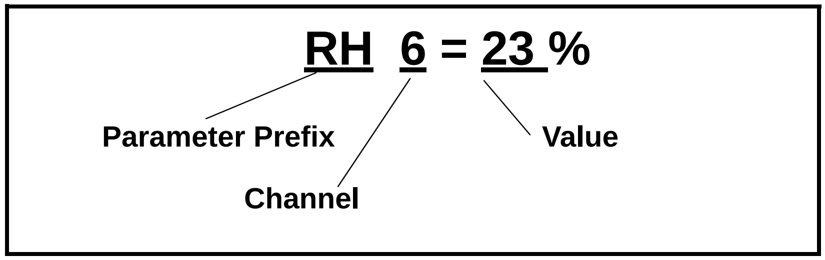


Figure 5-11: Display Format for RH

MH

MH is a diagnostic moisture measurement related to the admittance of the moisture probe.

The MH reading can be very useful in troubleshooting a faulty System 2 moisture measurement since it represents the raw signal from the probe before it is processed and converted to dew/frost point. Therefore, if you have an independent method of measuring the correct dew/frost point (such as another correctly working System 2 channel), and you know what MH values you should obtain with a known dew/frost point, you can determine whether a malfunction is occurring before or after the moisture sensing system.

Since we have gone through all the other readings, let us take a look at an MH reading. Assuming you have a Panametrics moisture or moisture/temperature probe connected, you can check MH. Turn the power on.

If your System 2 is not already programmed to display MH on channel 6, override the pre-programmed display mode by manually entering channel and mode from the front panel keypad with the key sequence shown in Figure 5-12 below:

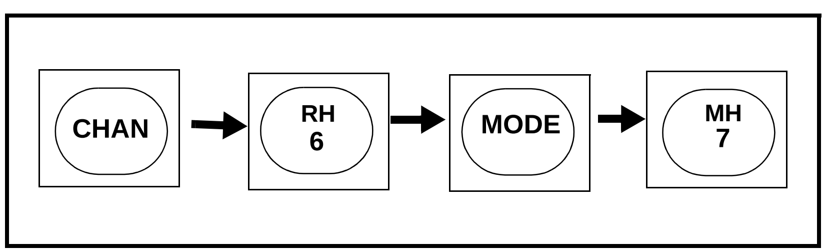


Figure 5-12: Key Sequence to Read MH on Channel 6

MH (cont.)

The resulting display reading should appear as shown in Figure 5-13 below (the value shown is for illustration purposes; the value you see will be different):

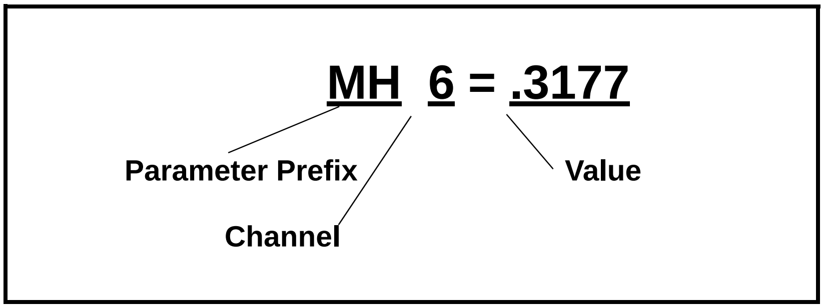


Figure 5-13: Display Format for MH

As we have indicated, when you call us for technical assistance, having this data, along with a measurement or even a good estimate of the existing dew/frost point temperature in the process system available, will greatly facilitate us in helping you resolve a moisture measurement problem.

#/MMSCF Option

All basic features implemented by this option are the same; however, each subsequent software release includes updates and minor changes.

Software Releases Covered by this Document

2101A	SYS2.SP007.003.B
SYS2.SP001.002.B	SYS2.SP011.003.C

General Description

Added features associated with this software family:

1. MODE 8 displays POUNDS OF WATER per MILLION STANDARD CUBIC FEET in NATURAL GAS.

2. MODE 9 displays POUNDS OF WATER per MILLION STANDARD CUBIC FEET in an IDEAL GAS.

Mode 8: #/MMSCF in Natural Gas

The instrument program for calculating #/MMSCF in natural gas is a function of the dew point and the pressure of the gas. The calculations take into account the non-ideality of natural gas under high pressure, through the use of compressibility factors.

Note: *Panametrics table number H-139E (available upon request) gives #/MMSCF values in natural gas as would be calculated by the System 2 Hygrometer for dew points between -80°C and +20°C, and pressures between 0 PSIG and 3000 PSIG. Note that the actual range of calculations made by your hygrometer depends on the version of software it is using.*

To select Mode 8 as the Major Mode for a channel, select 8 in answer to the mode prompt “MDn=X”. The display for Mode 8 in the Operate Mode is shown in Figure 5-14. The prefix “RG” identifies “Real Gas” and the suffix “LMM” identifies “pounds-of-water-per-million-standard-cubic-feet”.

RG1 = 290 LMN

Figure 5-14: Display of #/MMSCF in Natural Gas (Real Gas)

Mode 9: #/MMSCF in an Ideal Gas

The Instrument Program for calculating #/MMSCF in an Ideal Gas is a function of the dew point and the pressure of the gas. The formula is:

$$IG = \frac{P_w}{P_t} \times \frac{10^6}{21.1}$$

where P_w = partial pressure of water vapor (measured by the moisture probe) and P_t = total pressure

To select Mode 9 as the major Mode for a channel, select 9 in answer to the mode prompt “MDn=X.” The display for Mode 9 in the operate mode will be as shown in Figure 5-15. The prefix “IG” identifies “Ideal Gas” and the suffix “LMM” identifies pounds-of-water-per-million-standard-cubic-feet.

IG1 = 285.5 LMN

Figure 5-15: Display of #/MMSCF in an Ideal Gas

Chapter 6

Installation

Introduction

In Chapter 2, we demonstrated how to quickly get the System 2 up and running.

More than likely, however, you will install the System 2 as part of a complex process system. In such an environment, the probes and the System 2 may be subjected to environmental hazards such as temperature and pressure extremes, corrosive chemicals, mechanical vibration, and a host of other conditions that you must take into consideration.

This section contains information and instructions for installing a System 2 hygrometer in a process system. We discuss these environmental considerations and describe how to set up and connect the hygrometer for different options.

In all cases, if there is any question about the application or installation with which you need further assistance, please contact our hygrometer applications engineering staff.

Initial Inspection

Before operating a new System 2, please check for evidence of mishandling in shipment. Instruments are carefully inspected both mechanically and electrically before shipping. They should be physically free of mars or scratches upon receipt. If any evidence of damage in transit is observed, report this to the carrier and to Panametrics immediately.

Site Preparation

The drawings in this section provide clearance and other mounting dimensions you will need when preparing a site for the System 2 installation.

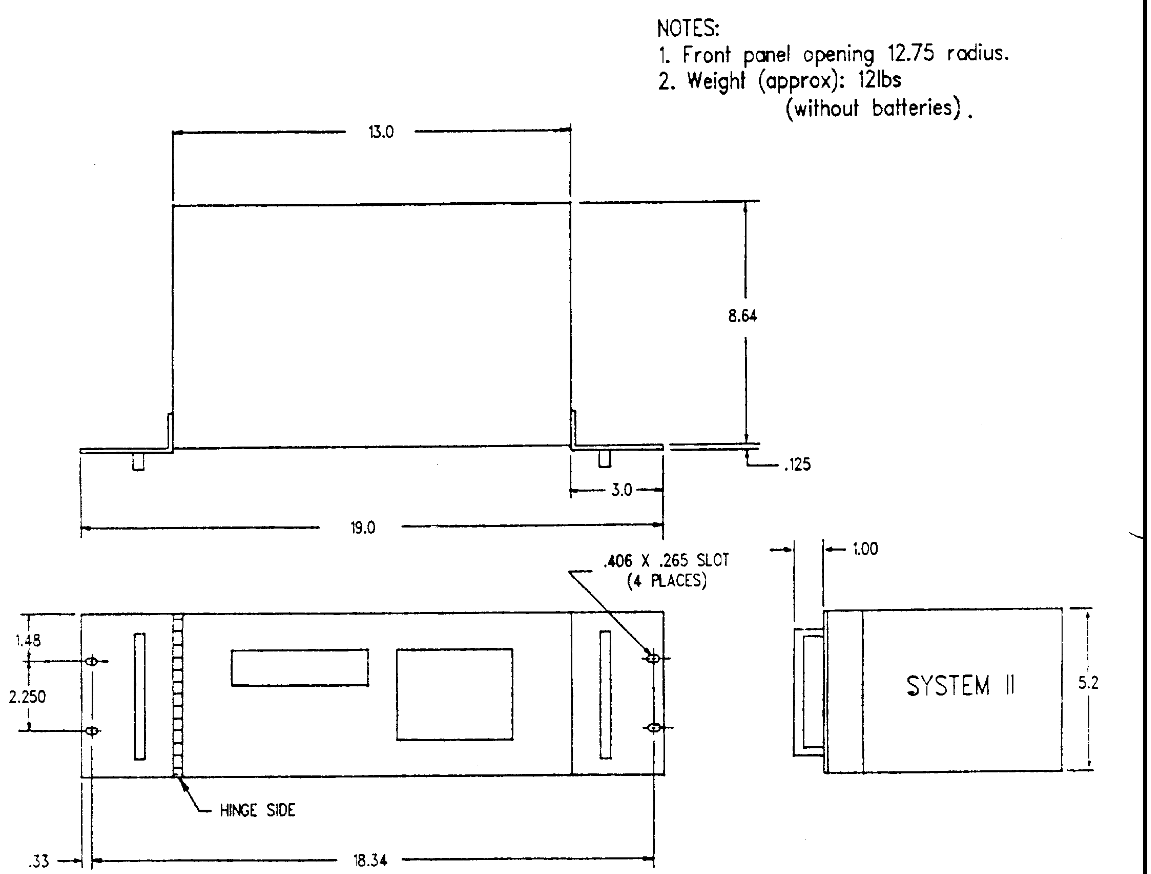


Figure 6-1: Rack Mount Installation and Outline Dimensions

Site Preparation (cont.)

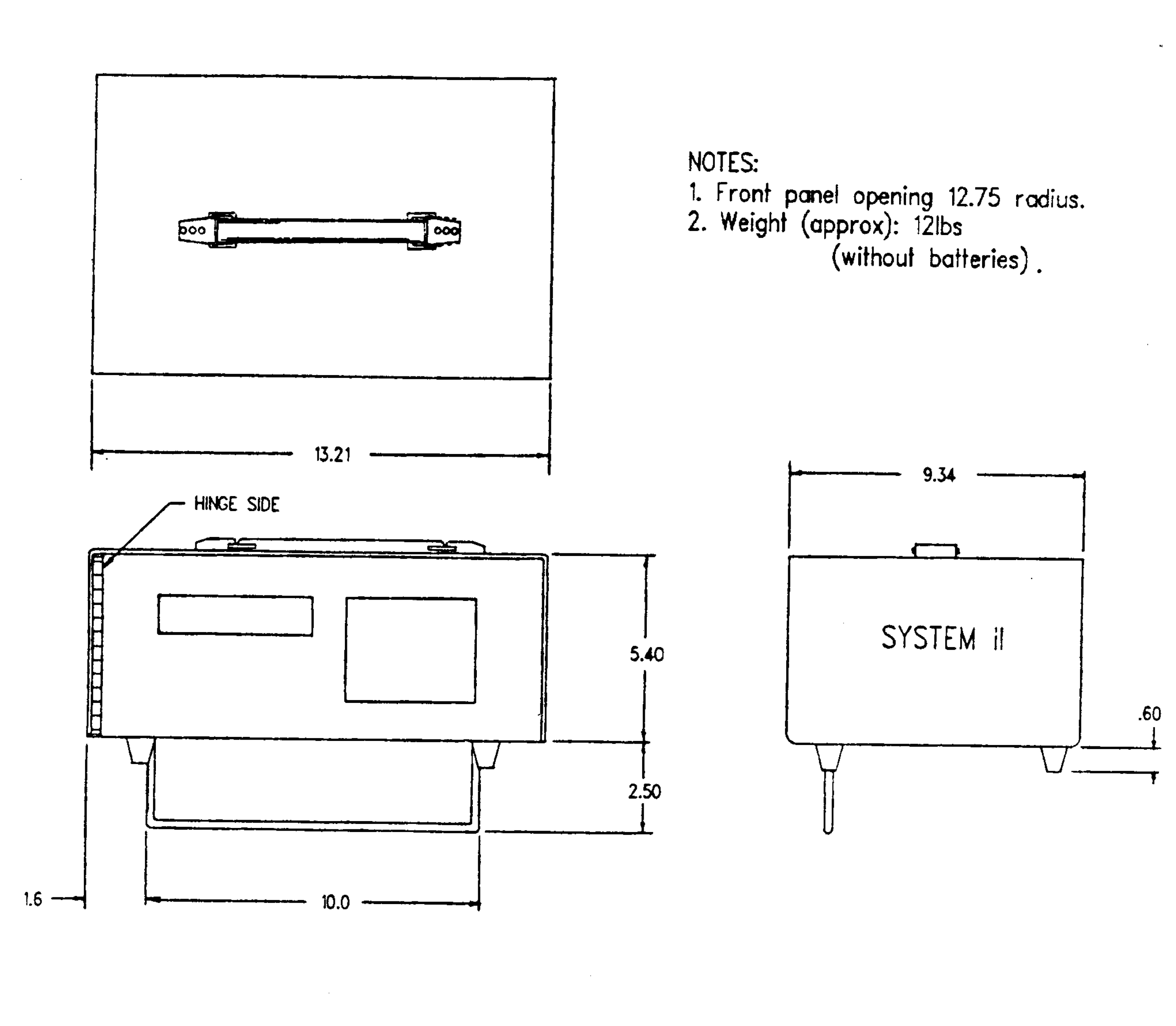


Figure 6-2: Bench Mount Installation and Outline Dimensions

Site Preparation (cont.)

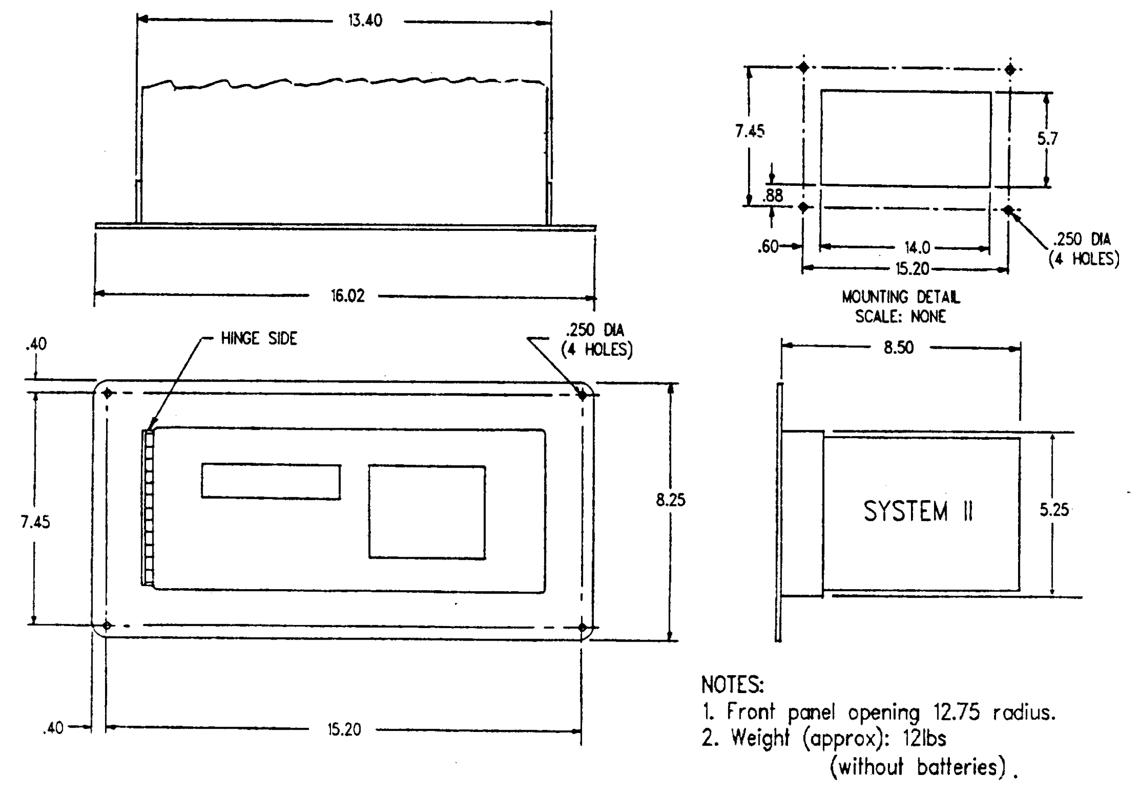


Figure 6-3: Panel Mount Installation and Outline Dimensions

AC Power and Grounding

The System 2 operates on 110/120 VAC or 220/240 VAC (factory-jumpered). In addition, the System 2 can be powered with an optional battery pack (see *Optional Battery Pack* on page 6-7). Make sure that only fuses with the required current rate of the specified type are used for replacement. If power is cycled on and off using the ON/OFF switch, allow 10 seconds between the OFF and ON operations to ensure complete reset and warm up of the system.

Instruments sold in the U.S.A. are designed for standard 120 VAC, 60 Hz outlets, and have a third wire grounding plug. Do not attempt to defeat the grounding.

Every effort is made to deliver instruments sold outside of the United States with the appropriate line-jumper configuration and AC plug. Verify this before applying power (refer to Figure 6-5 on the next page).

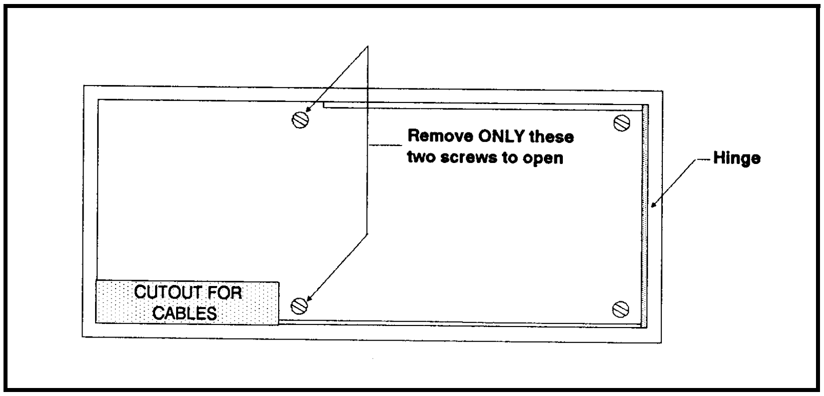
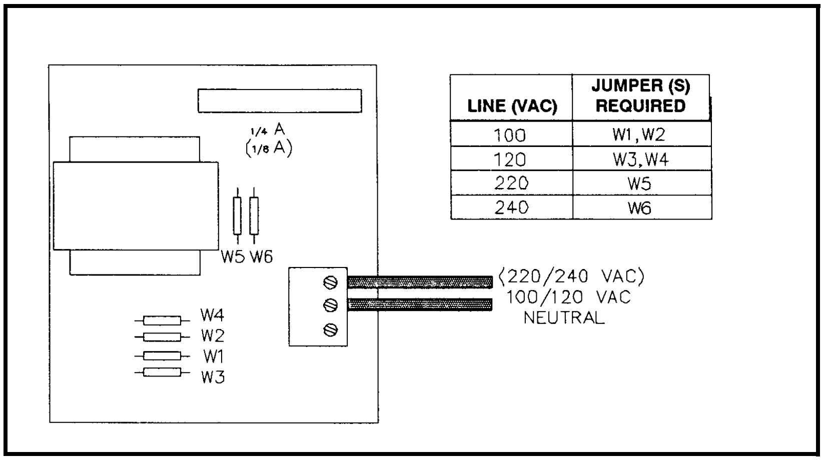


Figure 6-4: System 2 Rear Panel

To gain access to the power connections, line fuse and input/output terminations on card No. 19, the rear of System 2 must be opened. Figure 6-4 above shows a rear view of the System 2. The rear cover is hinged on the right. The open area on the left is a cutout for the input/output cables. To open the rear cover, remove the screws on the left hand side of the cover and swing the cover open.

AC Power and Grounding (cont.)



LINE (VAC)	JUMPER (S) REQUIRED
100	W1, W2
120	W3, W4
220	W5
240	W6

Figure 6-5: Power Supply Connections for 100/120/220 Volts

Figure 6-5 above illustrates the transformer board used on line (mains) powered units. Connections and jumpers are shown for various voltages. Note that the ground does not connect to the board, but directly to the chassis (marked inside rear cover).

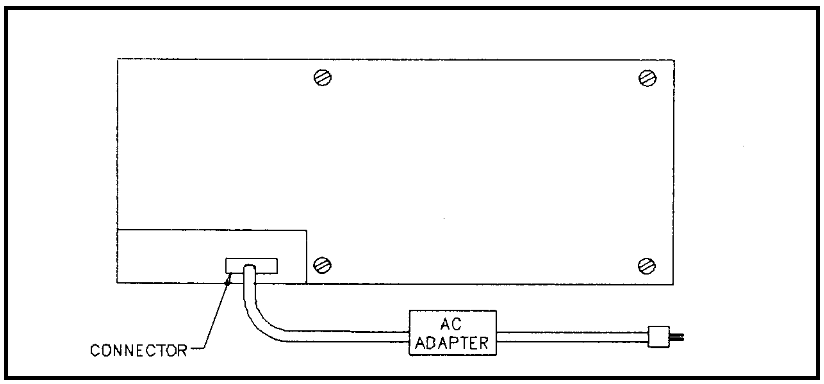


Figure 6-6: Connections for AC Adapter

The AC adapter provided with optional battery operated units is connected as shown in Figure 1-15. Adapters are available in two versions, 100/120 and 220/240 volts. Each has a switch to choose either input voltage plus an off position. Verify that the adapter is set for the appropriate line voltage before applying power (see Figure 6-6 above).

Note: *The 220/240 VAC connection is designed for European voltages only and NOT for U.S.A. voltages. The power supply is only fused on the hot wire and not on the neutral. 220/240 VAC for U.S.A. applications is derived from two wires, both of which are 120 VAC with respect to a neutral or common. For 220/240 VAC, 50-60 Hz, U.S.A., consult the factory.*

Optional Battery Pack

The System 2 can also be powered with an optional battery pack which is located inside the rear cover of the instrument (see Figure 6-7 below). When fully charged, it provides over eight hours of continous operation. Please note, alarms are not available with the battery pack option.

The System 2 batteries can be charged using either a slow charge or a fast charge. Both methods are described in the following sections.

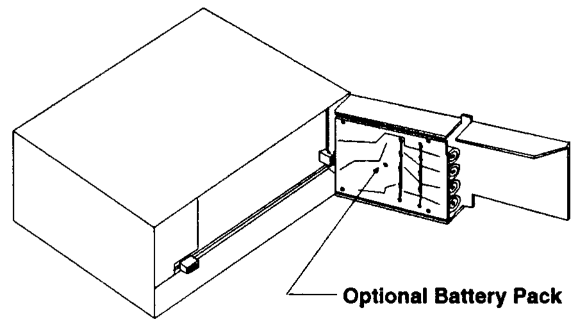


Figure 6-7: Location of Optional Battery Pack

Slow Charge

With the System 2 plugged into a power source and the appropriate setting selected on the adapter (100 VAC OR 120 VAC), a slow charge is applied to the batteries. This slow charge will serve to keep the batteries at full charge during idle periods.

Fast Charge

You can also fast charge the batteries (full charge cycle runs 8 hours). The fast charge option is set in the User Program (see Chapter 4), in the "CONT?" subroutine. With the System 2 plugged into a power source and the appropriate setting selected on the adapter (100 VAC OR 120 VAC), enter the "CONT?" subroutine and at the prompt "BATT?" press <ENT>. You will see "CHT=XXXXX HRS" on the display. For now, ignore this display and press <ENT> again. The next prompt you will see is FCH=X. A 1 entered for X starts the fast charge cycle. The cycle will run for 8 hours with the time remaining to full charge displayed after the CHT prompt.

Whenever the “BATT?” query mode is entered, the FCH-X prompt will be at zero; this does not mean that fast charging has stopped. To ascertain whether the unit is in fast charge, check the CHT=XXX prompt.

Note: *Do not habitually place the unit in fast charge mode unless you are certain the batteries are nearly depleted. Constant fast charging of Ni-Cad batteries produces an overall shortening of storage potential.*

Fuses are located on the battery card for protection of the instrument. These are 2-amp pico fuses and should only be replaced by a qualified technician, as removal of the card requires soldering.

Moisture/Temperature Probe Considerations

The probe consists of an aluminum oxide sensor mounted on the connector head and covered by a protective stainless steel casing.

The materials of construction used in the probe sensor and housing have been selected to maximize durability and to insure a minimum of water absorbing surfaces in the vicinity of the aluminum oxide surface. A 100-micron-porosity, sintered stainless steel endcap is used to protect the sensor from high flow rates and particulate matter. The endcap should not be removed except upon advice from the factory.

The sensor has been designed to withstand normal shock and vibration. Care should be exercised to insure that the active sensor surface is never touched or allowed to come into direct contact with foreign objects. Such contact may remove some of the conductive outer layer and adversely affect performance.

Observing these few simple precautions will result in a long and useful probe life. Panametrics recommends that probe calibration be checked routinely, at 6-month intervals, or as recommended by our applications engineers for your particular application.

The probe will measure the water vapor pressure in its immediate vicinity and thus the readings will be influenced by its proximity to the system walls, materials of construction, and other environmental factors. The sensor can be operated under vacuum or pressure, flowing or static conditions.

Environmental Precautions

a. Temperature Range

The standard probe is operable over a temperature range of +70°C to -110°C.

b. Moisture Condensation

Be sure the temperature is at least 10°C higher than the dew/frost point temperature. If this condition is not maintained, moisture condensation could occur on the sensor or in the sample system which will cause reading errors.

c. Static or Dynamic Use

The sensor can be employed equally well under conditions of completely still air or where considerable flow occurs. Its small size makes it ideal for measuring moisture conditions within completely sealed containers or dry boxes. It will also provide satisfactory use under gas flow conditions as high as 10,000 cm/sec. Refer to the tables for maximum flow rates in gases and liquids in Appendix A.

Environmental Precautions (cont.)

d. Pressure

Sensor output is precisely related to the water vapor pressure regardless of total ambient pressure without the need for a correction coefficient. Water vapor measurements can be made under vacuum or high pressure conditions from as little as a few microns Hg to as high as 5000 psi total pressure.

e. Long Term Storage & Operational Stability

The sensors are designed to provide long-term stability in both use and storage. Sensors continuously operated and cycled over wide humidity changes for 5,000 hours show no significant drift from original calibration values. Sensors are not affected by continuous abrupt humidity changes or damaged by exposure to saturation conditions.

f. Freedom from Interference

The sensor is completely unaffected by the presence of a wide variety of gases or organic liquids. Large concentrations of hydrocarbon gases, freons, ozone, carbon dioxide, carbon monoxide and hydrogen have no effect on sensor water vapor indications. The sensor will operate properly in either gaseous or non-conductive liquid environments.

g. Mounting

Moisture/Temperature probes are available for either an M2 (standard) mount where operating pressure is up to 5,000 psig, or an M1 (optional) mount for applications where operating pressures will not exceed 75 psig.

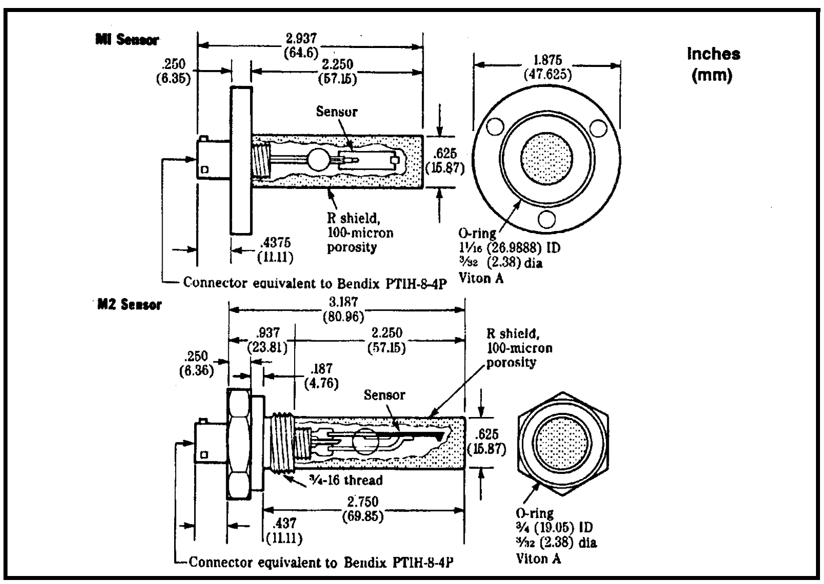


Figure 6-8: Moisture/Temperature Probe Mountings

Environmental Precautions (cont.)

With the correct cable, probes may be remotely located at distances of up to 4,000 feet. We recommend that only Panametrics moisture probe cables be used.

Caution!
Should connectors be removed from the cable, it is imperative that, when reinstalled, the original continuity of shielding be maintained. An incorrectly shielded cable will cause serious instrument errors.

Normal environmental precautions must be taken with cables to protect them from physical abuse and temperatures above 65°C or below -50°C. Standard cables, with connectors attached, may be ordered from Panametrics in any length of up to 4,000 feet.

Carefully mount type M1 (optional) probes with three bolts so that the "O" ring compresses enough to seal the joint. For M2 (standard) probes, screw the probe into the receptacle fitting until hand-tight, taking care not to cross the threads. Then, tighten it down securely with an appropriate tool with an additional 1/4 to 1/2 turn. The M2 mount uses machine threads; do not use Teflon tape on threads.

Although it may be removed for special applications, the stainless steel end cap should always be left in place for maximum protection of the aluminum oxide sensor. Note that, although you may insert the probe directly into the process system, Panametrics recommends the use of a sample system or a bypass loop.

f. Using Sample Systems

Sample systems are designed to remove all harmful components from the process stream and to ensure that the sample delivered to the sensor is representative of the actual moisture content of the overall stream.

In many process applications, you should use a sample system for the following reasons:

- so that the sensor may be easily removed from a pressurized pipeline for inspection, cleaning, or recalibration;
- so that the sensor does not become contaminated by pipe scale, carbon, salts, or other solid particles;
- so the sensor's accuracy is not affected by the presence of conductive liquid droplets of glycol or methanol (although these conductive liquids do not permanently harm the sensor and may be removed by the proper cleaning procedures described in Appendix A);
- so the sensor is not exposed to the high flow rates often directly encountered in gas pipelines.

Environmental Precautions (cont.)

The sample cell provides a convenient mounting for the moisture probe in a bypass loop, with minimal internal volume and surface area. Also, the probe can easily be removed from the sample system for inspection and cleaning.

Panametrics can supply sample systems for most applications. For more information, contact our nearest office or your Panametrics representative.

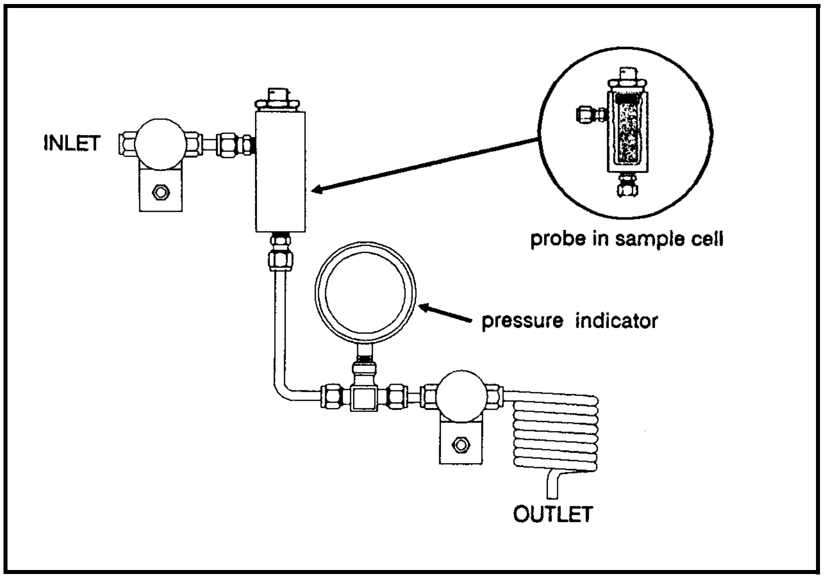


Figure 6-9: Typical Sample Cell Showing Probe Mounting

Moisture Cable Considerations

Caution!
An incorrect cable will invalidate the instrument accuracy specifications. THE IMPORTANCE OF CORRECT CABLING CANNOT BE OVEREMPHASIZED.

In Chapter 2, we noted that Panametrics cannot guarantee operation to the specified accuracy of the hygrometer unless you use Panametrics-supplied hygrometer cables.

Our experience has shown that many customers must use pre-existing cables, or in some cases modify the standard Panametrics cable to meet special needs. One common modification is to remove the connector and to splice the cable. When possible, instead of splicing, coil the excess Panametrics cable.

If you prefer to use your own cables or to modify our cables, you must observe the following precautions:

1. Use the same cable or a cable that matches the electrical characteristics of Panametrics cable (contact the factory in Waltham for specific information on cable characteristics). The cable must have individually shielded wire sets.

2. If possible, avoid all splices. Splices *will* impair performance.

3. If you must splice cables, be sure the splice introduces minimum resistive leakage or capacitive coupling between conductors.

4. Carry the shield through any splice. A common mistake is to not connect the shields over the splice. If a Panametrics cable is used by removing the connector, the shield will not be accessible without cutting back the insulation. Also, do not ground the shield at both ends. The shield should only be grounded at the hygrometer end (TB1901 pin 1). See Chapter 7 for cable connection information.

You can check the cable by measuring its MH. Check the MH of the cable by disconnecting the probe and using the System 2 MH function (see page 5-9). The MH for a cable with no probe connected should be zero, that is, MH = .0000. This is a sufficient test to be sure that your cable is not introducing errors in the dew/frost point temperature measurement.

If you do get a small error, you can determine its effect on the measurement accuracy by referring to the probe calibration sheet of <u>the probe you will be using with that cable</u> (see page 2-2). Note that the effect of this error will depend on the temperature, since a probe calibration curve is not linear.

Moisture Cable Considerations (cont.)

For example, using the sample calibration sheet in Figure 2-7 on page 2-4, we see that the calibration extends from -110°C to + 20°C (the standard probe operating range). At -110°C, the MH for this probe (MH_0) is 0.2632 (ND#0). The next calibration point shown is at -100°C, for which the MH given (MH_1) is 0.2703 (ND#1). By interpolation, we derive the local slope of the calibration curve to be:

$$\frac{TEMP_1 - TEMP_0}{MH_1 - MH_0} = \frac{(100) - (-110)}{0.2632 - 0.2703} = \frac{10}{-0.0071} = \text{-1408°C/MH unit}$$

Likewise, in the vicinity of +10°C, we have:

$$\frac{TEMP_{13} - TEMP_{12}}{MH_{13} - MH_{12}} = \frac{20 - 10}{0.9010 - 0.6559} = \frac{10}{0.2451} = \text{+41°C/MH unit}$$

If a particular cable introduced 0.0040 MH of error as indicated by the open cable test described above, then on the low end of the operating range (-110 to -100°C) the error would be:
0.004 x (-1408)=5.6°C, while on the high end of the operating range (10 to 20°C) the error would be: 0.004 x 41 = +0.160°C.

By calculations such as this, you can decide whether or not cable error is tolerable for your application.

Note: *It is possible to zero out the cable error by re-adjusting the probe calibration LOW REFERENCE on that channel. You can find more information on this topic in Appendix B.*

Intrinsic Safety

!WARNING!
FACTORY CONSULTATION IS ADVISED WHEN INTRINSIC SAFETY IS REQUIRED.

To provide intrinsic safety protection circuits for the moisture, temperature, and pressure transducers and their associated cabling, zener barriers must be used. The appropriate zener barriers are mounted in an enclosed assembly. Each wire running from the hazardous area must terminate to a zener barrier with the other side of the barrier connected to the electronic instrument. The Panametrics supplied barriers are approved by FM, CSA, PTB, BASEEFA, for intrinsic safety and can be used with all Panametrics probes. The barriers operate by limiting the energy that can pass through them to a level that is insufficient to cause combustion of a hazardous material. Figure 6-10 below shows typical zener circuit wiring for moisture and temperature transducers.

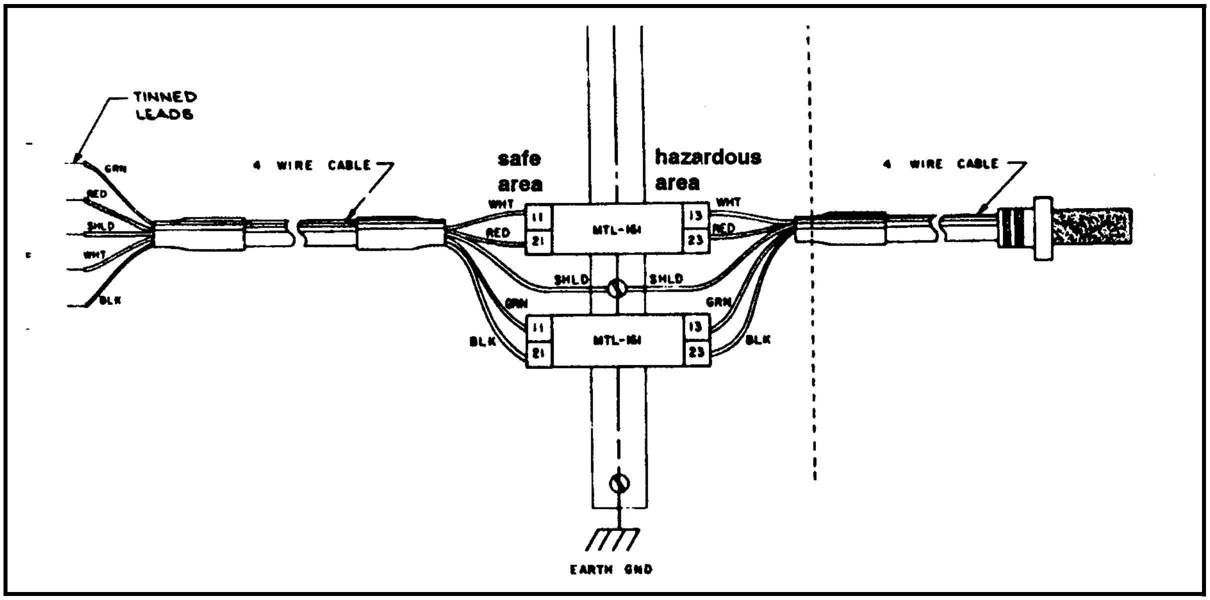


Figure 6-10: Connecting Zener Barriers

Installing a Pressure Transmitter

The pressure transmitter should be free from obvious physical damage when received. The pressure sensitive surface should be free of nicks, scars or any other marks. Care must be taken to avoid applying pressure in excess of twice the stated range of the transducer, as damage will occur. Special care should be taken on low range pressure transducers, as it is possible to exert over twice the stated pressure range simply by applying finger pressure.

For proper operation, the pressure transmitter must be installed at a point which is always at exactly the same pressure as the Moisture Sensor Probe. Installation adjacent to the location of the moisture sensor is recommended.

Using a Recorder

Most process system installations will involve the use of the analog output to feed a peripheral data device, such as a recorder or computer.

Recorder zero and span, as well as output type (voltage or current) and range, are not set at the factory unless you requested it in your order.

Zero and span are set in user programming as described and illustrated in Chapter 4, Example B. Output type (voltage or current) and range is set by switch settings on card No. 7 (see Chapter 8).

Recorder connection details can be found in Chapter 7, *Summary of Connections*. See Figure 6-11 below for a typical wiring diagram.

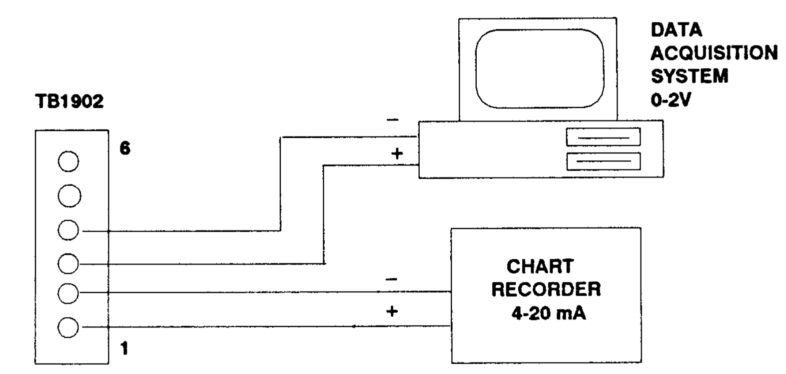


Figure 6-11: A Typical Wiring Diagram

Using Optional Alarms

You can order optional alarm relays, one high alarm and low alarm per output. The "Form C" high alarm relay contacts are shown symbolically in Figure 6-12 below.

Note: *Alarm relays are not available with battery-powered units.*

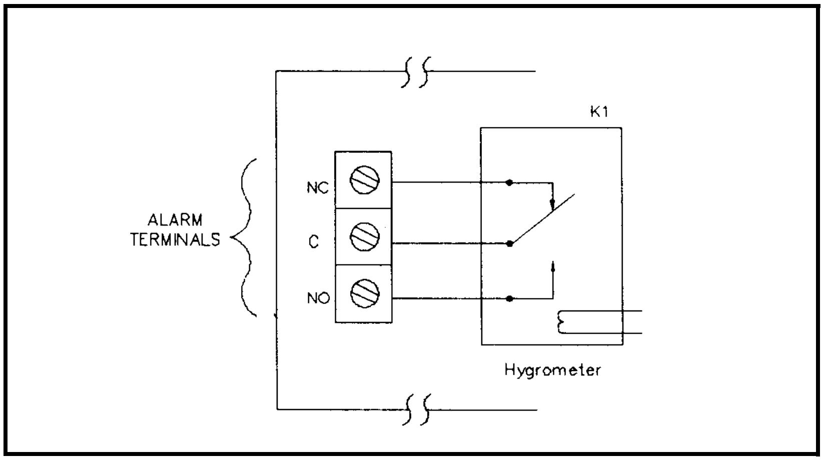


Figure 6-12: "Form C" Alarm Contact Circuit

The high alarm relay contacts (K1) will change state (alarm) when the monitored variable goes above a fixed reference. The terminals marked A (arm) and NC (normally-closed) provide a normally-closed conductive path which will open on alarm. The terminals marked "A" and "NO" (normally-open) provide a normally-open path which will close on alarm. The contacts for the Low Alarm (K2) are also shown in Figure 6-11, but the contacts will change state (alarm) when the monitored variable goes below a fixed reference.

Alarm trip points are not set at the factory unless you requested it in your order.

You may set alarm trip points in the User Program, as outlined in Chapter 4.

Alarm connection information can be found in Chapter 7, *Summary of Connections*.

Optional Digital Interface (UART)

The optional No. 5 UART card (see Figure 6-13 below) provides the System 2 with a serial interface for a printer, a terminal, or a computer. This section describes the UART option, including the following:

- Serial Interface Connections
- Baud Rate Selection
- Data Communication Equipment (DCE)/Data Transfer Equipment (DTE) Configuration
- UART Cable "D" Connector Pin Designations
- Remote Display
- Remote Control
- Serial Data Character Format

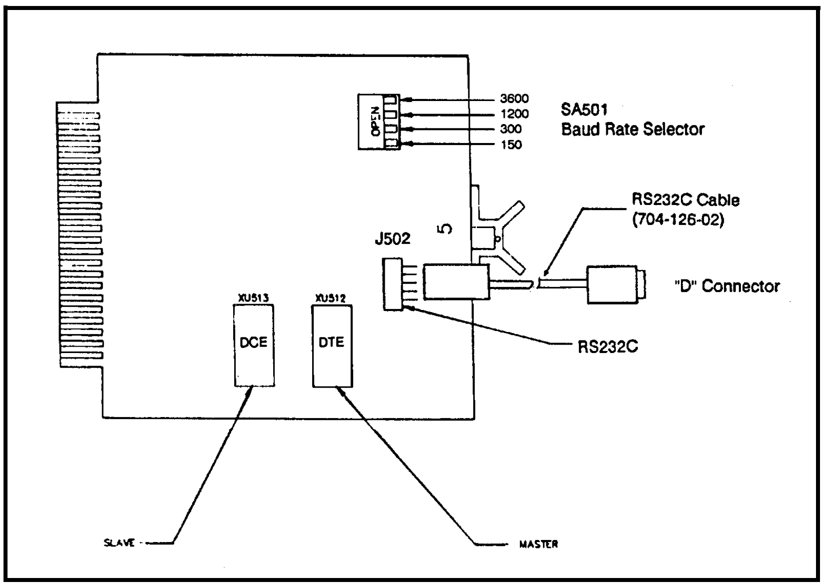


Figure 6-13: No. 5 UART Card

Serial Interface Connections

The #704-126-02 cable assembly is provided with the UART Card, enabling serial interface operation. Connect the cable assembly to J502, as shown in Figure 6-14 on the next page.

A 25-pin "D" connector is provided at the end of UART cable #704-126-02, for connection to the desired remote equipment. Table 6-1 below specifies the "D" connector pin assignment and signal description for DCE operation. Table 6-2 specifies the "D" connector pin assignment and signal description when the System 2 is configured for DTE operation.

Table 6-1: DCE/DTE Configuration (“D” Pin Number/Signal Description)

2-Transmit Data (TX) Input
3 - Receive Data (RX) Output
7 - Signal Ground (SGND) Common

Remote Display

The UART card and switch SA401 on the DVM card allow a copy of the System 2 front panel display information to be sent to a remote display device, such as a printer or display terminal. Switch SA401-1 must be activated (ON) for this function.

Baud Rate Selections

Switch SA501 is used to select the baud rate as follows (refer to Figure 7-1 on page 7-2):

SA501-1 ON = 150 BAUD
SA501-2 ON = 300 BAUD
SA501-3 ON = 1200 BAUD
SA501-4 ON = 9600 BAUD

Note: *Only one switch may be on at a time.*

DCE/DTE Configuration

A jumper plug is provided to configure the System 2 for Data Communications Equipment (DCE) or Data Terminal Equipment (DTE) for RS232C interface applications.

With the plug in the Master position (XU512), the System 2 is configured for DTE operation.

With the plug module in the Slave position (XU513), the System 2 is configured for DCE operation. The master and slave positions are shown in Figure 6-14 below.

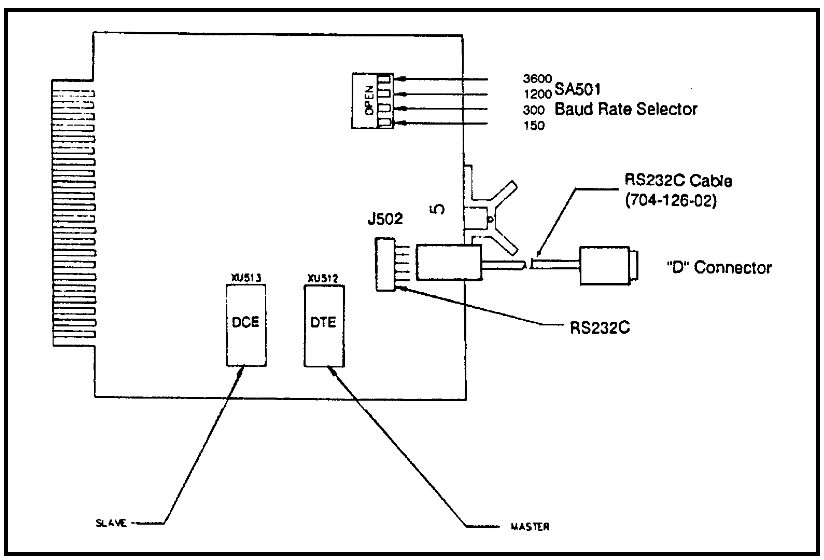


Figure 6-14: Location of Master-Slave Option Selects

Remote Control

Switch SA401 on the No. 4 DVM card also allows remote control of the System 2 via a terminal or computer equipped with the UART card option. When switches SA401-1 and SA401-2 are activated (ON), the System 2 front panel keyboard is disabled and all System 2 front panel keyboard functions must be sent via a terminal or computer. The System 2 front panel and remote displays are simultaneously updated. Table 6-2 below shows the correspondence between a remote keyboard and the System 2 front panel keyboard functions.

Table 6-2: Remote Terminal Keys

Corresponding Remote Terminal Keys	System 1/O2
O	OPER
C	CHAN
M	MODE
P	PROG
.	.
-	-
E	ENT
R	RUB
A	A (not used)
B	B (not used)

* Numeric keys remain the same.

Serial Data Character Format

The serial data character is composed of the following:

1 start bit
8 data bits (ASCII character)
1 stop bit
no parity

The Instrument Program

The instrument program is the System 2 operating system and consists of a set of EPROM program modules. Since these hardware devices contain the basic system operating software, they are occasionally updated to incorporate improvements and changes consistent with our product development program.

It is sometimes necessary to know which version of the instrument program you have in your hygrometer. You can find this out by reading the instrument program number. This number is found on the EPROM labels (see Figure 3-3), and is also displayed:

- when you turn on a System 2
- when you exit the the program mode (see Chapter 4)
- any time you activate the reset switch (see Chapter 7)

The instrument program number is of the form:

"RBP.NNN.L"

where:

RBP = Rack-Bench-Panel (model type)

NNN = the program number (signifying major updates),

L = the revision letter (signifying minor updates).

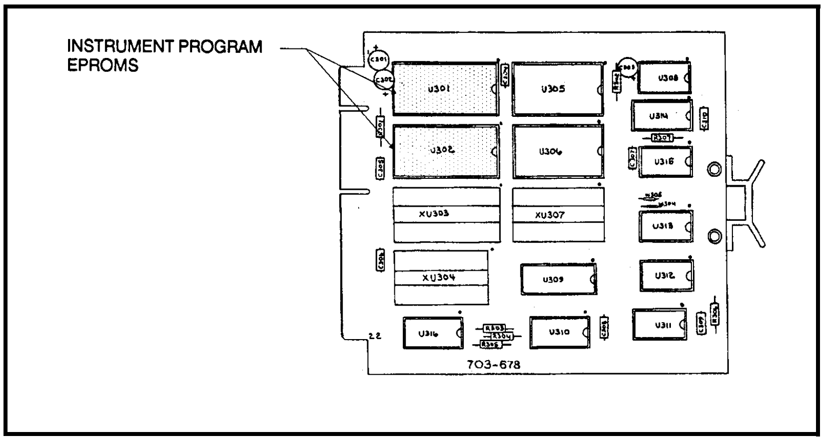


Figure 6-15: Memory Card No. 24 Showing Location of EPROMs

Recommended Spare Parts

Note: *The following parts listed are for all available standard options. When ordering spares, select parts consistent with the options in your hygrometer.*

Power Supply Group

Part Number	
703-685	Transformer Board
A193-025	Fuse (1/4 A for 100-120V)
A193-018	Fuse (1/8 A for 220-240V)
703-628	#10 Power Supply (Power Pak 3)
703-628-01	AC Operation Only
703-628-02	AC and Battery Option
705-652	Battery Pak 2
703-161	AC Adapter For Battery Powered Units
03-161-01	100/120 Volt Operation
703-161-02	220/240 Volt Operation

Plug -in Cards

703-619	#1 Processor Card
703-622	#4 Voltmeter Card
703-623	#5 UART Card
704-126	Connector Cables for use with the #5 UART Card
704-126-01	Current Loop
704-126-02	EIA
703-624	#6 Interface Card
703-625	#7 Hygrometer Card
703-625-01	Recorder A Only
703-625-02	Recorder A and Recorder B
703-765	#8A RC Cal Card
703-644	#14 Regulator Card
703-678	#24 Memory Card

Miscellaneous

703-668	Front Panel Keyboard
703-653	#19 Output Board
703-653-01	No Alarms
703-653-02	With Alarms

Chapter 7

Summary of Connections

Introduction

This section contains comprehensive connection information for the System 2 hygrometer. With the exception of power, connections are made via terminal blocks on the No. 19 I/O board in the rear of the hygrometer (see Figure 7-1). Provision is made to connect:

- one type M moisture or MT moisture/temperature probe
- one 20 mA loop type pressure transmitter
- one or (optionally) two analog output devices
- one or (optionally) two sets of alarms

The interconnection information in the remainder of this section is tabulated in three ways:

1. by illustration;

2. by terminal block;

3. by function.

Note: *Connections for the digital communications option are made on the optional UART card No. 5 (see Chapter 6).*

Number 19 I/O Board Connection Illustration

Figure 7-1 shows connections made on the No. 19 input/output board.

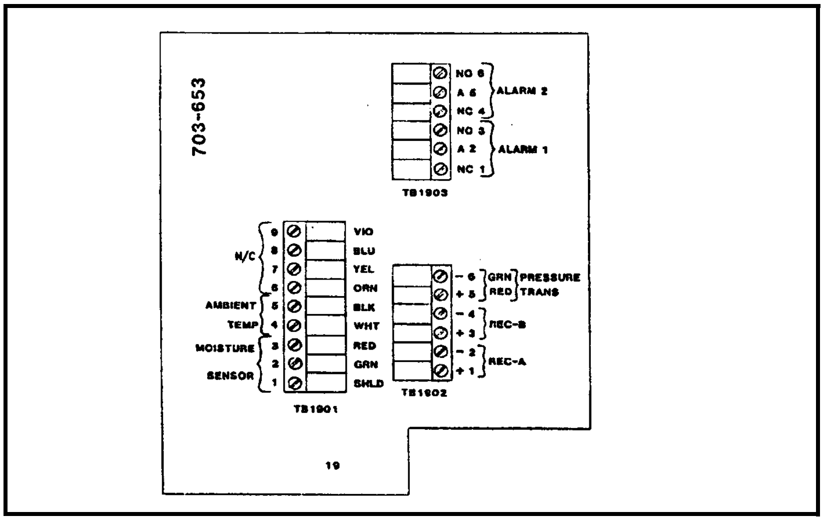


Figure 7-1: Connections to the No. 19 I/O Board

Summary by Terminal Block

TB1901	1	-	GROUND	-Shield
	2	-	MOISTURE	-Green
	3	-	MOISTURE	-Red
	4	-	TEMPERATURE	-White
	5	-	TEMPERATURE	-Black
	6	-	Not Used	
	7	-	Not Used	
	8	-	Not Used	
	9	-	Not Used	
TB1902	1	-	ANALOG OUTPUT A (REC A)	+
	2	-	ANALOG OUTPUT A (REC A)	-
	3	-	ANALOG OUTPUT B (REC B)	+
	4	-	ANALOG OUTPUT B (REC B)	-
	5	-	PRESSURE (20 mA loop) Current in	(<—-)
	6	-	PRESSURE (20 mA loop) Current out	(—->)
TB1903	1	-	NC	
	2	-	ARM “HIGH ALARM”	
	3	-	NO (Alarm 1)	
	4	-	NC	
	5	-	ARM “LOW ALARM”	
	6	-	NO (Alarm 2)	

Summary by Function

Inputs

MOISTURE PROBE

TB1901	1	-	Shield	(Colors refer to standard Probe
	2	-	Green	Cable, Panametrics part #A5N4)
	3	-	Red	

Note: *The probe is a standard Panametrics type M1 or M2 with a 4-pin, locking bayonet-type connector. Use with standard Panametrics Moisture Probe Cable # A5N4.*

TEMPERATURE SENSOR
(OPTIONAL- part of moisture probe)

TB1901	4	-	-White	(Colors refer to standard Probe
	5	-	-Black	Cable, Panametrics part #A5N4)

The optional temperature sensor is part of the moisture probe. Moisture probes with temperature measurement capability are the M1T and M2T, and are the same as the M1 and M2, respectively, except for the additional temperature sensor. Use with standard Panametrics Moisture Probe Cable #A5N4.

PRESSURE SENSOR (OPTIONAL)

TB1902	5	-	Current in (<—-)
	6	-	Current out (—->)

Use any standard 2-wire, pressure transmitter (20 mA current loop). Twisted pair wiring is satisfactory for runs of up to several thousand feet, depending on noise conditions and type of wire.

Outputs

ANALOG (RECORDER)

TB1902	1	-	(+)	"REC A"
	2	-	(-)	
	3	-	(+)	"REC B" (Optional)
	4	-	(-)	

One standard analog (recorder) output (REC A) is shipped with the System 2. A second analog recorder (REC B) is optional.

OPTIONAL ALARMS

TB1903	1	-	NC	
	2	-	ARM	"HIGH ALARM"
	3	-	NO	(Alarm 1)
	4	-	NC	
	5	-	ARM	"LOW ALARM"
	6	-	NO	(Alarm 2)

One or two optional alarm relays may be ordered for each channel. Alarm 1, the "LOW ALARM," will activate when the channel variable it is set to monitor goes below a programmed value. Alarm 2, the "HIGH ALARM RELAY," will activate when the channel variable it is set to monitor goes above a programmed value. Normally closed (NC) and normally open (NO) contacts are provided with both relays.

Chapter 8

Reconfiguring the System 2 Hygrometer

Introduction

Many of the System 2 operating characteristics can be configured by the user or operator. Some of these operating characteristics are set in software while some are set in hardware.

Chapter 4 covers programming operations that control many System 2 operating characteristics. User programmed operating characteristics are maintained even when power is disconnected and are therefore one aspect of instrument configuration.

Instrument operating characteristics that you can set in the User Program are:

- Major Mode
- Parameter(s) for Analog Output(s)
- Alarm Trip Points
- Saturation Constant for PPM_w
- $KPPM_v$ constant
- Probes Configuration
- Auto-Ranging

Other characteristics can be set with switches inside the System 2. These are:

- Analog (Recorder) Output, Current or Voltage
- Analog Output Range
- Measurement Units (English or Metric)
- Digital Interface Options

This section covers System 2 switch-selectable configuration options.

Switch-Selectable Options

Option switches are located inside the System 2 on the No. 7 Hygrometer card and the No. 4 DVM card. To reach these switches, open the front panel by unlocking the keylock (see Chapter 2) and swinging the panel open. (The panel is hinged on the left and swings out from the right. Refer to Figure 2-2 on page 2-2.)

With the front panel open, you will see the card cage, as shown in Figure 8-1 below.

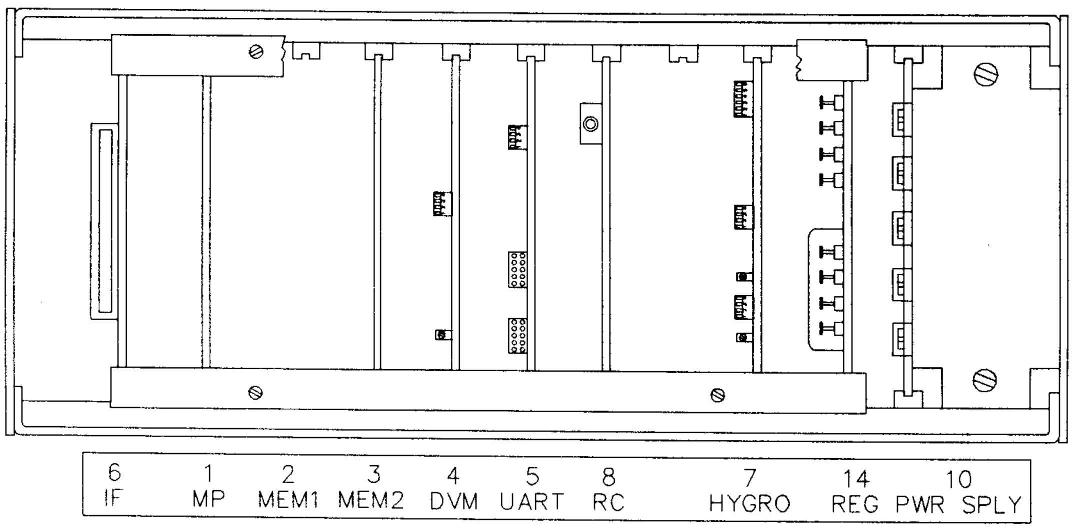


Figure 8-1: View of System 2 Card Cage with Front Door Open

All configuration switches are edge-mounted on the front of the cards so you can reach them without removing the card.

Analog Recorder Output Type and Range

Both analog outputs (REC-A and optional output REC-B) can be set for:

a. 0 - 100 mV

b. 0 - 2 V

c. 0 - 20 mA

Analog Recorder Output Type and Range (cont.)

You can also further adjust the System 2 current output range by offsetting the zero point (in programming - see Chapter 4) to obtain a full scale output range of:

d. 4 - 20 mA(standard current loop - USA)

Output type (REC -A) and range are controlled by switch array SA702 (and by switch array SA703 for the optional output REC-B) on card No. 7, as shown in Figure 8-2 below.

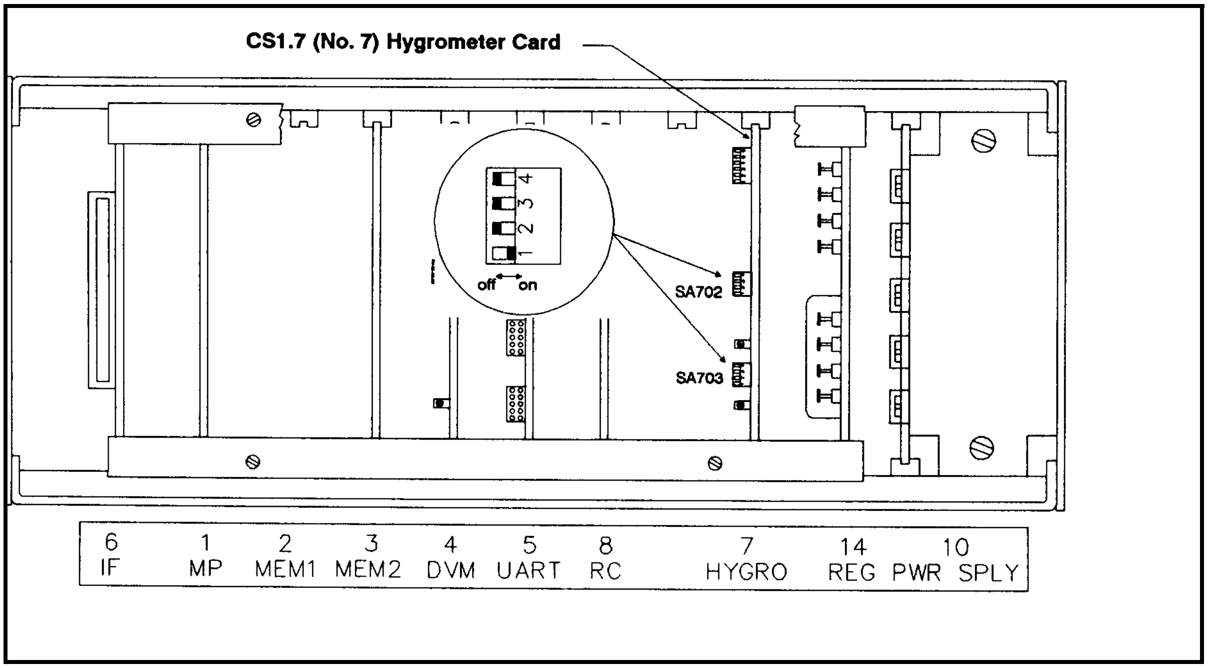


Figure 8-2: Location of Analog Output Range Switches

Table 8-1: Recorder Output Range Switch Settings

REC A SA 702		REC B SA 703	
Turn On	**For**	**Turn On**	**For**
1	0-2 Volts	1	0-2 Volts
2	0-100 mV	2	0-100 mV
3	0-20 mA	3	0-20 mA
4		4	

Measurement Units

You may select measurement units for temperature and pressure. (Note that the display will indicate the units selected, as described in Chapter 3, *Display Format*.)

Choices for temperature are °C and °F. Choices for pressure are PSIG and BARS. Selections are controlled by switch array SA401, switches 3 and 4, on the No. 4 card (see Figure 8-3 below).

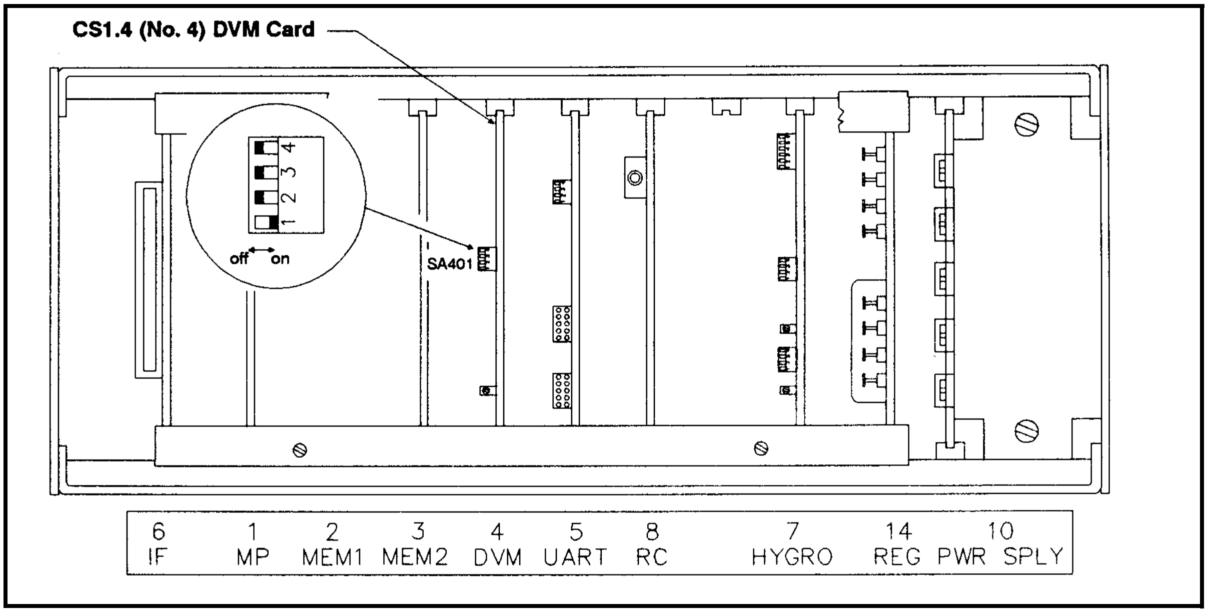


Figure 8-3: Location of Measurement Unit Switches

Set the switches as shown in Table 8-2 below.

Table 8-2: Measurement Unit Switch Settings

Switch SA401		
Set	**OFF *for***	**ON *for***
3	°C	°F
4	PSIG	BARS

Digital Interface Option

With an optional UART card (card No. 5) installed, the System 2 hygrometer can communicate with remote digital devices such as terminals, computers and data loggers (digital printers). You may use the digital option in two ways:

- REMOTE PRINTING - A digital printer can log measurements. (Front keypad control and display options are unchanged.)
- REMOTE CONTROL - A stand alone digital terminal takes over the function of the System 2 keypad and display.

UART installation connection and operation are covered in Chapter 6.

Selections are controlled by switch array SA401, switches 1 and 2 on the No. 4 card, as shown in Figure 8-4 below. To select these options, set switches as shown in Table 8-3 below.

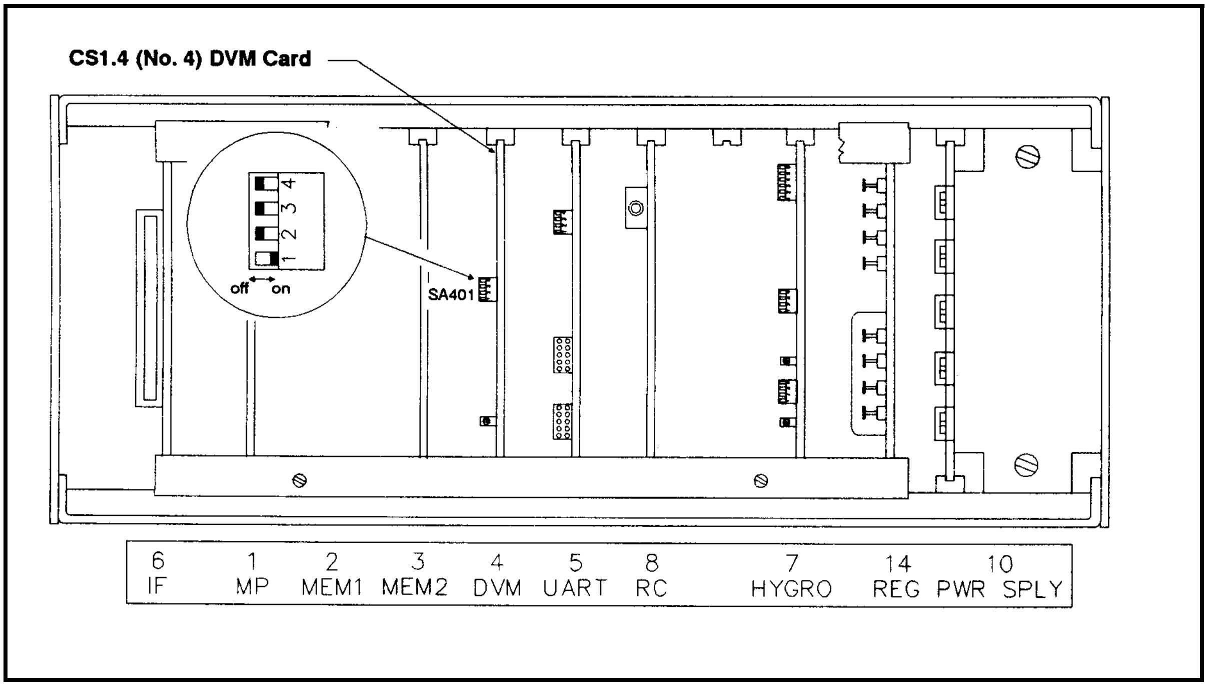


Figure 8-4: Location of Digital Interface Option Switches

Table 8-3: Measurement Unit Switch Settings

Switch SA401		
1	**2**	***For***
OFF	OFF	No Remote
ON	OFF	Remote Printing
ON	ON	Remote Control

Baud Rate Selection

The CS1.5 UART Module is an optional board to provide the System 2 with a serial interface for operation with a printer, terminal, or computer. Switch SA501 is used to select the baud rate as follows:

SA501-1 ON = 150 BAUD
SA501-2 ON = 300 BAUD
SA501-3 ON = 1200 BAUD
SA501-4 ON = 9600 BAUD

Note: *Only one switch must be on at a time.*

Hygrometer Card Channel Switch

Switch array SA701 on the No. 7 hygrometer card allows this card to be used in the multi-channel System I hygrometer, as well as in the single-channel System 2.

For the System 2, this switch array must always be set for channel 1.

As shown in Figure 8-5 below, the card is set for channel 1 by setting S1 on.

Note: *SA701 switches 2 through 6* ***must be OFF****.*

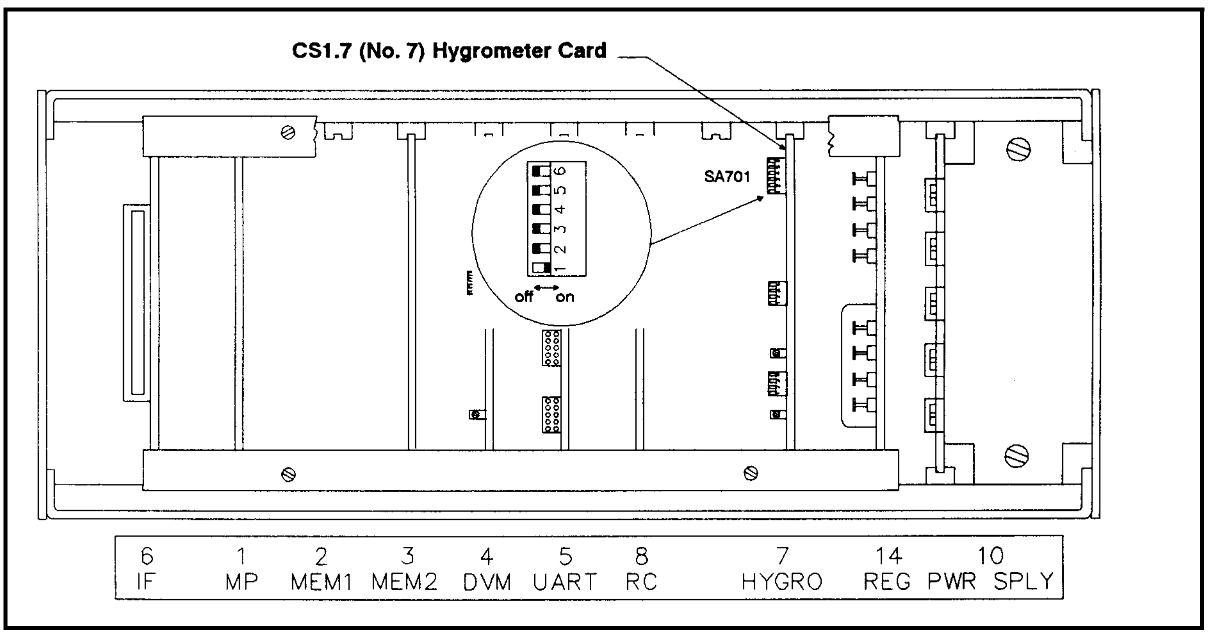


Figure 8-5: Location of Channel Set Switch Showing Channel 1 Selected

Power Supply Switch

Switch S701 on the No. 7 hygrometer card allows this card to be used with different power supplies.

For all System 2 applications, this switch must be in the position shown in Figure 8-6.

Note that you cannot reach this switch without removing the No. 7 PC card from the card cage.

If you have reason to remove the No. 7 hygrometer card, proceed as follows:

a. **With the System 2 unplugged (and disconnected from its battery pack if you have a battery-operated unit),** open the front panel as described in Figure 2-2 on page 2-2.

b. Locate the No. 7 hygrometer card (see Figure 8-1). Grasp the handle on the card, as shown in Figure 8-6 below, and pull the card straight out. (NOTE: Card handles are not shown in other illustrations.) When you have confirmed that S701 is in the correct position, replace the card by sliding it carefully back into the No. 7 slot, and seating it firmly in its socket. The card is correctly positioned when its edge lines up exactly with the card guide.

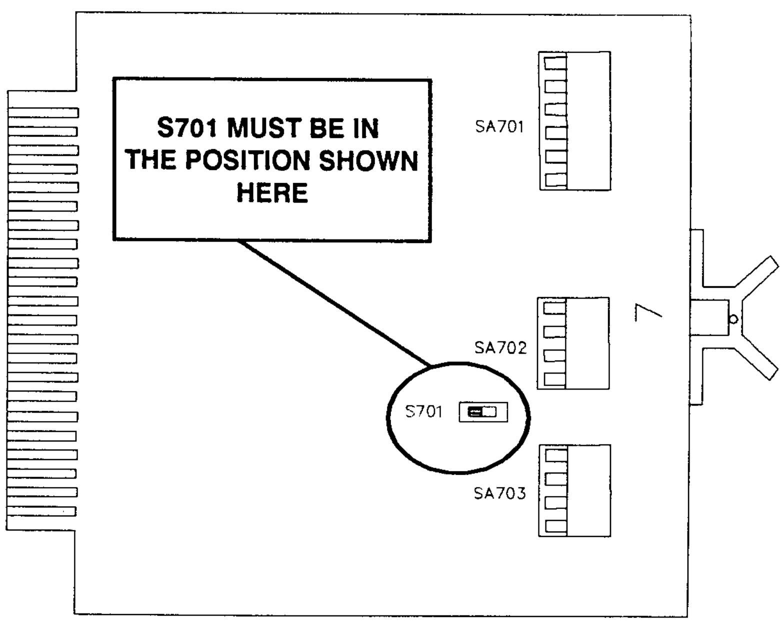


Figure 8-6: Locating and Verifying Proper Setting of Power Supply Switch S701

System Reset Switch

A momentary action system reset switch can be found on the No. 8 card, as shown in Figure 8-7 below.

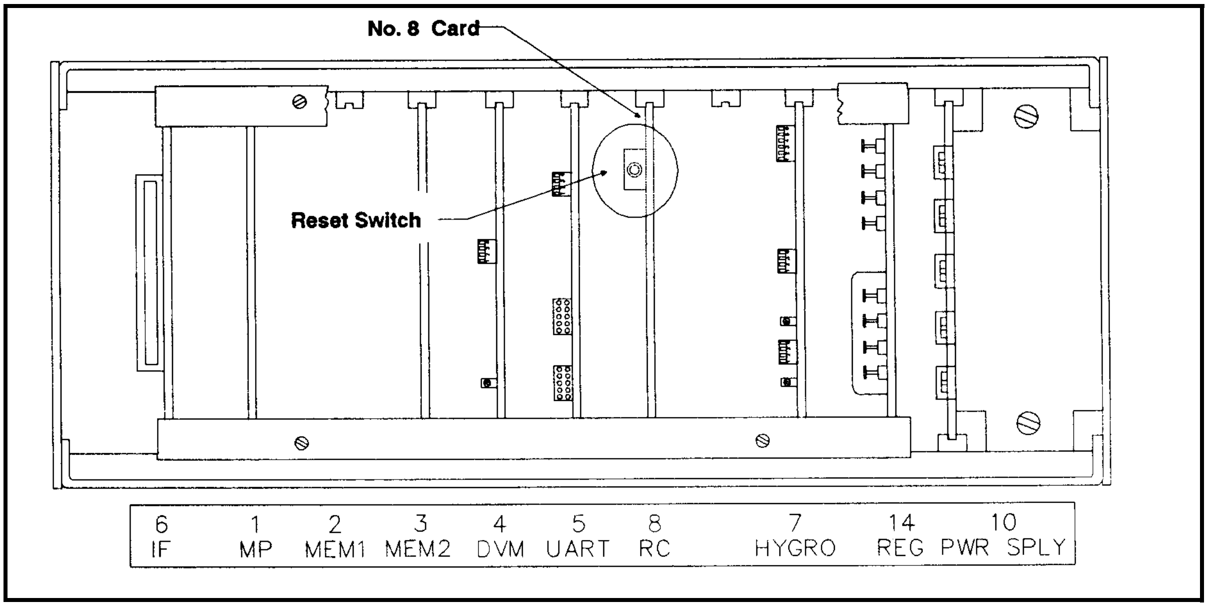


Figure 8-7: Locating the System Reset Switch Door Open

Use the reset switch any time you wish to re-initialize the System 2.

Note: *When you activate this switch, the System 2 will re-initialize and begin operation exactly as it would if power had just been turned on.*

Chapter 9

Specifications

Overall Specifications

General	Microprocessor-based, single-channel, aluminum oxide, absolute humidity hygrometer system; capable of storing up to six sets of moisture probe calibration data
Power	100/120/220/240 VAC, 50/60 Hz power, 10 Watts; Rechargeable 8-hour battery pack (optional)
Accuracy	±0.2% (electronics only)
Warm-up Time	Meets specified accuracy within 5 minutes of turn-on
Configuration	Bench-mount, with carrying handle (standard); rack-mount or panel-mount (optional)
Parameters	Each of up to six channels may be programmed to measure any of the following parameters with appropriate probes: dew point, temperature, pressure, PPM_v, PPM_w, and RH. Note that data is for overall system using standard probes. (See separate electronic and probe specifications for additional details.)

Dew/Frost Point Temperature Measurement

Ranges:	-110°C to +20°C (standard). -110°C to +60°C (optional).
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° from -110°C to -66°C.

Note: *All outputs are available in °C or °F.*

Pressure Measurement

Standard Transmitter

Range: 0 to 3000 psig in four subranges

Accuracy: ±0.20% of Span

Explosion-Proof Transmitter

Range: 0 to 3000 psig in four subranges

Accuracy: ±0.5% of Span

Temperature Measurement

Range: -30°C to +70°C

Accuracy: ±0.5°C

Note: *All outputs available in °C or °F.*

Other Moisture Parameters

Calculated using moisture and temperature or pressure inputs)
Parts Per Million by Volume (PPM_v)
Parts Per Million by Weight (PPM_w)
Relative Humidity (RH)

Two Optional "Special" Modes

Non-standard measurements, such as Pounds of Water per Million Cubic Feet (#MMSCF). Contact Panametrics for availability of other special measuring modes.

Calibration

Auto-calibration occurs at power-up. System 2 can be set to auto-calibrate periodically without user intervention.

Display

12-digit, green florescent, alphanumeric display. The display can show any one measurement parameter on any channel, or can cycle to show different parameters.
Display information includes parameter mode, channel number, parameter value and units. The display is also used interactively together with the keypad to program the System 2.

Inputs

Capability

Up to three inputs, one each, moisture, temperature and pressure

A/D Resolution

11 bits (0.05%)

Moisture Sensor Probe

Panametrics types M2L, M2LT Thin Film Aluminum Oxide

Temperature Sensor Probe

Thermistor (optionally supplied as part of the moisture probe assembly)

Pressure Sensor Transmitter

Panametrics P40, P40X, or equivalent 4-20 mA, current-transmitting, pressure transducer; scale factors are entered as part of the user program sequence.

Cable Length

Using Panametrics cables, all probes can generally be located a maximum of 1200 meters (4000 feet) away from the hygrometer under normal circumstances. Longer distances and special circumstances can be accommodated. (Consult Panametrics for special distance considerations).

Outputs

Analog

One standard, one optional; each output can correspond to any one parameter on that channel.

Zero and Span are user-programmable within the range of the instrument and the corresponding sensor.

The standard, switch-selectable outputs are:
(1) 0 to 100 mV, 10K ohm minimum load resistance
(2) 0 to 2 V, 10K ohm minimum load resistance
(3) 0 to 20 mA, 500-ohm maximum series resistance
(4) 4 to 20 mA, 500-ohm maximum series resistance

Resolution: ±0.5%

Digital

RS-232 interface or 20 mA current loop. Information is transmitted as ASCII characters at 150, 300, 1200, or 9600 Baud.The transmitted format is application dependent. (Consult Panametrics.)

Alarm Relays

Individual, alarm relay contacts (SPDT) are optionally available for high and low limits on each channel. The relay contacts can be set to trip at any numerical level within the range of the instrument. Contact ratings are 2 Amps at 28 VDC or 28 VAC.

Output Updating

The microprocessor samples, processes data, and calculates values for each channel sequentially. Update time is from 1 to 14 seconds per channel, depending on configuration and mode.

Miscellaneous

Operating Temperature	0°C to +60°C
Storage Temperature	- 30°C to +70°C
Memory Retention (for User Program Data):	Back-up battery retains program calibration data for approximately one year (depends on memory configuration). It is independent of AC power.
Applications in Flammable Atmospheres	Probe and cable assemblies are certified to meet BASEEFA standards for electrical equipment in flammable atmospheres *when used with external zener barriers* (consult Panametrics).

Dimensions and Weights

Rack Mounting	19"W X 5" X 9"D, approximately 14 lbs.
Bench Mounting	13"W X 5"H X 9"D, approximately 12 lbs.
Panel Mounting	16"W X 8"H X 8"D, approximately 13 lbs.

Probe Specifications

Moisture Probe

Type	M Series Thin Film Aluminum Oxide Moisture Sensor Probe (Patented)
Impedance Range	2 M ohm to 50 Kohm @ 77 Hz (depending on vapor pressure of water)
Calibration	Each sensor is individually computer-calibrated against known moisture concentrations. Calibrations are traceable to the National Bureau of Standards.

Dew/Frost Point

Temperature:	Standard Calibrated Range: - 110°C to +20°C Overall Capability: -110°C to +60°C (available on request)
Accuracy:	±2°C in range of -65°C to +60°C ±3°C in range of -110°C to -66°C
Operating Temperature:	-110°C to +70°C
Storage Temperature:	Maximum of +70°C
Operating Pressure:	Depends on mount: **M1:** 5 microns Hg to 75 psig **M2:** 5 microns Hg to 5000 psig
Flow Range:	Gases: From static to 10,000 cm/sec linear velocity @ 1 atm Liquids: From static to 50 cm/sec linear velocity @ density of 1 gm/cc.
Response Time:	Less than 5 seconds for 63% of a step change in moisture content in either wet up or dry down cycle.

Temperature Sensor(Optional)	**Type:**	Non-linear thermistor
	Range:	-30°C to +70°C
	Accuracy:	±0.5°C overall
	Maximum Operating Temperature:	70°C
	Time Constant:	Maximum one second in well stirred oil, 10 seconds in still air for a 63% step change in increasing or decreasing temperature
Pressure Transmitter (Optional)	**P40:**	General purpose
	P40X:	For Class I, Group D, Division 1 locations
	Transducer:	**P40 -** solid state piezoresistive silicon sensor in stainless steel housing; on-board zero and span trim **P40X -** capacitive sensor in explosion-proof housing; on-board zero and span trim
	Range:	Choice of: (A) 0 - 100 psig (B) 0 - 300 psig (C) 0 - 1000 psig (D) 0 - 3000 psig
	Accuracy:	**P40** ±0.20% of span **P40X** ±0.50% of span
	Operating Temperature:	**P40** -40°C to +121°C **P40X** - 20°C to +200°C
	Pressure Connection:	**P40** 1/4-18 NPT Male **P40X** 1/2-NPT on flange
	Overpressure Limits:	**P40** 200% of maximum span **P40X** 150% of maximum span
	Dimensions:	**P40** 4 1/10" L x 2 1/4" diameter **P40X** 4 1/2" W x 7" H x 4 1/2" diameter

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 ambient air at 1 atm of pressure, 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

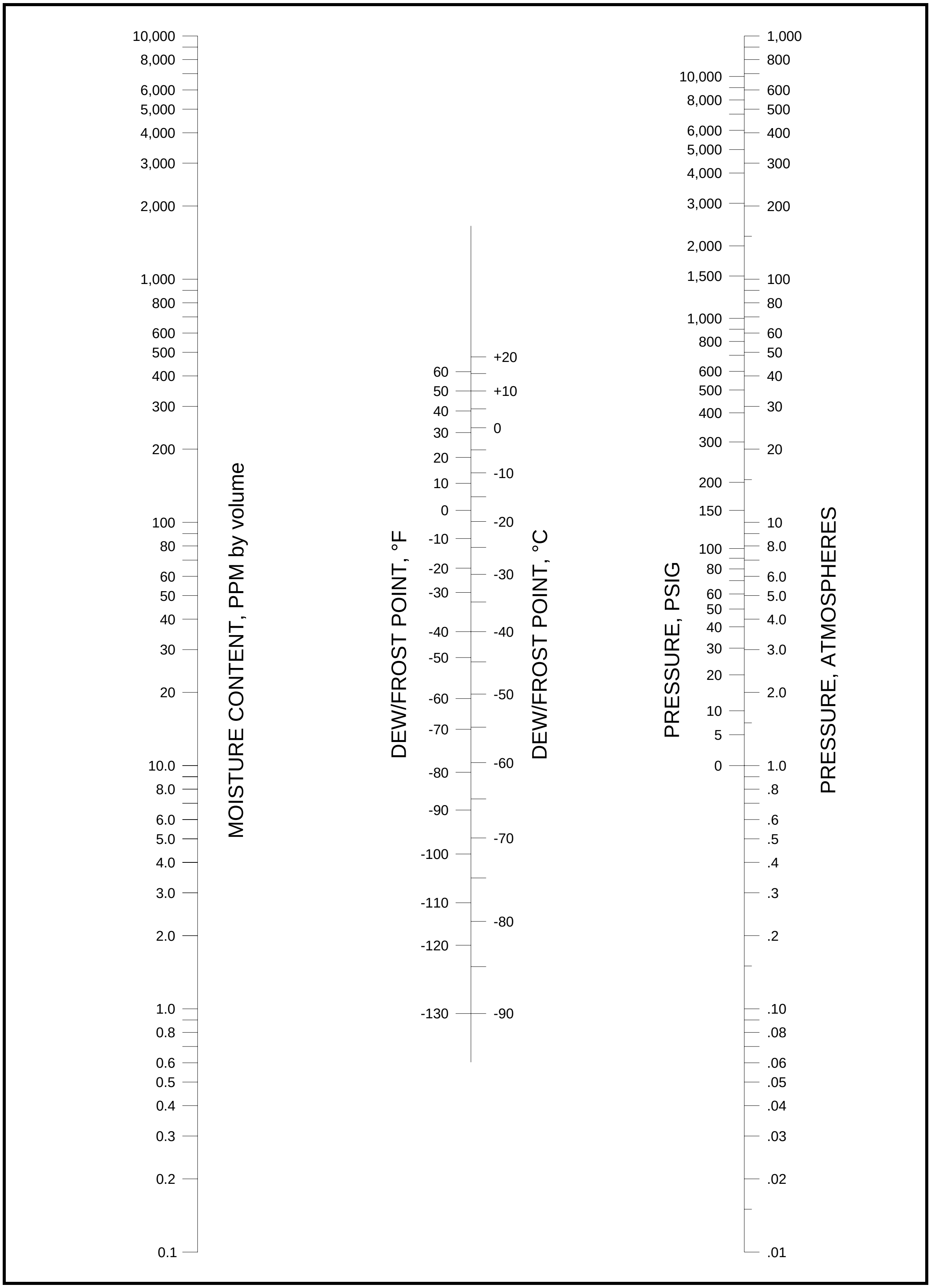


Figure A-1: Moisture Content Nomograph for Gases

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:

$$K = \frac{\text{Saturation PPM}_W}{P_S} \tag{b}$$

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:

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

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.

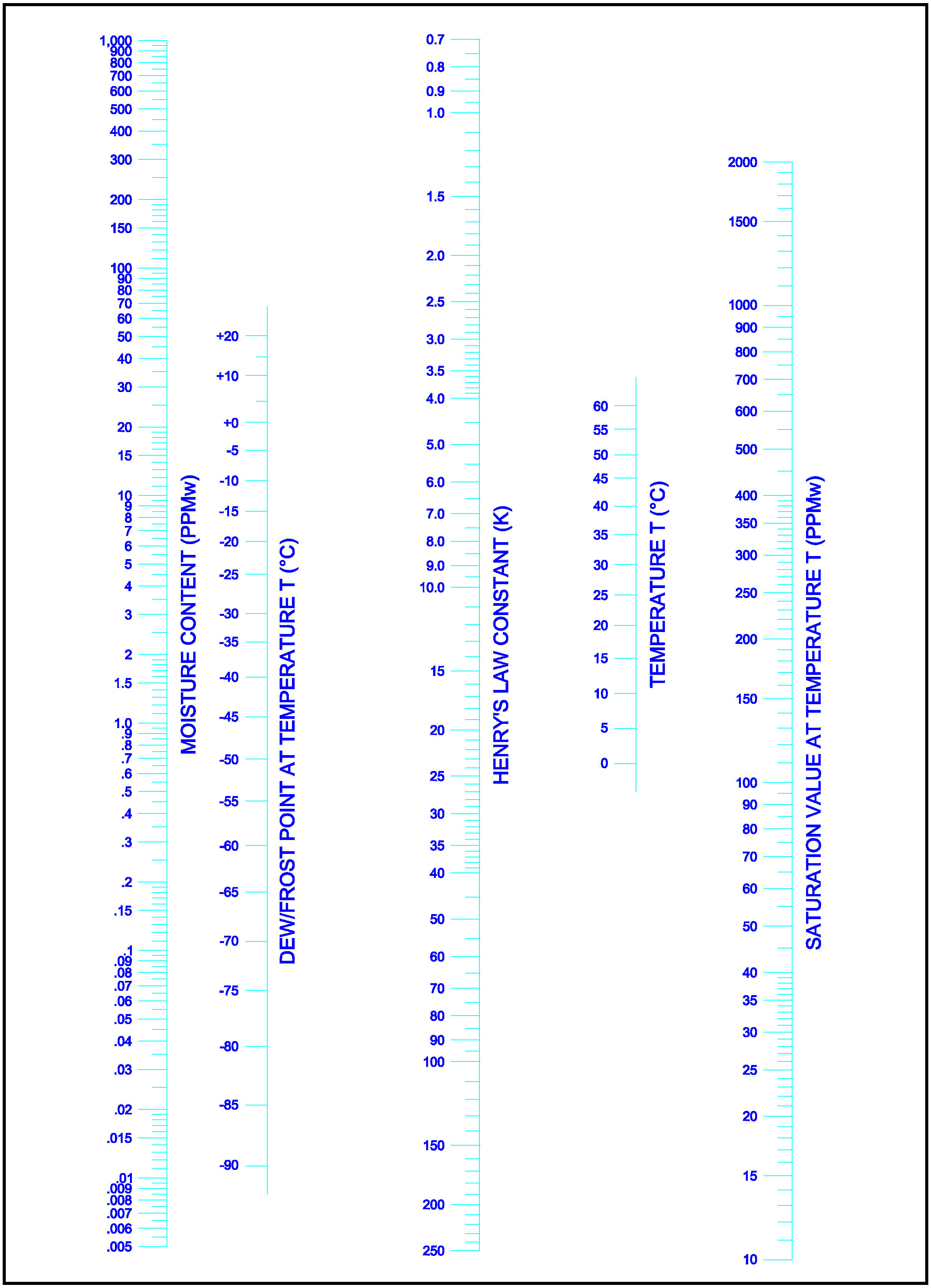


Figure A-2: Moisture Content Nomograph for Liquids

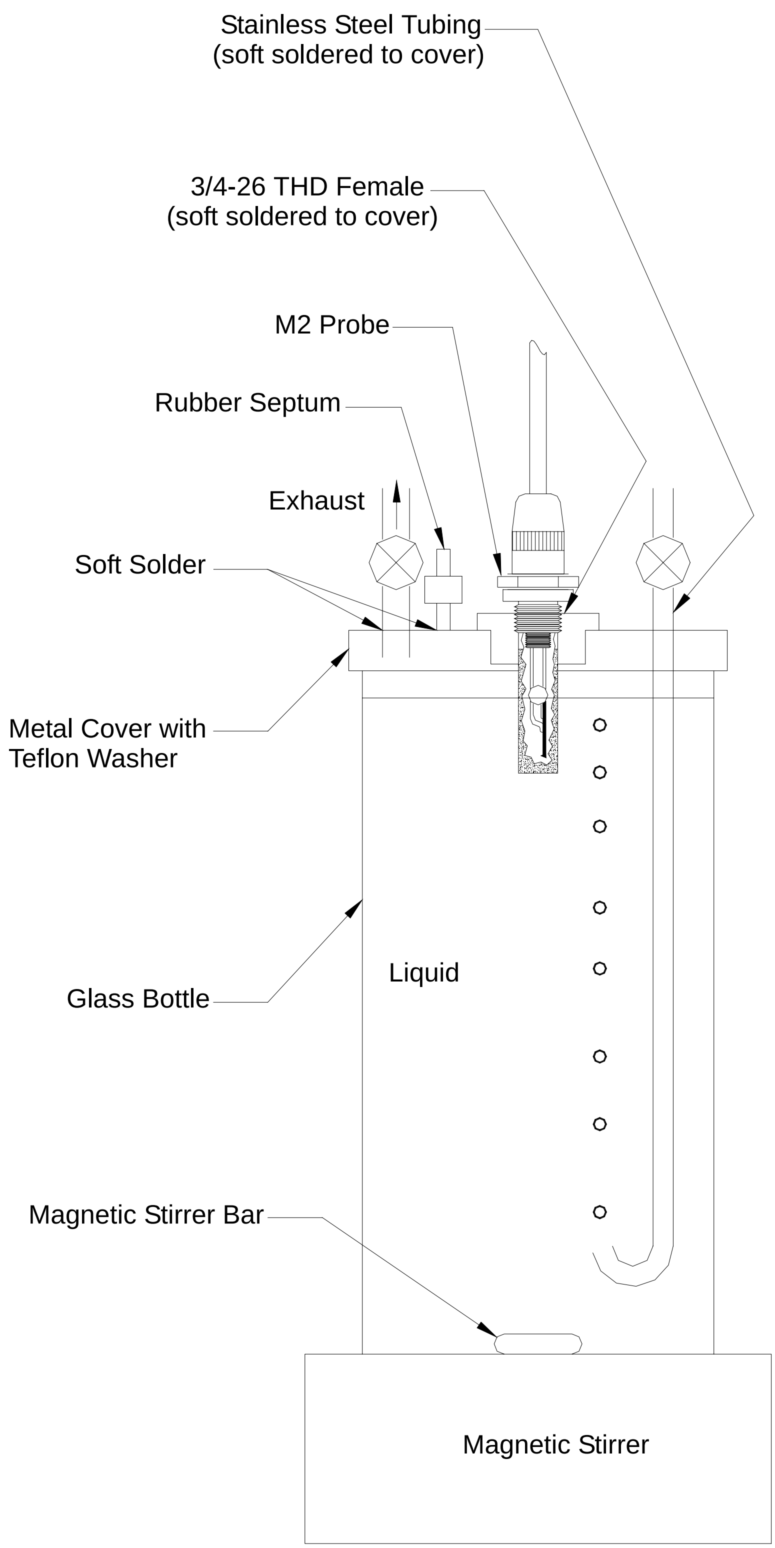


Figure A-3: Moisture Content Test Apparatus

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

Reference Calibration

Calibrating High and Low Reference Values

Caution!
Contact Panametrics before beginning this procedure.

Since the reference values for the System 2 are stored in RAM, they may be lost during shipment. Therefore, the ability to display and/or change the high and low reference values has been added to the "CONT?" section of the User Program (see Chapter 4). A discharged RAM battery will also cause the RAM memory to lose its contents. RAM battery is on the No. 14 card.

High and low reference values are now recorded on the No.8 calibrator card label. These recorded values provide the standard you use to check against the displayed high and low reference values.

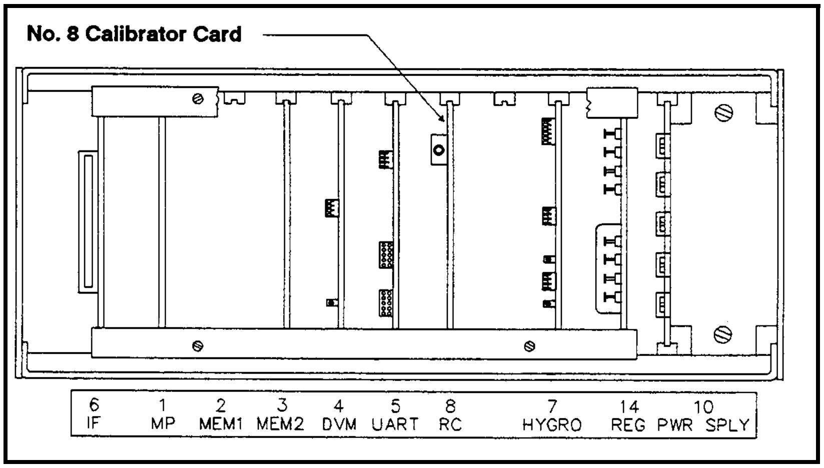


Figure B-1: Locating the No. 8 Calibrator Card

The procedure for calibrating high and low reference values is included on instruments that have software version .003.B or above and a No. 8 calibrator card (see Figure B-1 above).

The calibration procedure can be used to (1) replace missing data, (2) correct erroneous data, or (3) adjust low reference values to compensate for environmental conditions that may affect measurements.

Calibrating High and Low Reference Values (cont.)

This calibration procedure should be performed if one of the following applies:

A. RAM memory has been lost.

B. The No. 8 card has been repaired or replaced.

C. The calibration test (see the last section of this appendix) shows calibration to be out-of-spec.

D. You wish to adjust the low reference value to compensate for environmental factors (such as long cables) that may affect instrument measurements.

E. Card No. 14 has been removed or replaced, or its battery voltage has fallen. Call Panametrics for servicing.

Indication of Problem

The high/low reference calibration procedure may be necessary in the following cases:

- After using the RESET switch on the No. 8 card, the display shows "NODATA."
- There is doubt about the accuracy of the programmed high and low reference values.

If the hardware is working properly and if, after using the RESET switch on the No. 8 card, the display shows "NODATA," then the instrument has lost or is missing all or certain programmed information. Information can be lost because of the following reasons:

- Card No. 14 is removed.
- Card No. 14 RAM battery is dead.
- Unit may need servicing.

If this occurs, you must reprogram the hygrometer with the original probe data and operating parameters where necessary BEFORE ENTERING THE HIGH AND LOW REFERENCE VALUES.

Note: *Detailed information on programming the System 2 hygrometer can be found in Chapter 4 of this manual.*

Recorded Reference Values

The high and low reference values are recorded on the calibration label of the No. 8 card. If there is doubt about the accuracy of the programmed high and low reference values, power the instrument down and remove the No. 8 card. Record the reference values from the calibration label. Return the No. 8 card to its original location in the instrument and turn on the power switch.

Check the values you recorded from the No. 8 card against the displayed low and high reference values, and make any necessary corrections by following the calibration procedure outline in the next section.

Calibration Procedure

Caution!
Contact Panametrics before beginning this procedure.

Once you have recorded the high and low reference values from the No. 8 card, you can perform the calibration procedure as follows:

1. Disconnect the probe (leave the probe cable connected) and verify that the displayed MH value equals the zero reference value ±0.0003 MH (Mode 7 for MH units).

- If this reading is within spec, then no further testing is necessary.
- If the reading is less than the specified reading (previous recorded zero reference value ±0.0003), then add this difference to the low reference value.
- If the reading is greater than the specified reading (previous recorded zero reference value ±0.0003), then subtract this difference from the low reference value.

2. Note the final corrected low reference value and record it.

3. Reprogram the hygrometer with the new corrected low reference value (if required).

4. Verify that the probe cable is not connected to the probe. Return the unit to normal operating mode.

5. Note the zero reference readings and verify that the readings are now within ±0.0003 MH.

6. Fill out a new calibrator card (No. 8) label with the final low reference value:

HIGH REF = ORIGINAL RECORDED VALUE
LOW REF = NEW CORRECTED VALUE
ZERO REF = ORIGINAL RECORDED VALUE

Note: *This procedure may be used to nullify any error introduced by non-standard cables as described in Chapter 6.*

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