I-MOSBA-163

MODEL 911 DEW-ALL™
DIGITAL HUMIDITY ANALYZER

OPERATORS MANUAL
TM78-263

II-163

R.1
MANUAL SET
No. VM-494

EG&G ENVIRONMENTAL EQUIPMENT
217 MIDDLESEX TURNPIKE, BURLINGTON, MASSACHUSETTS 01803
TEL: (617) 270-9100 TELEX: 6817440 EGG

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AUGUST 1984

NOTE: This instrument is designed to operate on either 115 or 230 VAC. Read the "Preparation for Operation" section on Page 3-1 of this manual before plugging instrument into source of AC power.

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SECTION 1

INTRODUCTION

1.1 GENERAL DESCRIPTION

The Model 911 Digital Humidity Analyzer (Figure 1-1) is designed to measure moisture in gases for a wide variety of laboratory and industrial applications. The instrument is a portable, AC line operated hygrometer which utilizes the chilled mirror dew point condensation principle to determine the water vapor concentration in gas mixtures. It incorporates a digital display for dew point temperature in degrees Celsius that makes use of large area Liquid Crystal Displays for ease of readability even in high ambient light conditions.

The Model 911 Digital Humidity Analyzer is designed so that several options and accessories may be easily attached to the basic instrument to expand its capabilities. Analog outputs are provided at the rear panel connector for attachment to external recording equipment. As an example, the Model 911 Digital Humidity Analyzer can be equipped with an optional Model 911-AT Ambient Temperature Kit and optional Model 911-RH COMP™ RH Computer to provide front panel display and analog outputs corresponding to the relative humidity of the gas being sampled. Specifications for all options and accessories available for the Model 911 Digital Humidity Analyzer are given in subsection 1.3.

The Model 911-S1 Dew Point Sensor (Figure 1-2) is normally mounted directly on the rear of the Control Unit, but may be mounted remotely up to 250 feet from the Control Unit by means of the Model 911-RK Remote Mounting Kit. The sensor incorporates a new, inert proprietary NEBS™ (nickel electroplate based surface) mirror, which has (1) a bright, hard surface to provide superior corrosion and abrasion resistance, and (2) an inherent anti-wetting characteristic to enhance dew and frost formation. The NEBS™ mirror was developed as a result of ongoing material evaluation studies coupled with applied research in the physics of dew and frost formation on a mirrored surface.

1.2 OPTIONS AND ACCESSORIES

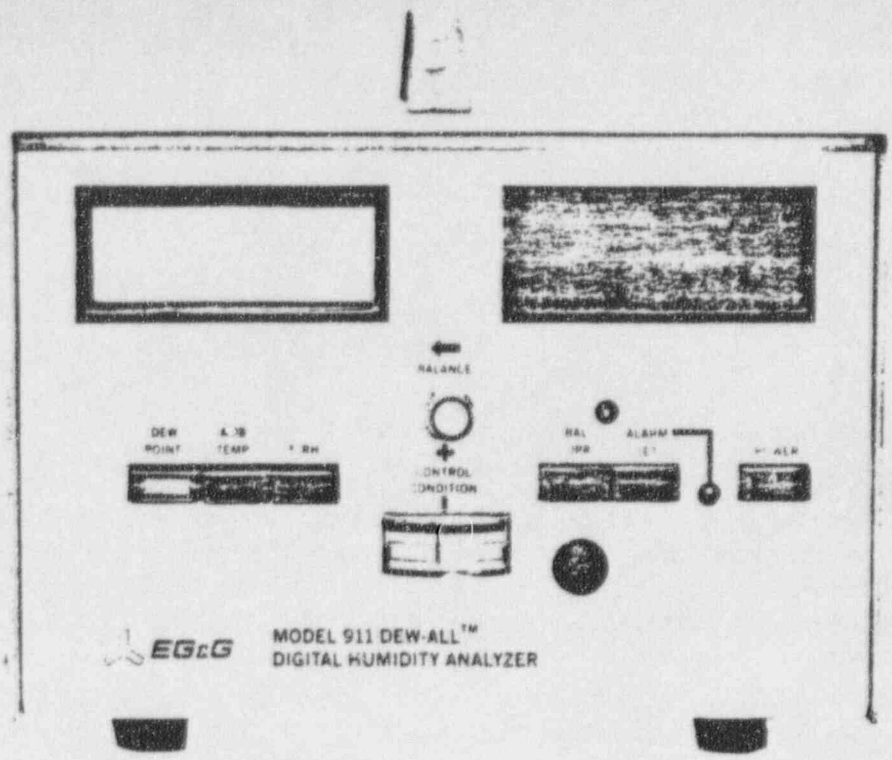
Options and accessories available for the Model 911 Digital Humidity Analyzer are designed to provide system expandability to meet a wide variety of application requirements. The options, when purchased with the basic Model 911, are installed at the factory prior to shipment. They may also be easily installed in the field at any time. Model 911 accessories are always shipped separately when they are to be installed in the field.

1.2.1 Model 911-RD LCD Readout Display Option (Figure 1-3)

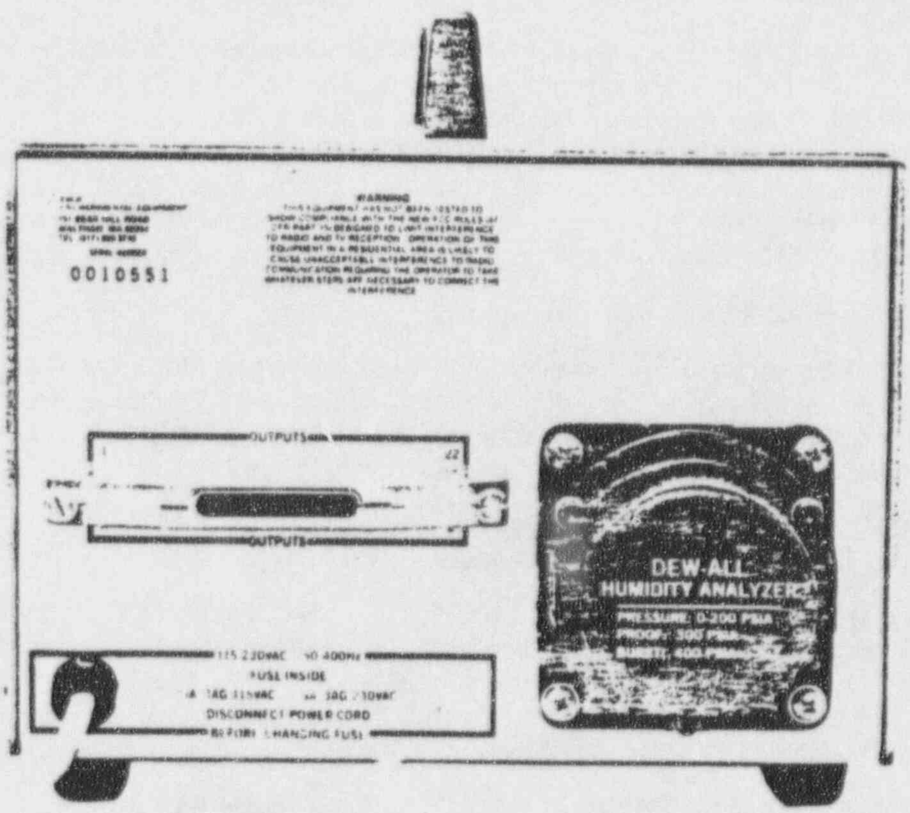
Normally, one front panel display is provided with the basic Model 911. However, when the Model 911 is provided with options or accessories that generate additional outputs and it is desired to display any two of the outputs on the front panel simultaneously, then this option is used. When two displays are used, the left-hand display always indicates the dew point temperature while the second Readout Display can indicate either ambient temperature or relative humidity as selected by front panel pushbuttons.

1.2.2 Model 911-CF/660 Sensor Interface Option (Figure 1-4)

This option card may be configured in any one of three ways if the instrument is so equipped. It can be utilized as a degree Celsius to degree Fahrenheit converter, as a Model 660 Sensor Interface, or as both. The °C to °F circuit converts the normal degree Celsius analog outputs of −4 volts to +6 volts over the range of −40°C to +60°C to −0.4 volt to 1.4 volts over a degree Fahrenheit range of −40°F to +140°F. The °F analog outputs are provided simultaneously with the °C analog outputs. In addition, this option performs the conversion for both the dew point temperature and the ambient temperature outputs if the Ambient Temperature option is being used. A switch is provided on the basic Model 911

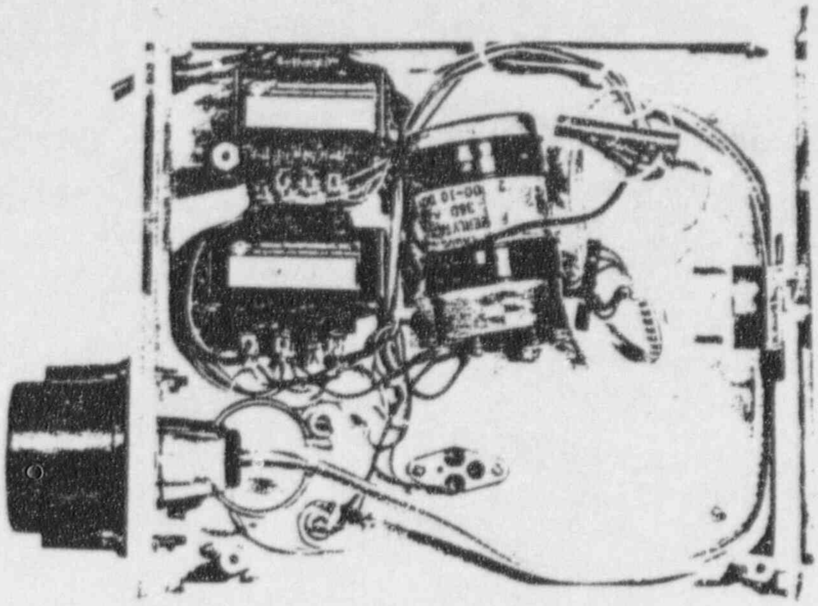


a. FRONT VIEW



b. REAR VIEW

FIGURE 1-1. MODEL 911 DIGITAL HUMIDITY ANALYZER



c. TOP VIEW OF INTERIOR

FIGURE 1-1. MODEL 911 DIGITAL HUMIDITY ANALYZER (Cont.)

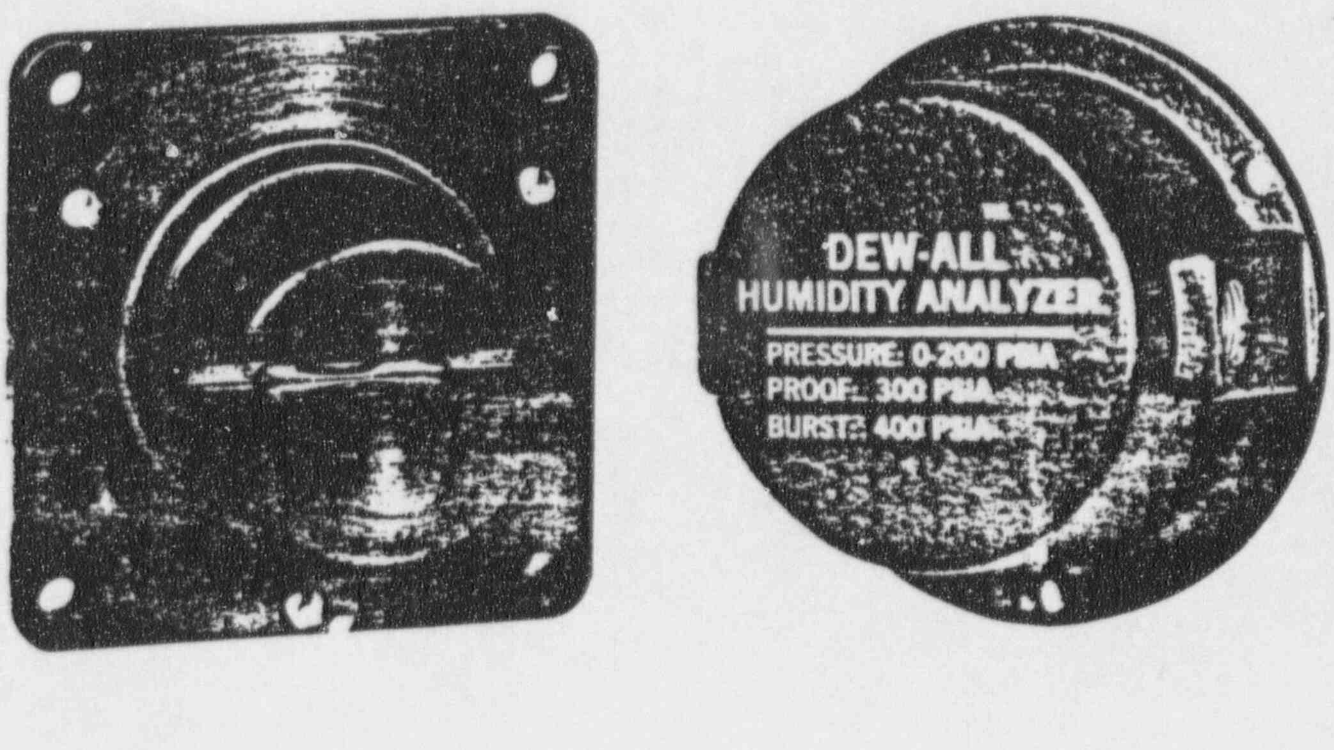


FIGURE 1-2. MODEL 911-S1 DEW POINT SENSOR WITH COVER REMOVED

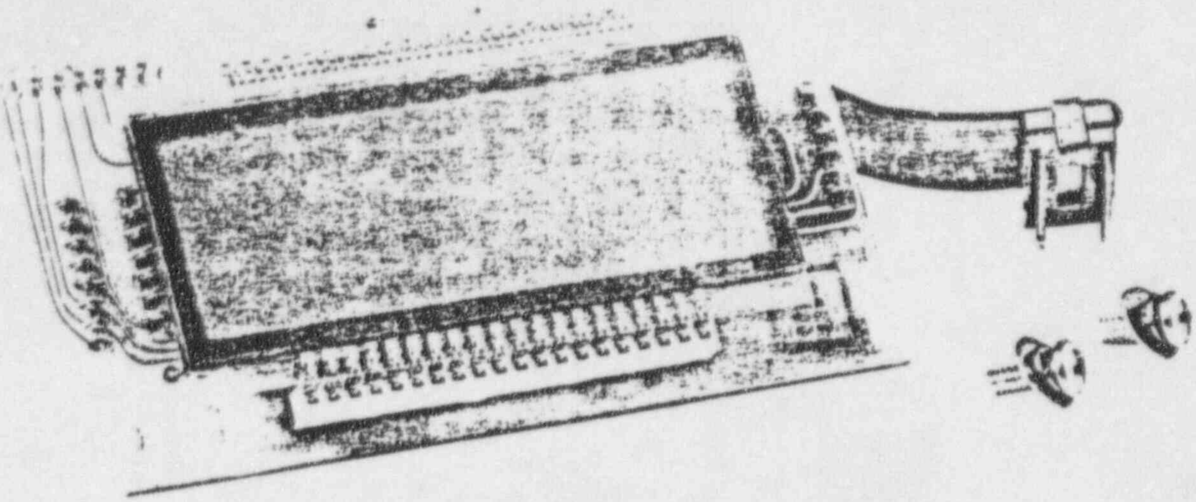


FIGURE 1-3. MODEL 911-RD LCD READOUT DISPLAY OPTION

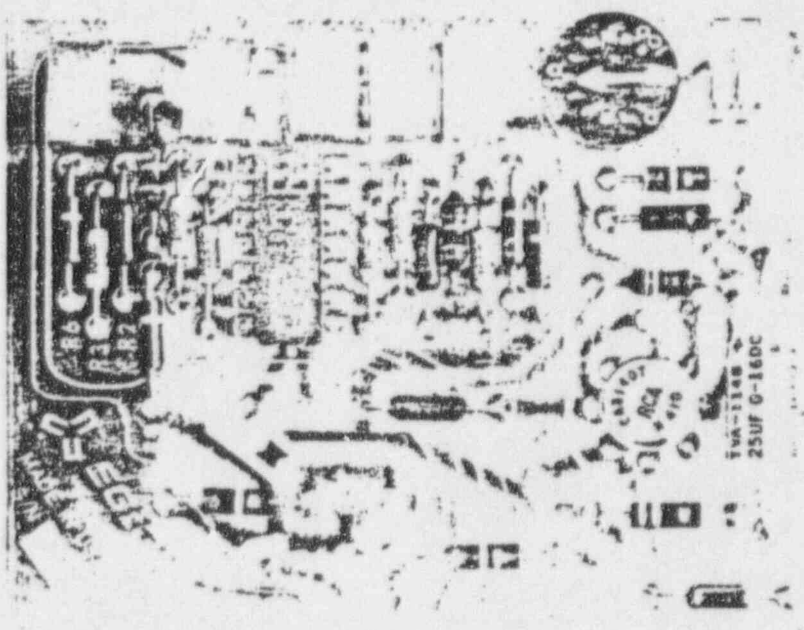


FIGURE 1-4. MODEL 911-CF/660 SENSOR INTERFACE OPTION

Circuit Card to allow the front panel digital display(s) to indicate in degrees Fahrenheit when this option is used with the Model 911.

The Model 660 Sensor Interface circuit provides the proper interface between the dual LED/Phototransistor optical system in the Model 660 Sensor and the single photoresistor input to the Model 911.

1.2.3 Model 911-AS/MA Module Option (Figure 1-5)

This dual function option may be configured to provide a single alarm set point and/or a 4-20 milliampere current output. The alarm set point is set as a percentage of full scale. A switch located on the AS/MA plug-in circuit card selects the 0-10 volt signal to be monitored, i.e., dew point temperature, ambient temperature, or relative humidity. A SPDT relay provides isolated contacts for remote indication of set point cross-over. A choice of two relays can be provided. Option 1 relay has contacts rated at 8 VA (resistive load), maximum volts 100 VDC, maximum switching current 0.25 ampere, and maximum operating current of 0.5 ampere. Option 2 relay has contacts rated at 50 VA (resistive load), maximum volts 100 VDC, maximum switching current 1 ampere, and maximum operating current of 2 amperes. The 4-20 MA option provides a current output signal which is proportional to the voltage supplied to it. A separate switch on the plug-in board selects the 0-10 volt signal to be converted to current. The MA option can be supplied with either isolated or non-isolated output.

1.2.4 Model 911-BC BCD Output Module Option (Figure 1-6)

This plug-in circuit card can be used when fully latched, parallel, T^2L compatible outputs are required. A switch on the BCD plug-in circuit card can be positioned to select either dew point or ambient temperature data for conversion to latched BCD. The output data correspond to the data provided for the front panel display for the parameter selected and represent 3-1/2 digits of data plus sign information, as well as a data update strobe.

1.2.5 Model 911-RH COMP™ RH Computer Option (Figure 1-7)

This option consists of a plug-in circuit card that accepts the dew point and ambient temperature information generated by the Model 911 and then calculates the percentage of relative humidity. The calculated data can be displayed on the front panel display when selected by the pushbutton controls. In addition, multiplexed BCD data are provided at the output data connector along with an analog output of 0 to +10 volts corresponding to 0 to 100% relative humidity.

Note

> The Model 911-AT Ambient Temperature Accessory or externally provided ambient temperature information is required in order for the Model 911-RH COMP™ RH to perform its computational functions.

1.2.6 Model 911-AT Ambient Temperature Accessory (Figure 1-8)

This accessory enables the Model 911 to measure and display the ambient temperature of the sample gas. It consists of a plug-in circuit card and a remote mounting Platinum Resistance Thermometer (PRT). The remote mounting PRT is equipped with 10 feet of interconnecting cable as standard. Longer lengths up to 250 feet are available on request. The PRT should be placed so as to measure the temperature at the point that the sample is being taken. If it can be determined that the temperature of the gas being sampled is the same temperature as the gas in the gas lines connecting to the Model 911 Dew Point Sensor, then the Model 911-TF In-Line Temperature Sensor Mount may be used to mount the PRT in series with the sample lines. The PRT is designed with a 3/8-inch NPT male pipe fitting for mounting purposes.

1.2.7 Model 911-TF In-Line Temperature Sensor Mount (Figure 1-9)

This accessory consists of brass fittings configured to provide an in-line protective mount for the Model 911-AT Ambient Temperature Accessory. Sample line inputs and outputs are both female 1/8-inch NPT

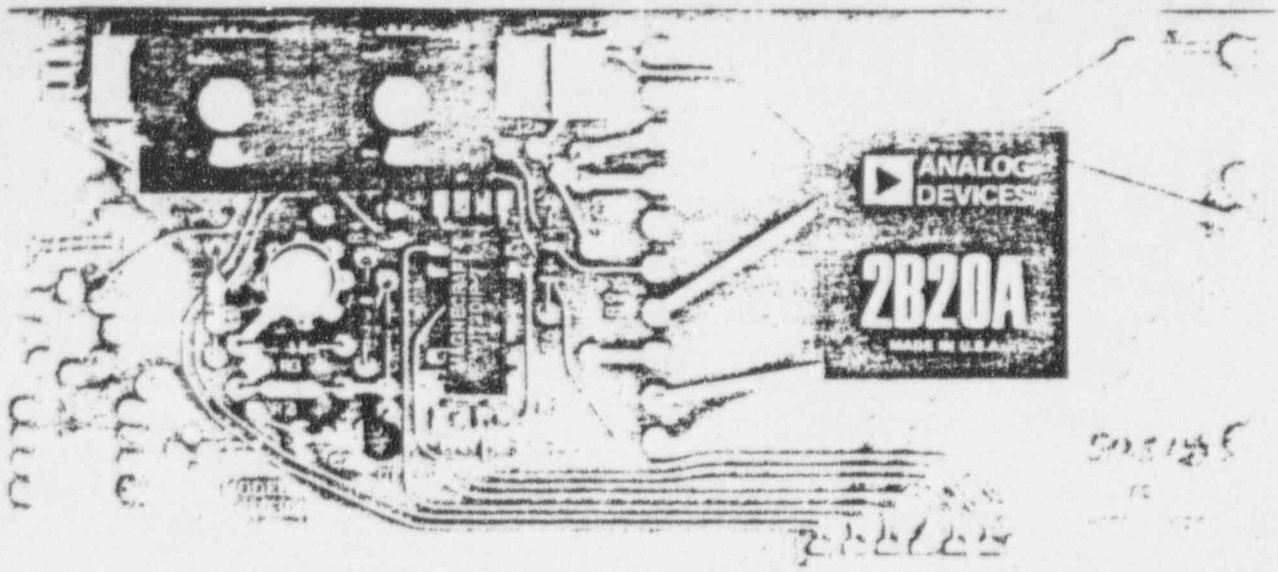


FIGURE 1-5. MODEL 911-AS ALARM SET/4-20 MA MODULE OPTION

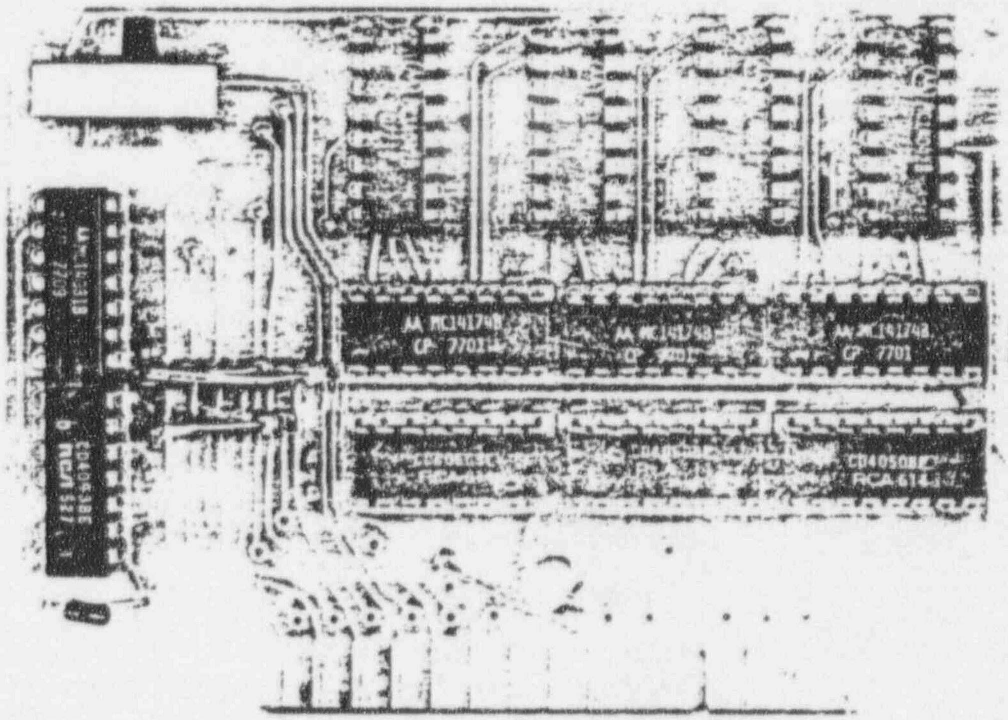


FIGURE 1-6. MODEL 911-BC BCD OUTPUT MODULE OPTION

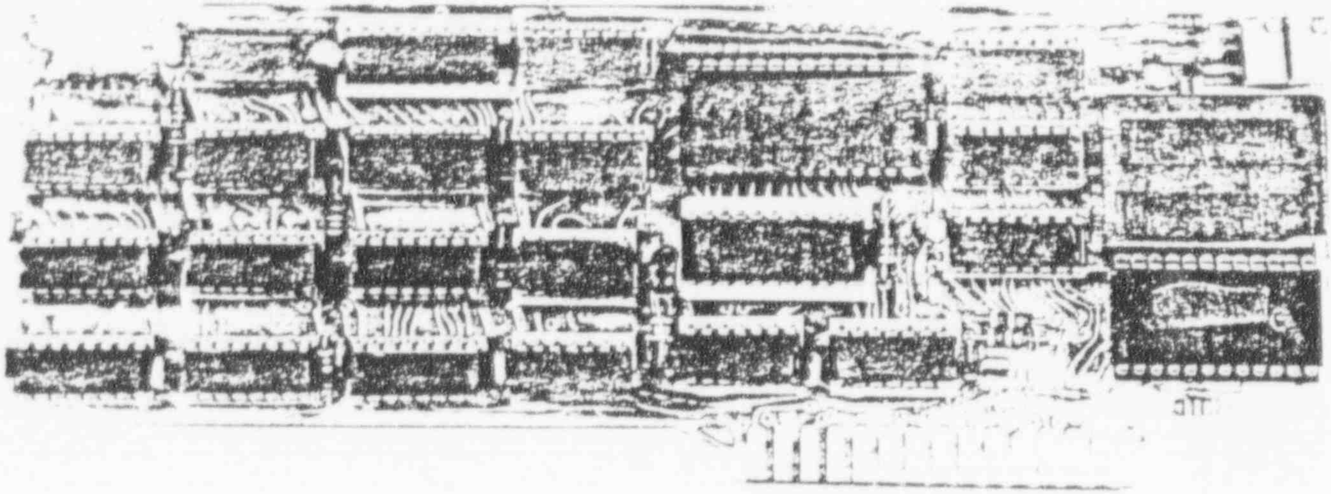


FIGURE 1-7. MODEL 911-RH COMP™ RH COMPUTER OPTION

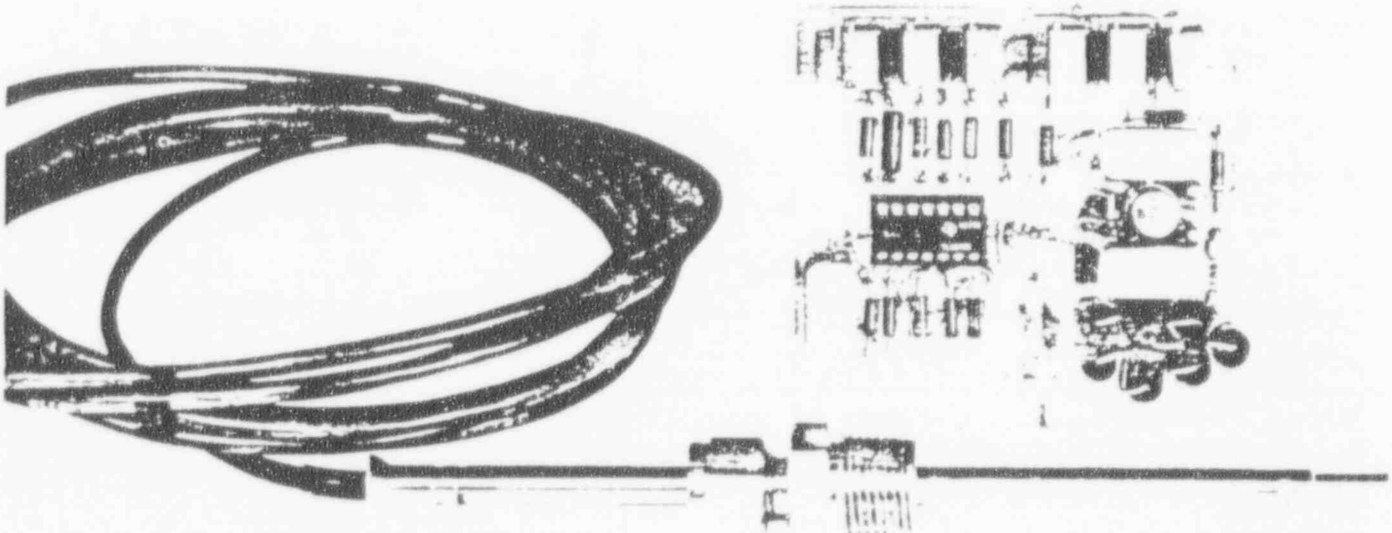


FIGURE 1-8. MODEL 911-AT AMBIENT TEMPERATURE ACCESSORY

pipe threads and the Model 911-AT Platinum Resistance Thermometer (PRT) mounts in a 3/8-inch NPT pipe thread. Pipe thread sealer is also provided to aid in mounting the PRT into the fittings.

This accessory should be used only when it can be determined that the temperature of the gas in the sample lines is the same as the temperature at the point the gas sample is being taken. Otherwise, it is recommended that the PRT be located at the sample line inputs. While the moisture content of the sample gas is not affected by a change of ambient temperature in the sample lines, subsequent calculations of parameters such as relative humidity are affected. For this reason care should be exercised in the placement of the ambient temperature PRT.

1.2.8 Model 911-PR Panel/Rack Mounting Kit Accessory (Figure 1-10)

This accessory is used to mount the Model 911 in a standard 19-inch rack or in a larger panel. The Model 911 Control Unit is attached to a swing-open door (7 inches high). The Model 911 Dew Point Sensor is mounted in a fixed position behind the door so that flexible sample lines are not required while still allowing access to the Control Unit as well as to the sensor for cleaning purposes. The standard Model 911 Control Unit cover is removed when this accessory is used and a separate dust cover, included as part of the kit, is used instead.

1.2.9 Model 911-RK Remote Mounting Kit Accessory (Figure 1-11)

This kit provides the necessary hardware to mount the Dew Point Sensor remotely from the Model 911 Control Unit. The standard cable length is 10 feet, although cable lengths up to 250 feet may be ordered. A mounting bracket is provided to mount the sensor at the remote location.

1.2.10 Model 911-DA DC/AC Inverter Accessory (Figure 1-12)

This inverter, used for portable field applications, converts a 12-volt DC storage battery power source to the 115 volts AC, 60 Hz power required by the Model 911.

1.2.11 Model 911-SS Sample System Kit Accessory (Figure 1-13)

The gas sampling system consists of a diaphragm pump, flow meter, and 8 feet of flexible polypropylene tubing with the necessary fittings to draw a gas sample through the Dew Point Sensor.

1.2.12 Model 911-CJ Coolant Jacket Accessory (Figure 1-14)

The sensor coolant jacket consists of an alumimum liquid cooled heat sink that is used to remove heat from the base of the Dew Point Sensor when attempting to measure low dew point temperatures in high ambient temperature conditions. Inlet and outlet connections are 1/8-inch female NPT. Approximately 0.25 GPM of coolant is required (pressure not to exceed 150 psig).

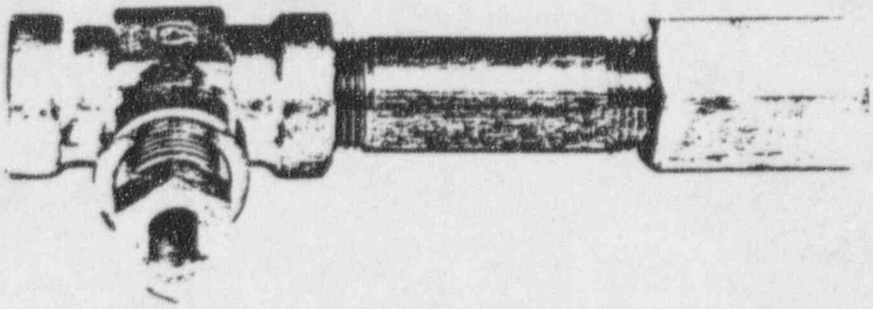


FIGURE 1-9. MODEL 911-TF IN-LINE TEMPERATURE SENSOR MOUNT

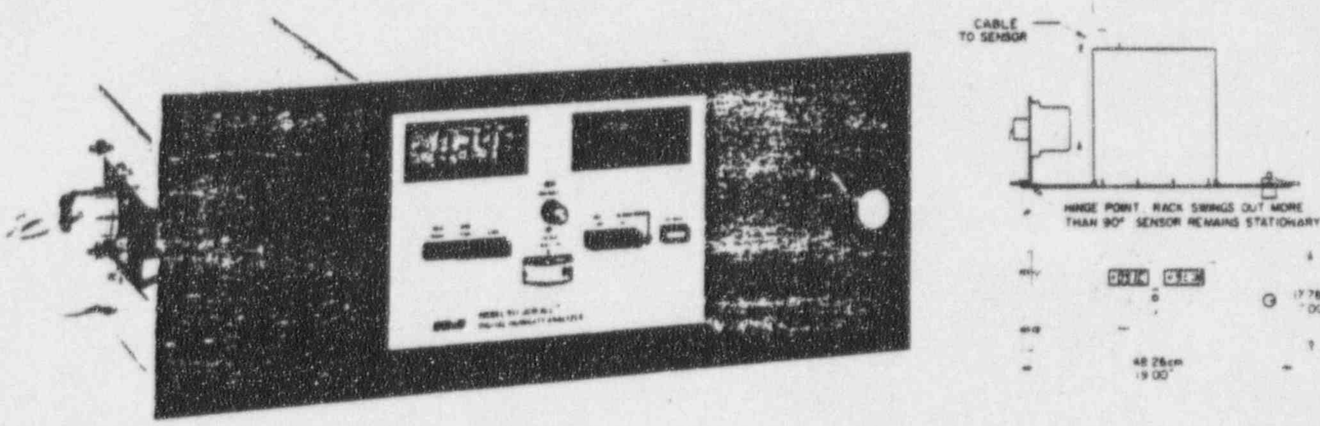


FIGURE 1-10. MODEL 911-PR PANEL/RACK MOUNTING KIT ACCESSORY

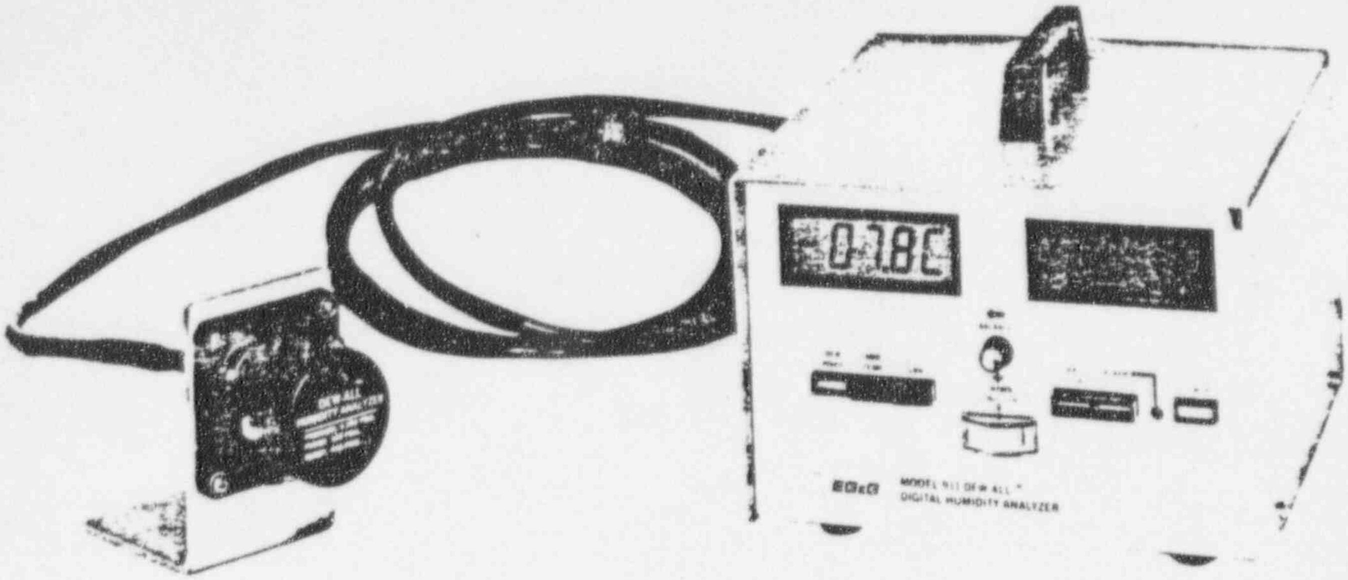


FIGURE 1-11. MODEL 911-RK REMOTE MOUNTING KIT ACCESSORY

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FIGURE 1-12. MODEL 911-DA DC/AC INVERTER ACCESSORY

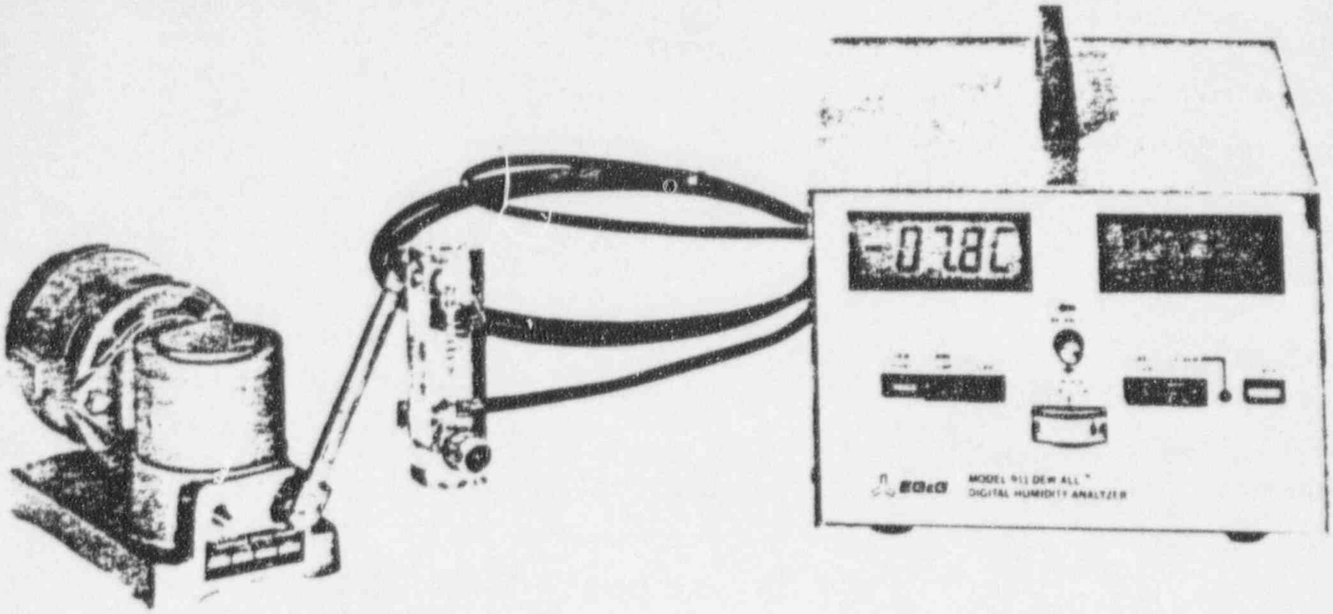


FIGURE 1-13. MODEL 911-SS SAMPLE SYSTEM KIT ACCESSORY

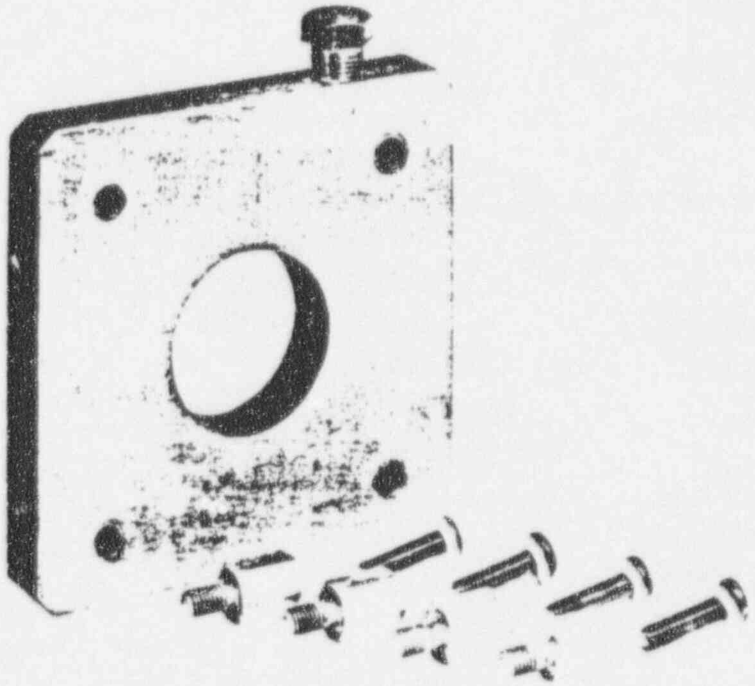


FIGURE 1-14. MODEL 911-CJ COOLANT JACKET ACCESSORY

1.3 GENERAL SPECIFICATIONS

DEW POINT AND RH RANGE	–40°C to +60°C (–40°F to +140°F) 5% to 100% RH with RH option
ACCURACY	±0.3°C (±0.54°F) Dew Point/Ambient Temperature, Nominal ±0.5% RH Nominal
DEW POINT DEPRESSION	45°C (80°F) Nominal
DEPRESSION SLEW RATE	2°C (4°F)/second maximum
DEW POINT SENSITIVITY	±0.06°C (±0.1°F)
SAMPLE FLOW RATE	0.25 to 2.5 liters/minute (0.5 to 5.0 SCFH)
SAMPLE PRESSURE	0 to 24 Kg/cm² (0 to 200 psia) Proof Pressure 21 KG/cm² (300 psia)
OPERATING TEMPERATURE	-50°C *to* +70°C (-60°F to +160°F) — Dew Point Sensor -50°C to +130°C (-60°F to +266°F) — Ambient Temperature Sensor +4°C to +50°C (+40°F to +120°) — Control Unit
AUXILIARY COOLANT (OPTIONAL)	Water (or other) — 1 liter/minute (1/4 gpm) at 10.5 Kg/cm² (150 psig) max., to augment cooling capability of sensor when necessary
DEW POINT TEMPERATURE SENSOR	3-wire Platinum Resistance Thermometer (PRT), 100 ohms nominal at 0°C
AMBIENT TEMPERATURE SENSOR (OPTIONAL)	3-wire Platinum Resistance Thermometer (PRT), 100 ohms nominal at 0°C
DISPLAY(S)	3-1/2 digit LCD digital data display, –40°C to +60°C, or –40°F to +140°F, resolution 0.1°C/0.1°F
OUTPUT(S)	Standard: –4 V to +6 VDC, Dew Point 0 V to +10 VDC, Dew Point Optional: 1) –4 V to 10 VDC, Ambient Temperature 2) 0 to 10 VDC, Relative Humidity 3) With °F Option: –0.4 V to +1.4 VDC, Dew Point –0.4 V to +2.66 VDC, Ambient Temperature 4) BCD, 3-1/2 digit, 8-4-2-1 parallel, T²L compatible 5) Multiplexed BCD for RH (All analog outputs are simultaneous when instrument is equipped with applicable options)
WEIGHT	5 Kg (11 pounds)
POWER	115/230 VAC ±10%, 50 to 400 Hz, 70 watts (maximum)

SECTION 2

INSTALLATION PROCEDURES

2.1 MECHANICAL INSTALLATION

The Model 911 Digital Humidity Analyzer mechanical dimensions are shown in Figure 2-1. The basic instrument is designed for bench-top mounting with plastic feet for support. The instrument should be used in an area where the ambient temperature is between +40 and +120°F (+4 and +50°C) and where free air circulation for convection cooling is provided.

The ambient temperature range of the Model 911 Sensor when mounted on the rear panel of the Model 911 Control Unit is the same as the Control Unit, +40 to +120°F (+4 to +50°C). When the Model 911 Sensor is mounted remote from the Model 911 Control Unit, using the Model 911-RK Remote Mounting Kit, the ambient temperature range of the Model 911 Sensor is −40 to +160°F (−40 to +70°C).

2.2 ELECTRICAL INSTALLATIONS

The Model 911 Digital Humidity Analyzer is provided with a standard 3-wire power line cord for use with a grounded 115 VAC, 60 Hz power outlet. Satisfactory operation is obtained over the range of 115 VAC ±10% and 50-400 Hz. The instrument requires up to a maximum of 70 watts and is fused with 0.75 amp Slo-Blo fuses located on the Main Circuit Card (Figure 2-2) inside the instrument (115 VAC). The instrument is also designed to operate on 230 VAC ±10%. If operation on 230 VAC is required, the Control Unit cover should be removed and 115/120 switch S8 should be operated to the 230 VAC position. At the same time, fuse F-1, located near S8, should be changed to a 0.375 amp Slo-Blo type.

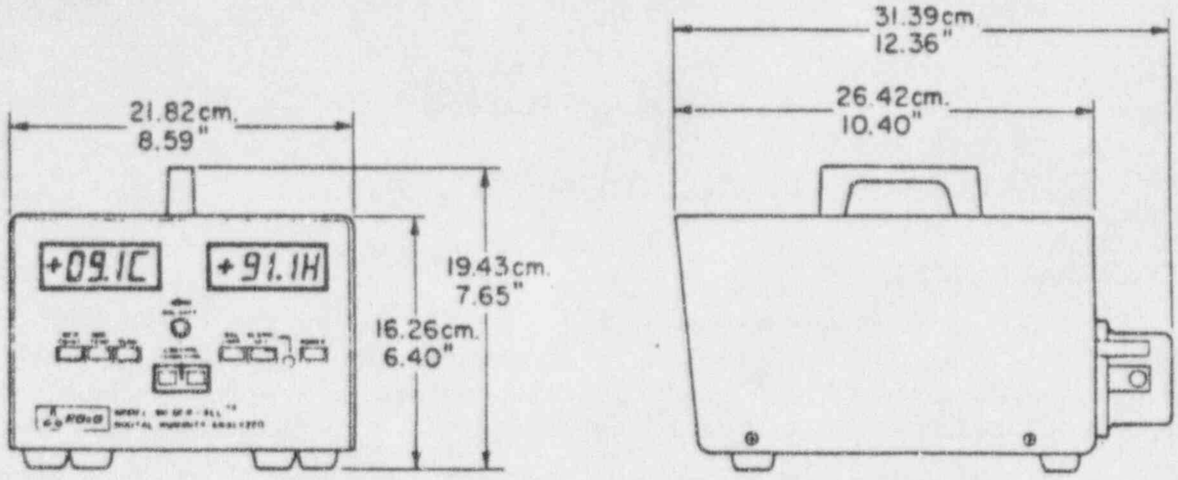
CAUTION

Access to S8 and F1 is obtained by removing the clear plastic cover attached to S8. Do not remove this cover or attempt to change the fuse without first making sure that the power cord is disconnected from the source of AC power. Fuses for operation on either range are included in the Cleaner Kit provided with each instrument.

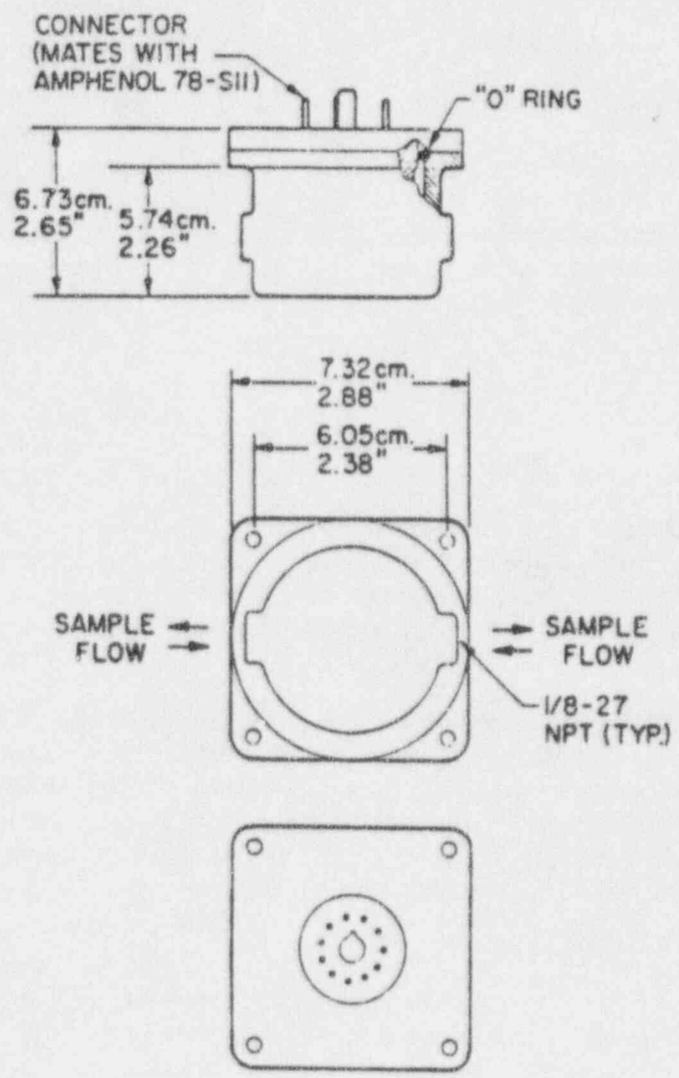
Output data connector J13 is located at the rear panel of the Model 911 Control Unit. Only isolated low voltages appear on J13. These outputs are not dangerous to touch. Mating connector P13, equipped with a cable hood, is provided to aid in making external connections to the Model 911 outputs. No output data connections are required for operation since the data generated by the Model 911 may be observed on the front panel display. However, when the Model 911 outputs are to be used for external recording or monitoring functions, connections should be made to P13 as shown in Table 2-1.

2.3 SAMPLING CONFIGURATION

The Model 911 Sensor gas sampling connections, while not intricate, may result in measurement difficulty if leaks and contamination problems exist. The Model 911 reads the dew point of the sample present in the sensor. However, contamination in the sample gas can result in some degree of error. Sample lines are connected by means of the 1/8 NPT sample ports at the sensor. Only clean lines which are non-hygroscopic and free of leaks should be used. Stainless steel, copper, or polypropylene tubing 1/8-inch or 1/4-inch in diameter should be used. The lines may be cleaned with freon or chlorothene if residual cutting oils or particulate matter are suspected to be present.



CONTROL UNIT (BENCH MOUNT)



DEW POINT SENSOR

FIGURE 2-1. MODEL 911 DIGITAL HUMIDITY ANALYZER MECHANICAL DIMENSIONS

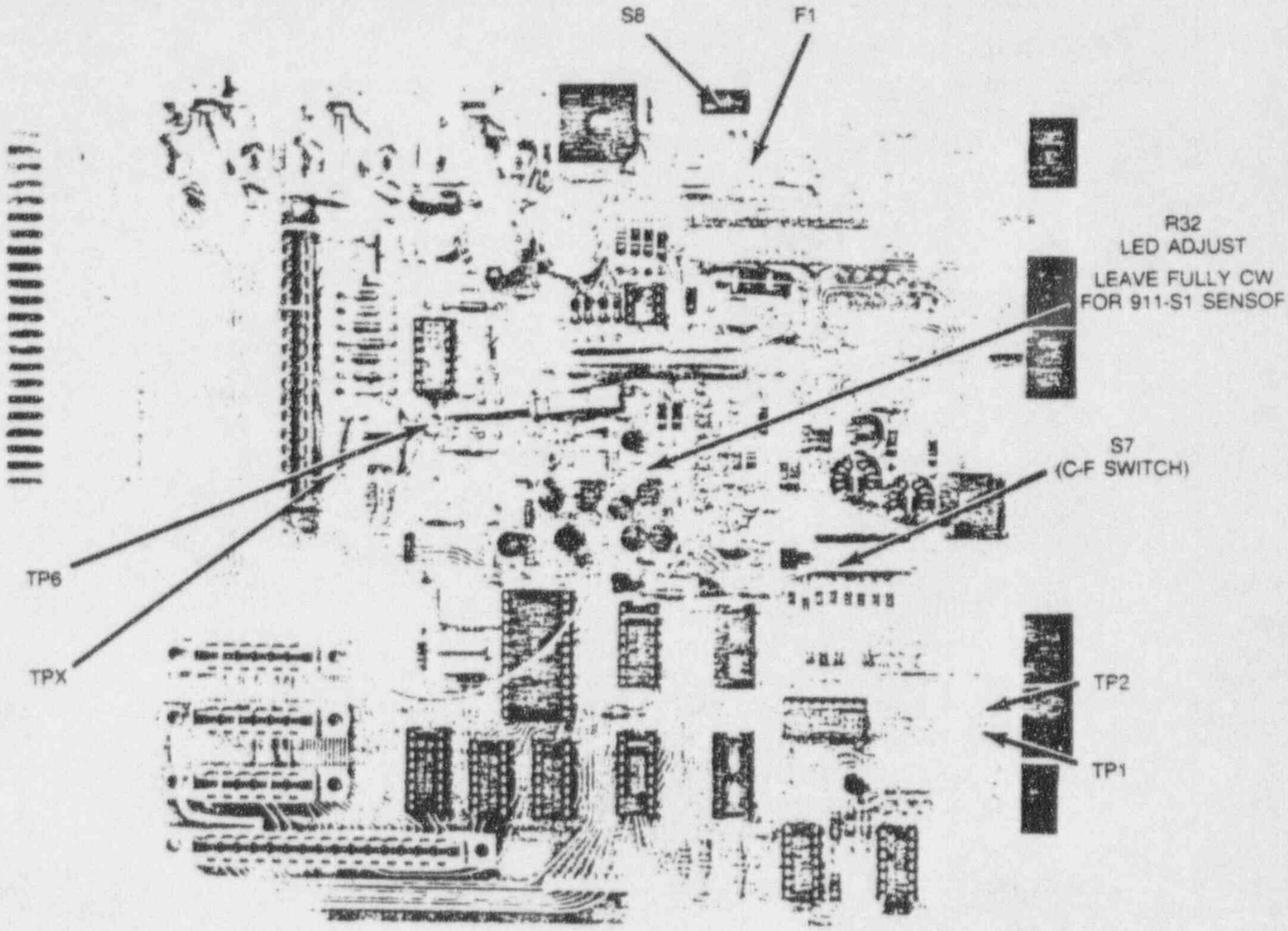


FIGURE 2-2. MODEL 911 MAIN CIRCUIT CARD — COMPONENT LAYOUT

TABLE 2-1. P13 OUTPUT CONNECTIONS

Pin Number	Description of Output or Input	Notes
1	+5 VDC Logic Voltage	1
2	+15 VDC	1
3	D.P. or A.T. BCD Digit 4-2	2
4	D.P. or A.T. BCD EOC (End of Conversion)	2
5	D.P. or A.T. BCD Digit 4-8	2
6	D.P. or A.T. BCD Digit 3-40	2
7	D.P. or A.T. BCD Digit 3-80	2
8	D.P. or A.T. BCD Digit 2-200	2
9	D.P. or A.T. BCD Digit 2-800	2
10	D.P. or A.T. BCD Polarity	2
11	Common Ground, Analog (Ambient Temperature PRT Drainware)	
12	0 VDC to +10 VDC Out, Dew Point	
13	−4 VDC to +13 VDC Out, Ambient Temperature, °C	3
14	−4 VDC to +6 VDC Out, Dew Point, °C	
15	Analog Relay Contact — Normally closed	5
16	Alarm Relay Contact — Common	5
17	Ambient Temperature Cable Input — Red Wire	3
18	−0.4 VDC to 2.66 VDC Out, Ambient Temperature °F	3,4,9
19	Relative Humidity BCD Out Q_10	6
20	Relative Humidity BCD Out DS_30	6
21	Relative Humidity BCD Out DS_20	6
22	Relative Humidity BCD Out Q_20	6
Pin Letter		
A	Common Ground, Digital	
B	−15 VDC	1
C	+5 VDC Reference (or 4-20 MA Return)	1,8
D	D.P. or A.T. BCD Digit 4-4	2
E	D.P. or A.T. BCD Digit 4-1	2
F	D.P. or A.T. BCD Digit 3-20	2
H	D.P. or A.T. BCD Digit 3-10	2
J	D.P. or A.T. BCD Digit 2-400	2
K	D.P. or A.T. BCD Digit 2-100	2
L	D.P. or A.T. BCD Digit 1 (1/2 Digit)	2
M	−4 V (or 4-20 MA Out)	8
N	−0.4 VDC to +1.99 VDC Ext. Ambient Temperature Analog Data In	7,9

TABLE 2-1. P13 OUTPUT CONNECTIONS (Cont.)

Pin Letter	Description of Output or Input	Notes
P	0 VDC to +10 VDC Out, Ambient Temperature Out (−40°C to +60°C)	3
R	Alarm Relay Contact — Normally Open	5
S	−0.4 VDC to +1.4 VDC Out, Dew Point, °F	4,9
T	Ambient Temperature Cable Input — Black Wire	3
U	0 VDC to +10 VDC RH Analog Out	6
V	Ambient Temperature Cable Input — White Wire	3
W	Relative Humidity BCD Out $Q_3$0	6
X	Relative Humidity BCD Out $DS_1$0	6
Y	Relative Humidity BCD Out $DS_4$0	6
Z	Relative Humidity BCD Out $Q_0$0	6

NOTES

1. Instrument supply voltages are provided on output connector for monitoring purposes only, not for powering of external loads.
2. Outputs available only when optional Model 911-BC Output Module Option is installed.
3. Outputs available only when optional Model 911-AT Ambient Temperature Accessory is installed.
4. Outputs available only when optional 911-CF°F Readout Capability Option is installed.
5. Outputs available only when optional Model 911-AS Alarm Set Module Option is installed.
6. Outputs available only when optional Model 911-RH COMP™ RH Computer Option is installed.
7. Provision for analog input voltage from external source for ambient temperature (Model 911-AT Accessory) not installed. Consult factory for other input ranges.
8. Supply voltages not present when 4-20 MA option is installed (see paragraph 3.2.2.4).
9. When the ABC option is installed, see paragraph 4.2.7, "Output Connector Changes."

The use of valves, regulators, or numerous fittings should be avoided, and when regulating valves, pumps or flow gauges are used, they should be located on the exhaust side of the system but not between the sample and the sensor, if possible. The optimum flow rate is between 0.5 SCFH and 5 SCFH. The sensor is insensitive to flow direction. In most applications, it is desirable to use a sampling system in which the pressure at the sensor is the same as the pressure at the desired point of measurement. Pressure changes in the sampling system are accompanied by dew point changes and must be taken into account during date interpretation (see Section 7, page 7-3). Where sample lines or components might be below the anticipated sample dew point temperatures, condensation may occur in the system, resulting in errors. In this event, heated lines and components must be used. Gases containing particulate matter should be filtered as close to the sampling point as feasible. Gases containing vapors (in addition to water) at concentrations that will cause them to condense at temperatures above the water dew point generally cannot be measured satisfactorily.

In some applications where the ambient dew point is being measured, the sample can be provided by air circulation if the sensor cover is removed. In these applications, avoid using intense light sources at the location of the sensor. Absence of any air motion is not considered conducive for proper operation. Section 7 of this manual contains additional information regarding sampling systems.

2.4 INSTALLATION OF OPTIONS AND ACCESSORIES

As a matter of convenience to the customer, installation of the Model 911 options will be made at the factory when ordered with the Basic Model 911 Digital Humidity Analyzer. All Model 911 accessories are designed to be field installed. Instructions given below should be followed for the installation of accessories and options when ordered separately. (All plug-in circuit cards are keyed to prevent installation in the wrong mating connector.)

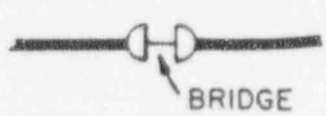
2.4.1 Model 911-CF °F Readout Capability Option

1. Turn AC power off.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. Plug the Model 911-CF option circuit card into J5 on the Main Circuit Card of the Model 911 Control Unit.
4. Operate switch S7 on the Main Circuit Card (push-push type) to its "IN" position if desired to display data in degrees Fahrenheit on the front panel display.
5. Replace the cover, using the four screws removed in step 2.
6. Turn AC power on and operate.

2.4.2 Model 911-AS/MA Module Option

1. Set AC power to off. Remove the AC line cord from the AC source.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. If the option is equipped with a milliampere (MA) module, proceed with steps 3A and 3B. If the option includes alarm set only, do not do steps 3A and 3B, but proceed to step 4.

   3A. Locate Bridge Pads M and C on the Main Circuit Card. Bridge Pad C is located to the far right of J3. Bridge Pad M is located to the near side of J7. The Bridge Pad is shaped as follows:



   3B. Use a sharp pen knife to carefully cut the bridges on Bridge Pads M and C. This step isolates the 4-20 MA output from the +5 V reference and −4 V outputs.

4. The Alarm Set circuit has an associated selector switch (S1) on the AS/MA option card. Likewise, the MA circuit has an associated selector switch (S2). Operate either or both switches as desired to activate the alarm relay and/or the MA output on either DP, AT, or RH.

Switch Position	Signal
1	Dew Point
2	Ambient Temperature (optional)
3	Relative Humidity (optional)

5. Plug the Model 911-AS/MA option into J7 on the Main Circuit card of the Model 911 Control Unit.
6. Attach external alarm indicating equipment to J13-15, 16, and R (see Table 2-1) as required, being careful not to exceed the alarm relay specifications outlined in paragraph 1.2.3.
7. Attach external current monitoring equipment to J13-M (+) and J13-C (−).
8. For the Alarm Set option, turn power on and press the Alarm Set pushbutton on the front panel. Adjust the display reading to % full scale alarm point desired by adjusting the potentiometer Rx located on the left side of the Alarm Set Board. An adjustment tool is provided as part of the cleaner kit. Refer to paragraph 3.2.2.4 for the associated transfer functions.
9. Release the Alarm Set pushbutton.
10. Replace the cover using the four screws removed in step 2.

2.4.3 Model 911-BC BCD Output Module Option

1. Turn AC power off.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. Operate the switch on the Model 911-BC option to either D.P. or A.T. as required by application.
4. Plug the Model 911-BC option into J3 on the Main Circuit Card of the Model 911 Control Unit.
5. Replace the cover using the four screws removed in step 2.
6. Make necessary connections from J13 to external equipment (see Table 2-1).
7. Turn AC power on and operate.

2.4.4 Model 911-RH COMP™ RH Computer Option

1. Turn AC power off.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. Plug the Model 911-RH option into J4 on the Main Circuit Card of the Model 911 Control Unit.
4. Replace the cover using the four screws removed in step 2.
5. Turn AC power on and operate.

2.4.5 Model 911-RD LCD Readout Display Option

1. Turn AC power off.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. Remove the two wire clamps and the black card from the right-hand opening on the front panel of the Model 911 chassis.
4. Install the Model 911-RD option behind the front panel in the same manner as the one already installed (same orientation).

5. Unplug left-hand display from DP2 on the Model 911 Main Circuit Card and plug it into DP1 on the same card.
6. Plug the new display just installed into DP2 on the Model 911 Main Circuit Card.
7. Replace the cover on the Model 911 chassis using the four screws removed in step 2.
8. Turn AC power on and operate. (The left-hand display will indicate dew point temperature and the right-hand display will indicate the parameter selected by the front panel pushbuttons.)

2.4.6 Model 911-AT Ambient Temperature Accessory

1. Turn AC power off.
2. Remove the Model 911 Control Unit cover by removing the four No. 6 screws securing it to the chassis.
3. Plug the Model 911-AT Accessory Circuit Card into J6 on the Model 911 Main Circuit Card.
4. Replace the cover using the four screws removed in step 2.
5. Remove external output data connector J13 from the rear panel of Model 911 Control Unit P13 and disassemble the plastic hood from around the connector.
6. Attach the leads from the Model 911-AT Accessory Platinum Resistance Thermometer (PRT) to the connector by soldering the wires to the appropriate connector pins:

Wire		Pin
Red	to	17
White	to	V
Black	to	T
Drain	to	11

7. Reassemble the connector hood removed in step 5 to J13.
8. Install the PRT in the desired location before plugging connector J13 back onto the rear panel of the Model 911 Control Unit.

NOTE

The standard cable length supplied with the Model 911-AT accessory is 10 feet. Cable lengths up to 250 feet may be purchased. For cable lengths greater than 50 feet, adjustment to the ambient temperature PRT amplifier must be made. This is normally done at the factory when the longer cable length is ordered with the kit. If additional cable is added after purchase, this readjustment must be made by the customer. The procedure for this adjustment is similar to that given for the dew point PRT in the Maintenance Section of this manual, Section 6, page 6-7.

2.4.7 Model 911-CJ Coolant Jacket Accessory

This accessory can be used when the Model 911-RK Remote Mounting Kit Accessory is used or when the sensor is to remain mounted to the rear panel of the Model 911 Control Unit.

1. Turn AC power off.
2. Remove the Model 911 Sensor from the rear panel of the Model 911 Control Unit by removing the four screws retaining it and by carefully removing the connector.
3. Install the four standoffs included with the Model 911-CJ Accessory to the rear panel of the Model 911 Control Unit where the sensor was removed, if the sensor is still to be mounted to the rear panel. The standoffs are not required to attach the sensor to the mounting bracket of the Model 911-RK Remote Mounting Kit, if it is used.

4. Attach the Coolant Jacket to the standoffs. Use the sensor to hold the Coolant Jacket in place. The longer screws provided are used to hold the sensor to the standoffs with the Coolant Jacket in between. Ensure that the coolant connections (1/8 NPT) for the Coolant Jacket and the sample line connectors for the sensor are oriented properly to facilitate other connections and that the sensor has been mated either to the Model 911 Control Unit sensor connector or the connector on the end of the Remote Cable.

2.4.8 Model 911-PR Panel/Rack Mounting Kit Accessory

The Model 911-PR Panel/Rack Mounting Kit Accessory allows the Model 911 to be converted from a bench-mounted model to one that can be mounted in either a panel or rack. When mounting in a panel, a template included with the kit provides for ease in locating the necessary cutout and mounting holes. Once installed in a panel, the hole cutouts are covered by the front panel of the kit.

For rack mounting, a standard EIA 19-inch rack is required. Panel height required is 7 inches. When mounted in this configuration, the Model 911 extends 10 inches behind the front panel.

Installation Instructions:

1. Unpack the Panel/Rack Kit and lay out all parts and hardware received.

   1 — Front Panel
   1 — Hinge
   1 — Hinge Plate
   1 — Control Unit Bottom Angle Support Bracket
   1 — Control Unit Top Support Plate
   1 — Control Unit Dust Cover
   1 — Sensor Support Bracket, Top
   1 — Sensor Support Bracket, Bottom
   1 — Cable Clamp
   1 — Panel Cutout Template for Panel Mounting Only
   1 — Lot Hardware

2. If the Model 911 is to be mounted in a panel, attach the template to the panel in the desired location with tape and cut out the panel opening and drill out the hinge mounting holes as indicated. If rack mounting is to be used, discard the panel template.
3. Remove the Model 911 bench mount cover with the handle and replace it with the unpainted handleless dust cover provided in the kit.
4. Remove the Model 911 Sensor from the rear of the Control Unit, saving the hardware, and unfold the cable connnecting the sensor to the Main Circuit Card.
5. Remove the two front plastic feet from the base of the Control Unit and attach the bottom single support bracket to the bottom front of the Control Unit using the screws of the rubber feet removed above.
6. Attach the bracket secured in step 5 to the 19-inch front panel of the kit with four No. 8 flat head screws (black).
7. Secure the top of the Control Unit front panel to the 19-inch front panel of the kit by means of the Control Unit top support plate and four No. 8 flat head screws (black).
8. Attach one side of the hinge to the 19-inch front panel using the 1/4-20 hardware.
9. Mount the two sensor support brackets to the sensor. The sensor may be rotated as desired for ease of plumbing.
10. Attach the free end of the hinge to the mounting holes of the panel or rack with 1/4-20 hardware, picking up the two sensor support brackets.
11. Using the cable clamp provided, secure the cable from the Control Unit to the sensor underneath the Control Unit by removing one of the rear plastic feet to provide an attachment point.

12. The Model 911 is now mounted on a swinging hinged door that allows it to be swung out for access to the electronics and also for access to the sensor for mirror cleaning. In this configuration, the sample lines to the sensor are stationary. The latch keeps the swinging door closed during normal operation.

2.4.9 Model 911-RK Remote Mounting Kit Accessory

This accessory is used when locating the Model 911 Sensor remote from the Model 911 Control Unit. The maximum distance is 250 feet. The standard length of the cable included in the kit is 10 feet. If additional lengths of cable are required, it should be specified at time of purchase.

NOTE

> When the Model 911-RK Remote Mounting Kit is purchased with the Model 911 Digital Humidity Analyzer, the Model 911 Control Unit Platinum Resistance Thermometer (PRT) amplifier will be adjusted for the length of cable purchased. When cable lengths greater than 50 feet are used, readjustment is necessary to maintain accuracy specifications. Consequently, if the Model 911-RK accessory is purchased after shipment of the Model 911 Digital Humidity Analyzer and the cable length exceeds 50 feet, perform the PRT Amplifier Calibration procedure included under Maintenance, Section 6, page 6-7.

1. Turn AC power off.
2. Remove the Model 911 Sensor from the rear panel of the Model 911 Control Unit by removing the four screws retaining it and carefully unplugging the sensor connector.
3. Attach the male end of the Model 911-RK accessory cable to the Model 911 Control Unit connector removed in step 2, and secure the cable mounting plate to the rear panel using the screws provided.
4. Mount the sensor to the remote mounting bracket provided and attach the female end of the remote cable to the sensor.
5. Recalibrate the PRT Amplifier, if necessary, as previously discussed.

2.4.10 Model 911-SS Sample System Kit Accessory

The Sample System Kit consists of a Neptune Dynapump Model No. 2, a Brooks 0-5 SCFH flowmeter, eight feet of tubing, and all necessary hardware and fittings for attaching to a Model 911 Sensor. Interconnecting suggestions are included with this accessory.

2.4.11 Model 911-DA DC/AC Inverter Accessory

This inverter will convert a 12 VDC battery power source to a 115 VAC, 60 Hz, power source to power the Model 911 Digital Humidity Analyzer in portable field applications. Attach a battery to the inverter, observing correct polarity, and plug the Model 911 Digital Humidity Analyzer into the inverter output.

SECTION 3

OPERATION

3.1 PREPARATION FOR OPERATION

The Model 911 Digital Humidity Analyzer, as shipped, is designed for operation on 115 VAC and has been tested as such. However, prior to using the equipment, certain precautionary checks should be made to ensure that the Model 911 is set up properly for the particular application in question.

3.1.1 AC Input Voltage Selection

Select the input voltage planned for your installation, either 115 VAC or 230 VAC. Switch S8 makes this selection easy after the cover of the Model 911 has been removed. When shipped, the Model 911 is equipped with a 3 AG 3/4 amp Slo-Blo fuse. If operation is planned for 230 VAC, fuse F1 should be changed to a 3 AG 3/8 amp Slo-Blo.

CAUTION

When changing the fuse for any reason, ensure that the Model 911 power cord has been disconnected from the source of AC power. The fuse will be electrically energized otherwise.

Access to the fuse is gained by removing the two retaining nuts on S8 that are securing the plastic protection shield. Reinstall the plastic shield after the fuse has been changed. See Figure 2-2 for the location of S8 and F-1.

3.1.2 Initial Setup

If possible, locate the Model 911 Digital Humidity Analyzer in a clean area where free convection of air is possible underneath and around the sides of the Model 911 Control Unit chassis. Install any options not previously installed and any accessories, following the installation instructions of Section 2 of this manual. Operate any option switches to their appropriate positions for the application. If equipped with the Model 911-CF option, select °C or °F for display by operating S7 (in for °F) located on the Main Circuit Card. Make any connection to external recording or monitoring equipment as necessary at rear output connector P13. Connect the Model 911 Sensor to the gas sample with cleaned, nonhygroscopic piping with leak-free connections, keeping the sample lines as short as possible, and provide for a sample flow rate of about 2 SCFH. Use nonhygroscopic filters, if necessary, to remove particulate matter from the gas sample.

3.2 OPERATING PROCEDURES

NOTES

The following procedures are applicable for operation of the basic Analyzer. If the Model 911 Automatic Balancing Control (ABC) option is used, refer to paragraph 4.2.7, page 4-5.

If the Model 660 S2 Sensor is used in place of the Model 911 S1 Sensor, refer to paragraph 3.2.2.7, page 3-5.

3.2.1 Operation of Model 911 Digital Humidity Analyzer

1. Turn the instrument on by depressing the POWER switch. When ON, the color of the switch changes from black to amber. If power is applied, the digital display(s) will illuminate also.
2. If a Model 911-RH COMP™ RH Computer option is installed, press AMB TEMP to display the ambient temperature. Then press the BAL/OPR switch to the BAL position. The BAL position is indicated by the switch changing from black to green. At this time, the mirror surface in the sensor is heating up to ensure that all condensate is removed. The BAL (balance) position of the BAL/OPR switch is further indicated by the illumination of an arrow annunciator in the display(s) over the ± sign.
3. Allow the instrument to remain in the BAL condition for at least one minute. If the DEW POINT is selected for display, the display will be indicating the sensor mirror temperature directly. After a minimum of one minute, adjust the BALANCE control knob if the indicator on the CONTROL CONDITION meter is not in the white section of the meter. If a balance condition cannot be achieved, clean the sensor mirror (see Section 6), if this has not already been done. If the mirror is known to be clean and balance cannot be obtained with the BALANCE control knob, set the BALANCE control knob to its full CCW position and adjust SEN CAL potentiometer R3 on the Main Circuit Card (see Section 6 and Figure 2-2).
4. When a balance condition has been achieved, place the BAL/OPR switch in the OPR (operate) position. The arrow annunciator in the display(s) will be extinguished and the BAL/OPR switch will change to black. At this time, the dew point temperature will begin to fall and the CONTROL CONDITION meter will indicate to the far right (blue), indicating that the instrument is cooling the mirror surface toward the dew point at its maximum rate.

When the dew point temperature is reached, the displayed value will drop below the dew point of the gas, and the CONTROL CONDITION meter will begin to swing to the left. This is caused by condensate forming on the mirror surface in the Model 911 Sensor and resulting in a reduction in the cooling rate of the mirror, causing it to heat up slightly. In a short time, the indicated dew point temperature will stabilize at the sample dew point. When this occurs, the CONTROL CONDITION meter will be reading steady to the right of center. The degree of deflection depends on the dew point depression required. The meter will read near the center for high dew points and to the far right for low dew points. (The dew point depression is the difference between the ambient temperature and the dew point temperature of the gas sample.)

Sudden changes in the dew point of the gas sample will result in a fluctuation of the CONTROL CONDITION meter followed by a change in the indicated dew point. A constant fluctuation of the CONTROL CONDITION meter is indicative of control loop oscillation and may occur at high sample flow rates or at high gain settings of the control electronics (an internal instrument adjustment). The constant fluctuation is not detrimental to obtaining good data when dew point temperature indication is steady.

3.2.2 Operation of Opticns and Ambient Temperature Accessory

When the basic Model 911 Digital Humidity Analyzer is equipped with various options and accessories, the basic operation just described is unaffected. Added options and accessories simply increase the versatility of the basic instrument. The added features of each are discussed below.

3.2.2.1 Model 911-RD LCD Readout Display Option

The basic Model 911 is equipped with one display. The dew point temperature is shown on this display in degrees Celsius, as indicated by the letter C to the right of the decimal digits. When only one display is incorporated and the Model 911-AT Ambient Temperature Accessory is used, the data selected for display are controlled by mutually exclusive selector switches DEW POINT or AMB TEMP. If the Model 911-RH COMP™ RH Computer option is also incorporated, then the % RH selector switch can be used to display % RH.

The character H is displayed to the right of the decimal digits when % RH is selected for display. However, if this Model 911-RD option is used, providing two simultaneous displays, then the left-hand

display will always display dew point data only and the right-hand meter will display the data selected by the data select switches — either DEW POINT, AMB TEMP, or % RH.

3.2.2.2 Model 911-CF °F Readout Capability Option

When the basic Model 911 Digital Humidity Analyzer is equipped with this option, °Fahrenheit analog outputs are provided simultaneously with the °Celsius analog outputs. Front panel display of data may, however, be either in °F or °C. By removing the cover to the Model 911 Control Unit, switch S7 on the Main Circuit Card becomes accessible. This switch determines which analog voltage, °C or °F, will be digitized for display purposes **and** for use by the Model 911-BC BCD Output Module if one is used. Switch S7 is of the push-push variety. When it is in the °F position, character F will be shown in the display(s) on the front panel along with the °F digital data, and when in the °C position, character C will be displayed. This option provides for °F conversion of **both** dew point and ambient temperature even though dew point may be the only parameter the instrument is equipped to measure. Later addition of an ambient temperature capability by means of the Model 911-AT Ambient Temperature Accessory does **not** require an additional Model 911-CF option. (If so equipped, both dew point and ambient temperature must be displayed in the same format, either °F or °C.)

3.2.2.3 Model 911-BC BCD Output Module

This module provides 3-1/2 digit, parallel, latched T^2L compatible outputs for either dew point **or** ambient temperature. Selection of dew point (D.P.) or ambient temperature (A.T.) for BCD output is made by means of slide switch S1, located on the top of the Model 911-BC Option Circuit Card. Access to this circuit card is obtained by removing the cover of the Model 911 Control Unit.

Connections to the BCD outputs are made at Model 911 Control Unit rear panel connector J13 in accordance with the output pin data shown in Table 2-1. Data are valid whenever the EOC line (J13-4) is high (+5 volts). Digit 4 is the Least Significant Digit (LSD). Note that the 1/2 digit (J13-L), the Most Significant Digit (MSD) information, is reversed from the other outputs in that a low (0 volts) output represents a digit 1 for the MSD, whereas a high output (+5 volts) on this MSD line indicates that the MSD is a zero. The polarity output on J13-10 is a low (0 volts) for NEGATIVE and a high (+5 volts) for POSITIVE.

3.2.2.4 Model 911-AS/MA Module Option

This option provides a single point alarm capability and/or a 4-20 MA current output for the Model 911 Digital Humidity Analyzer. The alarm may be set to any value within the dew point, ambient temperature, or relative humidity ranges. Switches on the Model 911-AS/MA circuit card select the output signal that the alarm circuitry will monitor or that will be converted to current. The Alarm Selector switch is S1. The MA selector switch is S2. Each switch selects Dew Point (position 1), Ambient Temperature (position 2), or % Relative Humidity (position 3). Access to the Model 911-AS/MA circuit card is obtained by removing the cover of the Model 911 Control Unit. The position of these switches should be checked to ensure that they are in the position desired.

To set the alarm point, press the ALARM SET pushbutton on the front panel of the Model 911 Control Unit. The display(s) will indicate the alarm set point as a % of full scale of the parameter being monitored, either dew point, ambient temperature, or % RH. Since the standard dew point and ambient temperature ranges are from −40°C to +60°C or a 100°C spread, then the alarm set point as a percentage of full scale is determined by adding 40 to the desired set point temperature. For instance, if the desired set point for either dew point or ambient temperature is 0°C, then the alarm set point as a percentage of full scale is 40%. Similarly, a +10°C alarm set point corresponds to 50% of full scale.

When the ALARM SET pushbutton is in, the switch color changes from black to yellow. At the same time, the display(s) will indicate character A to the right of the decimal data and the decimal data will indicate the set point as a percentage of full scale. Adjustment of the set point is accomplished by adjusting the potentiometer Rx on the left side of the Alarm Set Board. Use care to NOT adjust one of the other potentiometers on the board by mistake. Once the adjustment has been made, push the ALARM SET pushbutton again so that the black color shows and the front panel display(s) again indicate data

Since the relative humidity output is on a percentage basis already, the alarm point for the % RH output can be set directly.

Depressing the ALARM SET switch to display the alarm set point does not affect the operation of the Model 911 Digital Humidity Analyzer or the analog output of dew point and ambient temperature. However, the BCD outputs from the Model 911-BC option will change and indicate the alarm set point. The % RH digital and analog outputs will go to 99.9% RH for as long as the alarm set point is being displayed.

The 4-20 MA option is available at rear connector P13, Pin M (+), and Pin C (return). Normal supply voltages (+5 Ref and −4 V) have been deleted from this connector with the installation of this option. The 4-20 MA output corresponds to the instrument range of −40°C to +60°C (−40°F to +140°F). The transfer functions for Dew Point and Ambient Temperature are:

(MA output x 6.25) — 65 = DP or AT in degrees C

(MA output x 11.25) — 85 = DP or AT in degrees F

The transfer function for Relative Humidity is:

(MA output x 6.25) — 25 = % Relative Humidity

3.2.2.5 Model 911-RH COMP[illegible] [illegible]H Computer Option

This option provides the Model 911 Digital Humidity Analyzer with the capability to display percentage or relative humidity based on the dew point and ambient temperature inputs. The dew point data are provided by the Model 911 Sensor. The ambient temperature data are provided by either the Model 911-AT Ambient Temperature Accessory or an externally provided analog input voltage corresponding to temperature. At the same time, an analog output voltage of 0 to +10 VDC is provided at the Model 911 Control Unit output on J13-U corresponding to 0 to 100% relative humidity.

Multiplexed 3-digit BCD % RH data are also provided at the rear output connector of the Model 911 Control Unit. These data are provided by Q_00, Q_01, Q_02, and Q_03. Q_00 is the Least Significant Bit (LSB) of each digit and Q_03 is the Most Significant Bit (MSB) of each digit.

Digit Select DS20 goes high to signify that the data on Q_00 to Q_30 at that moment correspond to digit two. Similarly, Digit Select Output DS30 indicates when the data on Q_00 to Q_30 correspond to digit three. Finally, Digit Select Output DS40 is high for output data for digit four. Digit Select Output DS10 is not used. Digit two is the most significant digit.

The % RH multiplexed digital data should be strobed into external hardware on the trailing edge of the appropriate Digit Select signal. The Digit Select lines and output data lines operate between 0 volts and +5 volts DC, but are C/MOS rather than T^2L compatible.

Percentage of RH is indicated on the front panel display by depressing the % RH pushbutton switch on the front panel of the Model 911 Control Unit. Character H will appear to the right of the decimal digits, indicating that the display is providing % humidity.

3.2.2.6 Model 911-AT Ambient Temperature Accessory

When equipped with the Model 911-AT Accessory, the Model 911 Digital Humidity Analyzer will measure the ambient temperature sensed by the remote Platinum Resistance Thermometer (PRT) included in the accessory kit. The PRT cable should be attached to the Model 911 Control Unit rear panel connector J13 in the following manner:

Wire		Connector
PRT Cable Drain (shield)	to	J13-11
PRT Cable Red	to	J13-17
PRT Cable Black	to	J13-T
PRT Cable White	to	J13-V

To display ambient temperature, depress the AMB TEMP pushbutton.

3.2.2.7 Model 911 with 660 S2 Sensor

The Model 911 Humidity Analyzer may optionally be equipped with a Model 660 S2 Sensor. (Any reference in the Manual to the Model 911 S1 Sensor should be considered with the data contained in this paragraph.) The required changes to the system operation and adjustments are detailed here.

The Model 660 S2 Sensor can be used in place of the Model 911 S1 Sensor when the dew point range or the ambient temperature range is beyond the specifications of the Model 911 S1 Sensor.

The dew point range of the Model 660 S2 Sensor is −50°C to +100°C and the ambient temperature range is −50°C to +100°C. Two separate sets of LEDs and phototransistors are used in the sensor. One set is used to illuminate the mirror surface and to detect the reflected light from the mirror. The second set is located within the sensor and serves as bias controls on the effects of temperature changes on the LED output intensity and phototransistor gain. The combined outputs of the direct and bias phototransistors are used to drive the thermoelectric dew point temperature control amplifier circuit.

Mirror Cleaning

To clean the mirror surface in the Model 660 Sensor, remove the spin-off cover from the sensor to expose the mirror.

CAUTION

If operating with a pressurized sampling system, remove pressure from the sensor prior to removing the sensor spin-off cover.

When the cover has been removed, lightly dampen a Q-tip with Type A cleaner. Both are provided in the Cleaning Kit shipped with the Model 911. Do not use an excessive amount of cleaner on the Q-tip. Shake the Q-tip to remove all excess fluid prior to cleaning the mirror surface. After cleaning the mirror surface, remove all traces of the cleaning fluid with the dry end of the Q-tip. If particulate matter is present around the mirror surface and it is desired to remove it, use a clean, dry Q-tip, not Type A cleaner, for this purpose.

For those applications where the Type A cleaner appears to be ineffective in removing hard deposits or varnishes, a polishing paste — Semichrome Polish (Competition Chemicals, Iowa Falls, Iowa 50125) — may be used sparingly.

If the optical section of the sensor is protected with a glass window, clean the window with a dry Q-tip.

Coolant Connections

For most applications, the Model 660 Sensor can be operated without the need for auxiliary cooling of the sensor base. The sensor measures the dew point of gases where the dew point is as low as −35°C when the sensor is attached to the Control Unit, and when the Control Unit is in an ambient temperature of +25°C or less. Low flow rates of the sample gas aids in reading even lower dew point temperatures because the heat load of the sensor mirror surface is reduced as the sample gas flow rate is reduced.

However, for those applications where dew point temperatures approaching −40°C to −50°C are experienced, it is necessary to lower the base temperature of the sensor to augment its cooling capability. This can be accomplished by providing coolant to the integral brass coolant jacket that forms the base of the sensor. This coolant can be ordinary tap water, chilled water, or even a chilled antifreeze solution such as ethylene glycol or methanol. Typically, coolant at 5°C or less will be sufficient to enable the sensor to indicate dew point temperatures at −50°C and lower. Coolant flow rates of 0.5 GPM (2 LPM) are adequate. The coolant pressure maximum rating is 100 psia (70 Kg/cm²). Connections for the coolant are made to the brass coolant jacket of the sensor by means of 1/8-27 NPT fittings.

NOTES

Where the coolant temperature is below the dew point temperature of the atmosphere surrounding the Control Unit and sensor, the sensor should be unfastened from the rear of the Control Unit and allowed to attain the temperature of the coolant by itself. This prevents condensation from forming on the rear portion of the Control Unit, as would normally happen if it were colder than the dew point of the surrounding atmosphere. The use of the optional Remote Mounting Kit will also allow the sensor to operate at lower, as well as higher, temperatures than the Control Unit.

Always maintain sensor temperature at least 5°C above the dew point temperature of the gas being measured.

System Adjustments

Since the Model 660 S2 Sensor is a two LED/Phototransistor system, which is different from the Model 911 Sensor, a Model 660 Sensor Interface card is used. This multipurpose card plugs into slot J5. (See paragraph 1.2.2 for details.) In addition, other changes have been made to the Main Circuit Card to accommodate the Model 660 Sensor. Consult the factory, if required, for details.

LED Current Adjustment

Two Light Emitting Diodes (LEDs) are used to illuminate a Bias Phototransistor and a Direct (reflected light) Phototransistor. The currents through the LEDs must be such that the phototransistors are not saturated from the LED light. LED current is set at the factory and usually no further adjustment is needed. However, there are two cases when an adjustment may be required: 1) if a new sensor is installed, and 2) if the system response seems poor.

Adjustment Procedure

1. Set the system to the Balance mode and clean the sensor mirror (see section "MIRROR CLEANING").
2. Use a Digital Voltmeter (DVM) to measure the voltage across R21 (100K) located on the Interface Card. Adjust the LED current potentiometer (see Figure 2-2) until the voltage is 12 VDC. If full clockwise rotation of the potentiometer will produce only between 7 and 12 VDC, the circuit is acceptable. Less than 7 VDC generally indicates a dull mirror or contamination of the surface of the LEDs or phototransistors.

Balance Adjust

Balance adjust potentiometer R22, located on the Interface Card, is used to balance the output signal from the phototransistors when the sensor mirror is clean and dry. This potentiometer is adjusted at the factory and normally needs further adjustment only if 1) a new sensor is installed, or 2) if the mirror is cleaned after being heavily contaminated.

1. Set the system to the Balance mode and clean the sensor mirror (see section "MIRROR CLEANING").

2. A two-section switch is located next to the Balance potentiometer. Section 1 is not used. Section 2 is used to open the Compensation circuit when making this adjustment. Normally, the end of the switch with the number "2" on it should be depressed. For now, depress the other end of the switch.
3. Connect the small test hook, normally connected to TP6 on the Main Circuit Card, to the test point on the Interface Card. (Note that the C/F switch on the Main Circuit Card must be in the C position — released — to use the test hook as a voltage probe.)
4. Adjust the Balance potentiometer to obtain 00.0 on the front panel display.
5. Reconnect the small test hook to TP6.
6. Depress the end of the dual switch with the number "2" marked on it.

Compensation Adjust

The Compensation control is a single turn potentiometer located on the Interface Card. It is provided to introduce phase lead into the amplifier circuit to compensate for the thermal phase lag characteristics of the thermoelectric cooler in the sensor. Introduction of this phase lead into the optical system and mirror temperature control loop permits the loop to be operated at a higher gain setting without oscillation, resulting in improved dynamic performance. The frequency response of this compensation network is such that it is effective primarily at dew points above 0°C.

The Compensation control has been set at the factory for optimum dynamic response at ambient dew point temperatures. However, if oscillation of the dew point temperature is noticed, adjustment may be accomplished when the Model 911 is operating in the presence of a dew point sample at the highest dew point anticipated. If the dew point temperature has a slow oscillation, with the Control Condition meter fairly constant, rotate the Compensation potentiometer clockwise in about 1/8th turn increments until the oscillation stops. Wait 2 to 3 minutes between settings to allow the system to stabilize. If the Control Condition meter indicates wild swings from left to right, or even mild continuous oscillations, rotate the Compensation potentiometer counterclockwise in 1/8th turn increments until oscillation stops. Wait 2 to 3 minutes between settings to allow the system to stabilize. After obtaining a stable operating point, and before returning to normal operation, always depress the BAL/OPR switch and allow the mirror to heat up for 3 to 4 minutes.

0-10 V Outputs

Because the Model 660 Sensor has an extended range, the 0-10 V output circuit has been modified to provide the 0-10 V output over the full range of −50°C to +100°C. If the AT option is supplied, its 0-10 V output also covers this same range.

SECTION 4

CIRCUIT DESCRIPTION

4.1 BASIC INSTRUMENT BLOCK DIAGRAM DESCRIPTION

NOTE

If the Model 911 Automatic Balancing Control option is used, refer to paragraph 4.2.7 before proceeding with this section.

Operation of the Model 911 Digital Humidity Analyzer is best understood by reference to the block diagram, Figure 4-1.

AC power is applied to the Model 911 Control Unit via cable W4, the power cable, and P1/J1 on the Main Circuit Card. AC power passes through a fuse to the POWER switch. The fuse should be a 3/4 amp Slo-Blo when operating on 115 VAC or a 3/8 amp Slo-Blo when operating on 230 VAC. When switched on, AC power is applied to isolating, step-down transformers mounted on the chassis of the Model 911 Control Unit via J1/P1 and W3. A portion of this isolated lower voltage AC is then passed back to the Main Circuit Card where it is rectified, filtered, and regulated to produce the system operating voltages of ±15 VDC, +5 VDC for reference purposes and +5 VDC for logic purposes. The rectifiers and Model 911 Sensor power components are also located on the chassis.

When energized, the Model 911 Dew Point Control Loop monitors and controls operation of the Model 911 Sensor under control of the BAL/OPR switch. CONTROL CONDITION meter monitors operation of the control loop and indicates to the operator such factors as mirror heating, mirror cooling, and balance condition. Dew Point Control Loop energizes the Light Emitting Diode (LED) light source in the Model 911 Sensor with a constant current source and responds to the impedance of a photoresistor that changes with the condition of the Model 911 Sensor dew point mirror surface as well as with the amount of dew on the mirror surface when the instrument is controlling on the dew point.

The Model 911 Sensor operates to measure the dew point temperature by directing the light from the LED reflected from a polished mirror surface to the photoresistor. When in the BAL (balance) mode, the mirror surface is heated to ensure that no condensate is present on the mirror surface. This heating of the mirror surface is accomplished by energizing, in the proper direction, the thermoelectric module attached to the mirror surface.

It is during this time that the balance condition of the Model 911 Sensor is established by adjusting the BALANCE control knob on the front panel until the CONTROL CONDITION meter indicates in the center section of the scale. In OPR (operation), the thermoelectric module attached to the mirror surface in the sensor is caused to reduce the temperature of the mirror surface until it is below the dew point temperature of the gas sample passing over it. The presence of dew on the mirror surface results in a scattering of the light from the LED source which is detected by the photoresistor as a reduction in light level. This reduction in light level is used by the Dew Point Control Loop to hold the mirror temperature at exactly that temperature required to maintain a layer of dew (frost if below 0°C) on the mirror surface in equilibrium with the gas sample. Changes in the dew/frost point are automatically tracked by the Dew Point Control Loop to maintain the equilibrium dew/frost layer. Since the mirror surface is being held at the dew/frost point when in the OPR mode, a Platinum Resistance Thermometer (PRT), embedded just beneath the mirror surface, measures the mirror temperature. This PRT is interfaced with the PRT AMP that converts the resistance of the PRT to a voltage. This voltage is such that 1 volt equals 10°C and is adjusted to provide two parallel outputs for external recording and monitoring purposes: −4 VDC to +6 VDC over the range of −40° to +60°C and 0 VDC to +10 VDC over the same range. The PRT AMP measures the mirror surface temperature at all times, even during the periods of heating when in the BAL mode.

In addition to providing analog outputs for the dew/frost point temperature, the analog output signal of −4 to +6 VDC is also applied to an Analog to Digital Converter (ADC) for conversion to Binary Coded Decimal (BCD) information that can be used for display purposes and as inputs for the Model 911-BC BCD Output Module Option. In the basic Model 911 Digital Humidity Analyzer, the BCD output of the ADC is presented to socket DP1 (J8) and socket DP2 (J9). Cable W2 connects J9 to J10 on the Liquid Crystal Display (LCD) module.

NOTE

When only the basic LCD is used, it is plugged into socket DP2 (J9) which allows the single display to display the parameter selected by the front panel pushbutton controls: DEW POINT, AMB TEMP, or % RH. (The Model 911-AT Ambient Temperature Accessory is required for AMB TEMP and the Model 911-RH COMP™ RH Computer is required for % RH.) When the Model 911-RD Readout Display Option is used, then the left-hand display should be plugged into socket DP1 (J8) and the right-hand display into socket DP2 (J9). This causes the left-hand display to indicate dew point at all times, whereas the right-hand display will then display data as selected by the pushbutton controls.

4.2 OPTIONAL CIRCUITS DESCRIPTION

The usefulness of the basic Model 911 Digital Humidity Analyzer is expanded by the use of plug-in options. On the Digital Humidity Analyzer block diagram, Figure 4-1, each plug-in option or accessory is indicated by an asterisk (*). The operation of each device is discussed separately in the following paragraphs.

4.2.1 Model 911-BC BCD Output Module Option

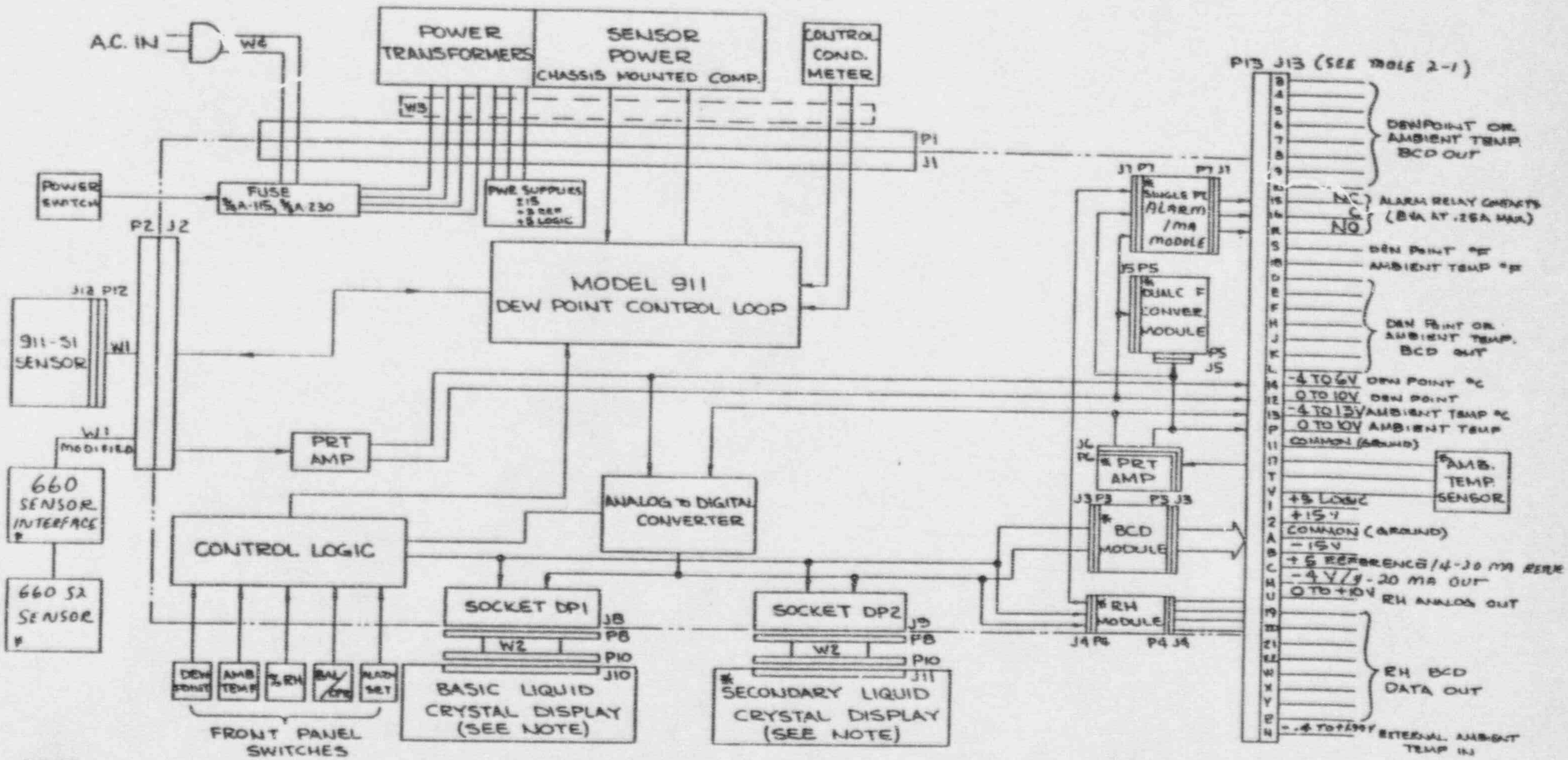
As discussed in the operation of the basic Model 911, the Analog to Digital Converter (ADC) produces a multiplexed Binary Coded Decimal (BCD) output based on its analog input. The analog inputs to the ADC are alternated between the dew point analog data and the ambient temperature analog data. The multiplexed BCD outputs are applied to the Model 911-BC socket J3. When the BCD Output Module is plugged into J3, the module will demultiplex the BCD inputs for either dew point or ambient temperature as selected by a switch located on the BCD Output Module. The demultiplexed data are stored in parallel latches and output buffers are used to produce 3-1/2 digit T^2L compatible outputs with sign information.

4.2.2 Model 911-AT Ambient Temperature Accessory

This accessory consists of a plug-in circuit card that plugs into J6 on the Main Circuit Card of the basic Model 911 Control Unit. This plug-in circuit card contains a PRT AMP similar to the one used for the PRT of the Model 911 Dew Point Sensor. The ambient temperature measuring PRT is attached to the basic Model 911 Control Unit at rear output connector P13. The PRT AMP converts the resistance of the ambient temperature PRT to a voltage such that 1 VDC equals 10°C and is adjusted to provide two parallel outputs for external recording and monitoring purposes: −4 VDC to +6 VDC over the range of −40° to +60°C and 0 VDC to +10 VDC over the same range. Actually, the ambient temperature capability is linear and is usable to +130°C (+13 VDC), although the corresponding 0 to 10 volt output will fail before this point is reached.

4.2.3 Model 911-CF °F Readout Capability Option

This option plugs into J5 of the Main Circuit Card of the basic Model 911 Digital Humidity Analyzer and accepts the analog inputs from dew point PRT AMP and ambient temperature PRT AMP (if so equipped) and converts them to analog voltages corresponding to degree Fahrenheit temperatures instead of the degree Celsius temperatures that are standard. These °F outputs are in addition to the °C outputs. Both types of outputs appear simultaneously at the rear output connector. The °F outputs are −0.4 VDC to +1.4 VDC corresponding to −40 to +140°F (−40 to +60°C). Two identical channels of con-



NOTE:
WHEN ONLY ONE DISPLAY IS USED, PLUG THE BASIC DISPLAY INTO SOCKET DP2. IF TWO DISPLAYS ARE USED, PLUG THE BASIC DISPLAY INTO SOCKET DP1 AND THE SECONDARY INTO SOCKET DP2.

* DENOTES OPTIONS

FIGURE 4-1. MODEL 911 DEW-ALL DIGITAL HUMIDITY ANALYZER BLOCK

version are provided. The °F analog outputs are provided to °C/°F switch S7 on the Model 911 Main Circuit Card so that °F information can be displayed on the LCDs on the front panel. When °F data are selected for display, the output of the Model 911-BC BCD output module will be °F information also. The analog output of the ambient temperature channel will go to +2.66 volts corresponding to +266°F (+130°C), which is the maximum °C output of the ambient temperature circuitry. However, the digital output for °F on the front panel display and the BCD outputs for °F are limited to +199.9°F (1.999 VDC on the °F analog output).

4.2.4 Model 911-RH COMP™ RH Computer Option

This option plugs into J4 on the Main Circuit Card. It accepts the BCD data for dew point and ambient temperature from the ADC on the Main Circuit Card. A microprocessor used in conjunction with a program stored in fixed memory computes the corresponding % RH equivalent based on these inputs. Three-digit, multiplexed BCD outputs corresponding to % RH are provided at rear panel connector J13 as well as an analog voltage signal of 0 to 10 VDC corresponding to 0 to 100% RH.

Computation of % RH performed by the microprocessor under program control is based on a modified Goff-Gratch relationship for the saturation vapor pressure of water. All dew point inputs below 0°C are assumed to be frost point and are converted to dew point prior to being included in the computation.

4.2.5 Model 911-AS/MA Module Option

This option plugs into J7 on the Main Circuit Card of the Basic Model 911 Digital Humidity Analyzer. Analog inputs of 0 to 10 VDC dew point, ambient temperature, and % relative humidity are applied to the inputs, along with a comparable input from the alarm set control. Switches on this option card select which parameter the alarm set point will monitor or which parameter will be used to produce a 4-20 MA output current. Either dew point, ambient temperature, or % relative humidity can be selected. A comparator circuit compares the alarm set point input with the input from the selected parameter. When the input from the selected parameter exceeds the alarm set point input, the alarm relay will operate and change state, thereby indicating this fact to external monitoring equipment.

4.2.6 Model 911-RD Readout Display Option

This option mounts behind the front panel of the basic Model 911 Digital Humidity Analyzer and is plugged into socket DP2 (J9) on the Main Circuit Card of the Model 911. The BCD outputs of the ADC or Model 911-RH COMP™ RH Computer Option will be converted to the appropriate 7-segment signals necessary to illuminate the LCD. Pushbutton switches DEW POINT, AMB TEMP, or % RH determine which parameter will be displayed at any given time. The appropriate options must be provided to enable ambient temperature or % relative humidity to be displayed.

4.2.7 Model 911 Automatic Balancing Option

NOTE

> For this option, the Balance potentiometer has been removed, the BAL/OPR switch has been disabled, and the SEN CAL potentiometer requires special adjustment procedures as detailed in paragraphs 6.3.3 and 6.3.4, pages 6-4 and 6-5 of Section 6.

Some Model 911 Digital Humidity Analyzers have been equipped with an option that allows for unattended operation for long periods of time without requiring manual balance adjustment to account for changes in the sensor reflectivity. In addition, a Track and Hold feature has been included to provide a constant voltage at the output during the automatic balancing procedure to effectively mask the mirror temperature excursions during balance.

Features of the Automatic Balance Option:

- Automatic initiation of balance function adjustable from 1 hour to 31 hours in increments of 1 hour.
- Front panel manual initiation of the balance function.
- Remote initiation of balance function via rear panel connector.
- Illuminated manual initiation switch indicates the balance function (steady illumination) as well as the Track and Hold function (blinking illumination) that continues during and after the balance function.
- Three different time periods for the balance function can be selected.
- Digital Logic Alarm indicator for remote detection of when the mirror conditions cannot be balanced (mirror too dirty).
- Track and Hold analog output at rear panel connector simultaneously with the direct analog output.
- Front panel displays and RH COMP options may be operated from either the Track and Hold or the direct analog output.
- Front panel alarm indicator to indicate when mirror is too dirty for proper re-balancing.
- Switch to optionally select maximum cooling (pre-cool) just prior to re-balance.

The Model 911 Automatic Balance Circuitry (ABC) is fabricated on an L-shaped board that is installed behind the Model 911 front panel and supported by three standoffs attached to the bottom of the Model 911 chassis. The pushbutton for manual initiation of the ABC is located on the front panel directly beneath the BAL/OPR switch. When the ABC option is installed, the BAL/OPR switch is disabled.

Connection from the ABC to the main circuit card mounted above the ABC is made by means of a 24-conductor ribbon cable. A 24-pin connector on this cable plugs into the ABC card.

Programming of the Model 911 ABC option is accomplished by means of an 8-pole switch mounted on the ABC card. This switch is accessible for programming through a large hole in the bottom of the Model 911 chassis. It is not necessary to remove the Model 911 cover to effect the programming.

Prior to using the Model 911 with the ABC option, the programming should be set up. The eight levels of the switch allow you to accomplish the necessary programming.

The 8-level switch is labeled from 1 to 8. The first five switches (1-5) are used to select the period of automatic self-initiation of ABC. Each switch is "weighted," that is, each switch from 1 to 5 has a value associated with it in hours as follows:

Switch Number	Switch "Weight" In Hours
1	1
2	2
3	4
4	8
5	16

Each switch that is closed contributes its "weight" to the time period between each automatic self-initiated ABC. If, for instance, it is desired for ABC to occur every 6 hours, then switches 2(2) and 3(4) would be closed and switches 1, 4, and 5 left open. If every 4 hours were desired instead, then only switch 3 (4 hours) would need to be closed. From this, the time for automatic self-initiation of ABC can be selected to range from once every hour (only switch 1 closed) to once every 31 hours (switches 1-5 closed). If no switches are closed, then the ABC function can only be initiated either manually from the pushbutton on the front panel or remotely by means of the rear panel connnector. A switch is closed by pushing down on the end of the switch marked with a bar. Opening of a switch is accomplished by pushing down on the unmarked end of the switch. Any small pointed object such as a pencil point or a small screwdriver can be used to operate the switches. The ABC function should always be performed at power turn on. This should occur automatically. Remote initiation of the ABC function can be made by temporary application of 15 to 25 volts DC to pin N of the rear panel connector. The ABC function

will not begin until the initiation voltage is removed. When it is desired to initiate the ABC function remotely, programming switches 1 to 5 should be left open or should be set to a time period greater than that anticipated from the external source, in which case internal automatic ABC function initiation would occur in the absence of an external command.

The remaining three switches of the 8-pole programming switch are used to select the time period for the ABC function and the time the Track and Hold circuitry is to remain in Hold during and after the balance cycle.

NOTE

At least one of switches 6, 7, or 8 should be closed at all times but **never** more than one.

If none of switches 6 to 8 are closed, the ABC function will halt and remain in its present state until one of the switches is closed. The time periods selected by each of switches 6 to 8 are as follows:

Switch Closed	Balance Portion of Cycle	Hold Portion of Cycle After Balance	Total Cycle time
6	1.7 minutes	2.5 minutes	4.3 minutes
7	3.5 minutes	5 minutes	8.5 minutes
8	6.9 minutes	10 minutes	17.1 minutes

The switch position selected should be determined by the anticipated operating dew point. For dew points 10°C and above, close switch 6. For dew points between −10°C and +10°C, close switch 7. For dew points below −10°C, close switch 8. Remember that only one switch of switches 6 to 8 should be closed at any one time.

The 911 ABC board has a small red switch mounted on it which can be reached through an access hole in the bottom side of the Control Unit. When the slide on the switch is moved toward the number "1" printed on the switch, the instrument is in the "normal" operate mode. When the slide on the switch is moved to the position *away* from the "1," the system will go into a maximum cool mode of operation prior to the mirror heating mode whenever ABC is initiated. The ABC still functions as detailed elsewhere in this paragraph. However, it is suggested that switch position 7 or 8 be closed on the ABC board (see above table) so that the Sensor Mirror can be fully dry before the ABC cycle ends. A Light Emitting Diode (LED) has been added to the front panel. The purpose of this diode is to give local indication that the ABC was unable to complete the balance cycle. The LED is turned on by the same logic signal found at Pin 18 of the rear connector. Normally the LED should be off. If it comes on, the dew point sensor mirror should be cleaned. The LED can be reset to "off" by initiation of the ABC function from any normal source.

Output Connector Changes

To provide for the extra features afforded by the Model 911 ABC option, the pin assignments for the output connector have changed in the following cases:

PIN N Formerly used for direct analog ambient temperature input line. This function has been disabled. This pin is now used for the remote or external ABC function initiate signal. A DC voltage applied to Pin N that is between 15 and 25 VDC will initiate an automatic balance cycle. If not used, this pin can be left open.

PIN S Formerly used for the dew point temperature analog output for °F if the Model 911 C/F option was installed. This function has been disabled. This pin is now used for the dew point analog output corresponding to the output of the Track and Hold circuitry.

PIN 18 Formerly used for the ambient temperature analog output for °F if the Model 911 C/F option was installed. This function has been disabled. This pin is now used to indicate that the ABC

was unable to properly complete the balance cycle. This output is a CMOS logic level. Normal operation is indicated by a low (ground) output on this pin. If the circuitry is unable to complete the balance properly, this output will be brought high (+5 volts) to indicate to customers' external equipment that the dew point sensor mirror should be cleaned. This alarm signal is reset by initiation of the ABC function from any source.

Operation

As mentioned previously, the Model 911 ABC programming should be set up initially before the instrument is placed in operation. The programming may be altered at any time without turning power off. ABC should always be initiated following power turn on.

After power turn on and during the first balance cycle, the output of the Track and Hold circuitry will be invalid since there is no previous dew point information to be remembered.

In addition to providing analog outputs for the direct output and the Track and Hold output, the Model 911 also provides for front panel digital display as well as other options for °C to °F, RH COMP for %RH calculations, and BCD for parallel BCD outputs. These additional outputs now have the choice of being driven either from the direct dew point analog signal or from the output of the Track and Hold circuitry. This choice is made on the Model 911 Main Circuit Card. Normally, the test hook that is used to allow the Model 911 output digital display to act as a voltmeter is attached to TP6. TP6 has on it the direct analog output for dew point and if the test hook is attached to TP6 the digital display and the 0 to 10 volt output plus the options previously mentioned will be driven by the direct analog output. This means that the values displayed will reflect the temperature of the mirror in the dew point sensor at all times, even during the balancing cycle when the mirror is heated to remove dew from the mirror for balancing purposes.

With the addition of the ABC option to the Model 911, a new test point TPX has been added, physically located behind potentiometer R63. By attaching the test hook to TPX instead of TP6, the input to the digital display, the 0 to 10 volt output, the RH COMP option, and the BCD option will be driven from the Track and Hold analog output. Therefore, these outputs will remain steady during a balance cycle as the output signal is held at the level it was previous to the initiation of the ABC function.

SECTION 5

INTERPRETATION OF DATA

5.1 DESCRIPTION OF OUTPUT DATA

The Model 911 Digital Humidity Analyzer measures the dew/frost point of the gas sample flowing through the Model 911 Sensor. This measured data is displayed on the front panel digital display and is also provided at rear panel connector J13 in analog form. The front panel display also indicates the type of data being displayed; the character following the decimal digits is used to describe the data being displayed at any given time.

C indicates temperature in degrees Celsius (Figure 5-1)
F indicates temperature in degrees Fahrenheit (Figure 5-2)
A indicates Alarm Set point as a percentage of full scale (Figure 5-3)
H indicates percentage of relative humidity (Figure 5-4)

In addition, the annunciator arrow on the displays indicates when the instrument has been placed in the BAL (balance) mode (Figure 5-5). When the annunciator arrow is illuminated, the dew point temperature indication is really a measure of the mirror temperature in the sensor, which is being heated and is generally well above the true dew/frost point temperature. When the annunciator arrow is not illuminated, the instrument is in the OPR (operate) mode and the temperature output for dew point may or may not be at the true dew/frost point temperature. The dew point temperature reading is likely to be correct when the answers to the following questions are affirmative.

1. Is the gas sample in the Model 911 Sensor uncontaminated and representative of the gas to be measured?
2. Is the flow rate between 0.5 SCFH and 5 SCFH?
3. Is the dew point of the gas within the measuring range of the instrument with regard to temperature and depression requirements?
4. Does the hygrometer CONTROL CONDITION meter pointer return to the balance point (center scale) when the instrument is placed in the BAL mode?
5. Does the hygrometer exhibit the proper dynamic behavior when switched from the BAL to the OPR mode?
6. For a constant sample, does the hygrometer repeat the reading after balancing in the BAL mode and returning to the OPR mode?
7. Is the water vapor dew point the highest dew point in the measured gas? (Occasionally, a higher dew point of another vapor constituent exists and the instrument will measure this higher dew point. High hydrocarbon dew points are often encountered.)

With reference to Question 5, the proper dynamic behavior is as follows:

After switching to the BAL position, enough time is allowed to let the water film evaporate from the mirror surface. This is indicated by the movement of the CONTROL CONDITION meter pointer toward the center scale position. When the CONTROL CONDITION meter pointer position is at the maximum point to the right that it will reach and is stable (for about one minute), the BALANCE knob is adjusted for a center scale reading. Then, the front panel control switch is placed in the OPR position, whereupon the CONTROL CONDITION meter swings to the far right and the sensor mirror temperature dew point output shows a decreasing mirror temperature.

When the mirror reaches the dew point temperature, it continues to cool slightly below this temperature (overshoots by 2 to 5°C). At this point, the CONTROL CONDITION meter begins to move to the left and the indicated mirror temperature rises and settles on a stable reading of the dew point. The amount of overshoot and the amount of time required to settle on the correct dew point reading varies from

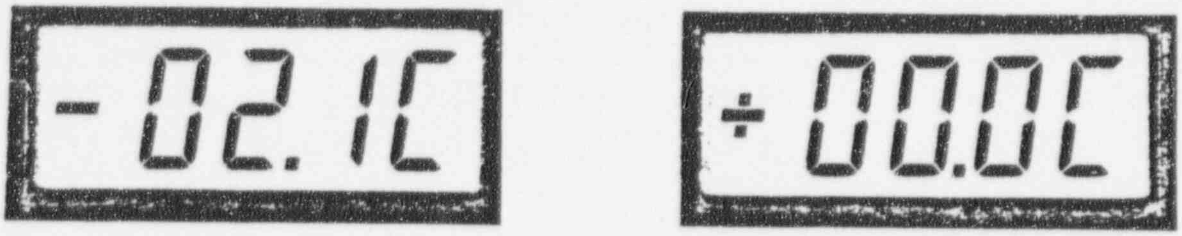


FIGURE 5-1. DISPLAYS INDICATING DEGREES CELSIUS

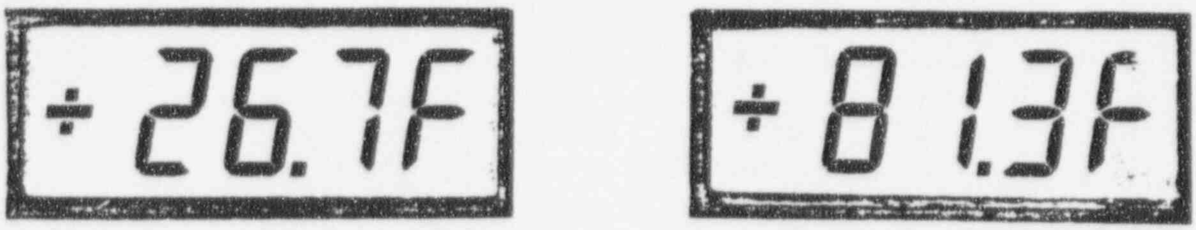


FIGURE 5-2. DISPLAYS INDICATING DEGREES FAHRENHEIT

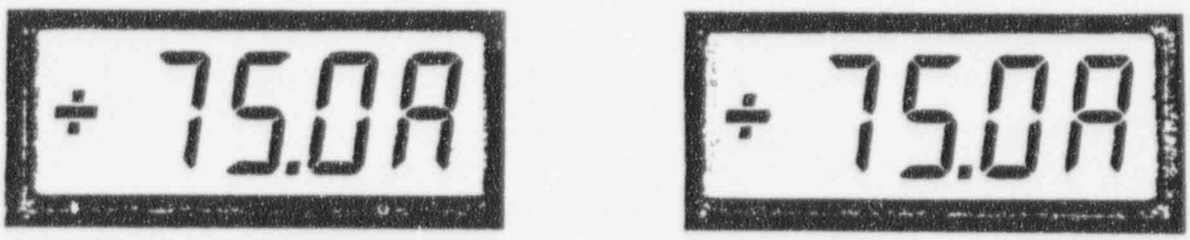


FIGURE 5-3. DISPLAYS INDICATING ALARM SET POINT

FIGURE 5-4. DISPLAYS INDICATING % RELATIVE HUMIDITY

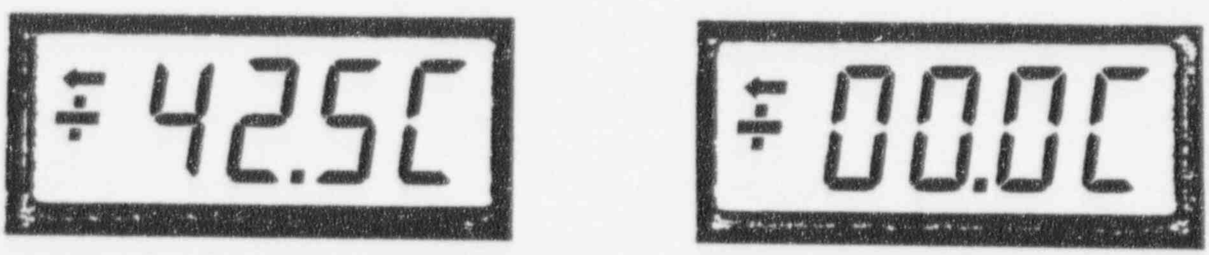


FIGURE 5-5. DISPLAYS INDICATING BAL MODE

1 or 2°C and about 10 seconds at high dew points and high flow rates, to 10 or 20°C and up to 10 minutes at the lowest dew points and low flow rates.

Under certain conditions, the control system oscillates at a rate of several seconds per cycle. This occurs at high dew points and high flow rates. If the deviation of the mirror temperature is one or two degrees, no action need be taken and the temperature can be averaged. The oscillation can usually be eliminated by reduction of the sample flow rate. In some cases, the internal dew thickness (THK) setting or the GAIN setting may have to be lowered to reduce or prevent these oscillations.

5.2 OUTPUT DATA BELOW 0°C (32°F)

At mirror temperatures below 0°C (32°F), the water on the mirror surface can be ice or can be supercooled liquid. Generally, it is in the form of supercooled liquid only for a short time, i.e., when the temperature is not far below the freezing point, but, eventually, it transits to the ice state. This fact is significant because, for a given gas sample with fixed vapor content, the temperature at which a surface of ice must be maintained to be in equilibrium with the water vapor is slightly higher than that for water. Dew Point/Frost Point relationships in both metric units (°C) and English units (°F) are shown in Section 7 of this manual.

5.3 OUTPUT DATA AT PRESSURES OTHER THAN ATMOSPHERIC

In a gas system where the sample goes through a pressure change, provided there is condensation due to the change, the change in water vapor pressure is proportional to the total pressure change and can be calculated from Dalton's law accordingly:

$$e_2 = e_1 - \frac{P_2}{P_1}$$

where e_2 is the partial pressure of water vapor at total pressure P_2, and e_1 is the partial pressure of water vapor at total pressure P_1. There is one-for-one correspondence between the partial pressure of water vapor (e) and the dew point temperature (Smithsonian Meteorological Tables).

A useful approximation is:

$$\Delta TD = 14 \frac{\Delta P}{P}$$

where ΔTD is the change in dew point temperature (°C) due to a change in sample pressure, ΔP is the change in sample pressure, and P is the sample pressure. Thus, a 10% change in pressure

$$\left(\frac{\Delta P}{P} = -\frac{1}{10} \right)$$

will result in about −1.4°C change in the dew point temperature.

5.4 ANALOG OUTPUT DATA

All analog outputs from the Model 911 Digital Humidity Analyzer are of the low impedance type, the output of an operational amplifier. The maximum load impedance should be greater than 10K for best results. If the cable lengths from the Model 911 outputs to the recording or monitoring equipment are long, the recording or monitoring equipment should be of the high input impedance type to reduce to a negligible amount any signal loss in the interconnecting cable due to current flow.

SECTION 6

MAINTENANCE

6.1 GENERAL

The Model 911 Digital Humidity Analyzer requires little maintenance due to its solid state design. The only components requiring periodic maintenance are the sensor and associated sampling system.

A Model 911 Sensor Cleaning Kit is shipped with each instrument. The Cleaning Kit consists of a small bottle of EG&G Type A cleaning fluid and a package of cotton swabs. Also included are spare fuses for both 115 and 230 VAC operation and an adjustment tool for adjusting the ALARM SET point or any Model 911 internal potentiometer adjustments.

6.2 PERIODIC MAINTENANCE

The sensor incorporates optical sensing devices and must therefore be maintained at some minimum level of cleanliness. The frequency of sensor cleaning required for proper maintenance will vary widely with sampling conditions. Cleaning the sensor can usually be ignored until an excessive balance shift or the inability to adjust the CONTROL CONDITION meter pointer back to the balance point make cleaning the sensor a necessity. In some cases, accumulation of soluble materials will result in high readings and the sensor should be cleaned more often. In the event that the sample is excessively dirty, the entire sample line and sensor should be cleaned and a filter (typically 5 to 10 microns) installed at the input to the sample line. In many installations, the sensor will require cleaning every 1000 to 2000 hours of operation. The presence of significant contamination on the mirror surface is evidenced by the fact that the CONTROL CONDITION meter pointer will not fall within the white color-coded band when the front panel control switch is placed in the BAL mode and any moisture on the sensor mirror surface has evaporated. A small shift is of no concern, however, and may be compensated for by adjustment of the BALANCE control by turning it in a clockwise direction. When contamination interferes with instrument operation or the BALANCE control is at the end of its range, clean the sensor as follows:

1. Remove the three sensor cover rim-screws and carefully draw the cover back and away from the sensor, exposing the sensor configuration.

   NOTE

   Save the three screws as they are special screws that ensure the pressure integrity of the Model 911 sensor cover.

2. If the inside of the sensor cover and the outer metal portions of the sensor are soiled, clean with isopropyl alcohol or chlorothene.
3. Clean the mirror surface using a cotton-tip applicator dampened with a very small amount of EG&G Type A Cleaner. If the Type A Cleaner is not available, isopropyl alcohol may be used. Clean the optical parts above the mirror and **lightly** buff the mirror with a dry, clean applicator. **Avoid scratching the mirror surface. The black material surrounding the mirror is a plastic foam insulating material which is soft and subject to damage under careless use and excessive use of cleaner.**
4. Reassemble the sensor after inspecting the O-ring and O-ring seal to be certain of achieving a gas-tight seal. Test for leaks if necessary after replacing the cover. (Be sure to use the same screws removed in step 1.)
5. Place the instrument into operation by following the operating instructions as described in Section 3, with the following exception when necessary. After cleaning or changing sensors, reset the SEN CAL potentiometer (R3) positioned on the Main Circuit Card as shown in Figure 6-1 inside the instrument as follows:

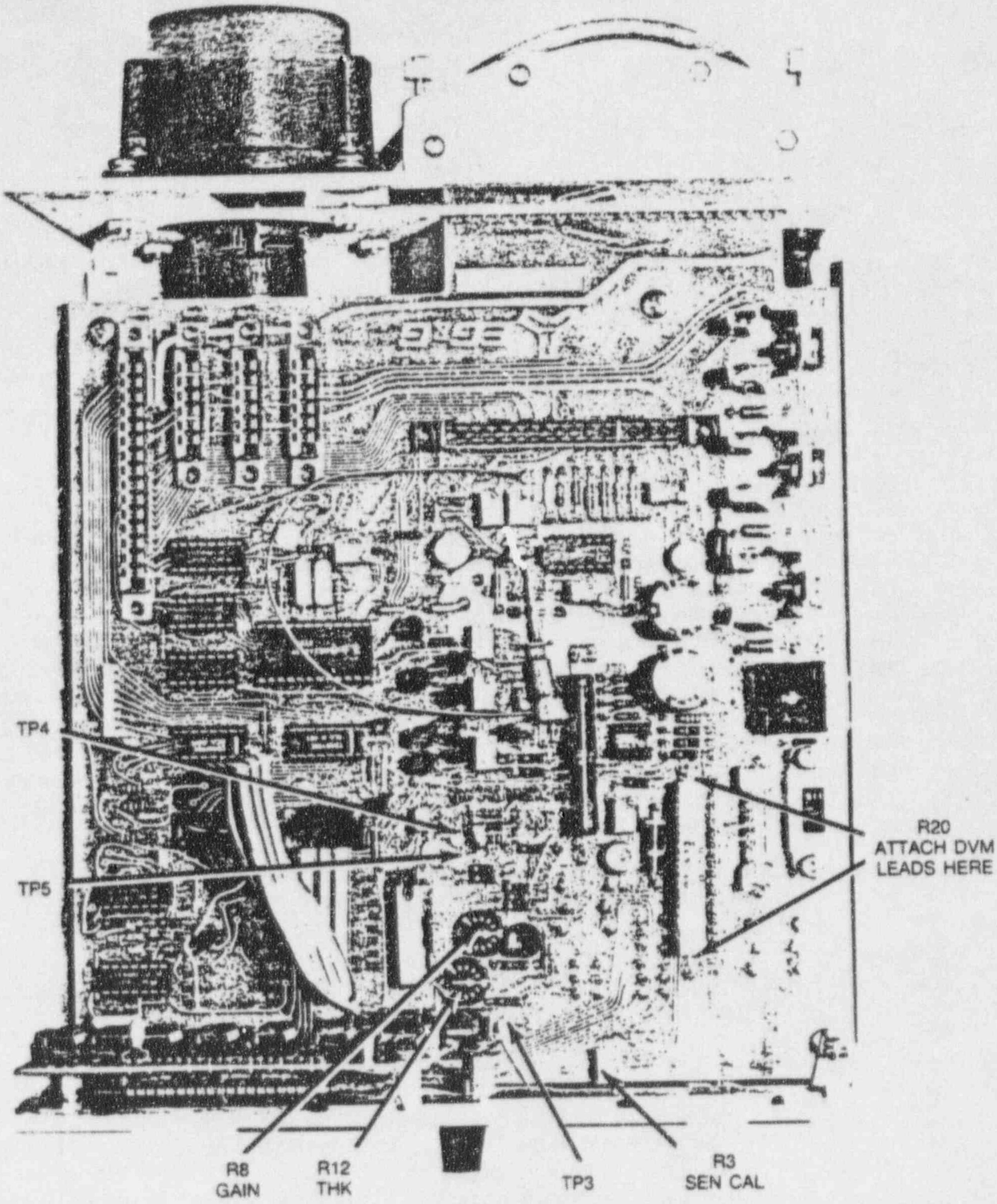


FIGURE 6-1. MODEL 911 MAIN ASSEMBLY

a. In step 3 of the operating procedure (page 3-2), set the BALANCE knob fully counterclockwise (control switch in BAL position).

b. Set the SEN CAL potentiometer (R3) so that the CONTROL CONDITION meter reads at the center of the scale.

c. Proceed to step 4 of the operating procedure.

6.3 DEW POINT CONTROL LOOP ADJUSTMENT

NOTE

The following procedure is used for adjusting the dew point control loop of the Basic Analyzer. If the Model 911 Automatic Balance Control (ABC) option is used, refer to paragraphs 6.3.3 and 6.3.4. If the Model 911 C1/660 S2 Sensor is used, refer to paragraph 6.3.5.

6.3.1 Adjustment of Basic Analyzer

The Model 911 Digital Humidity Analyzer internal adjustments are factory aligned and generally need not be readjusted unless a component has been changed. The adjustments in this section deal with the hygrometer dew point control loop circuit, CUR LIM, THK, GAIN, and SEN CAL.

The CUR LIM control is used to set the maximum current delivered to the cooler in the Model 911 Sensor. A setting too low will result in inadequate depression capability.

SEN CAL balances the photocell bridge circuit and the result is, essentially, the same as a coarse adjustment for the BALANCE control on the front panel.

The GAIN control sets the gain of the dew point control circuit. Excessive gain can cause oscillation while insufficient gain will result in sluggish operation or loss of adjustment sensitivity of the front panel BALANCE adjustment.

The THK adjustment sets the light level reduction from the Model 911 Sensor mirror which is required to start cutting off the cooler current; thus it sets the dew layer thickness during normal operation.

6.3.2 Adjustment Procedure for Basic Analyzer

1. To set the internal adjustments, start with a clean sensor mirror surface and aspirate the sensor with room air. The instrument should be in the BAL mode. Place the front panel BALANCE control fully CCW.

NOTE

Do not leave the Model 911 BAL/OPR control switch in the BAL position for more than 5 minutes. If this control switch has been in the BAL position for 5 minutes, set it to OPR for 2 minutes before returning to the BAL position.

2. Remove the cover from the Control Unit and place a digital voltmeter, set to read a voltage in the vicinity of 500 mVDC, across the leads of R20 (0.2 ohm) on the Main Circuit Card. Refer to Figure 6-1 for the location of the leads of R20.
3. With the front panel BAL/OPR switch in the BAL position, adjust the SEN CAL potentiometer (R3) (accessed through the front panel hole above the BAL/OPR switch) so that the CONTROL CONDITION meter (CC meter) indicates at the junction of the red and white portions of the meter scale. Then adjust the front panel BALANCE control slightly CW so that the CC meter indicates center scale.
4. Set the GAIN and THK potentiometers fully clockwise.

5. To set the CUR LIM potentiometer, place the BAL/OPR switch to the OPR position and quickly adjust the CUR LIM potentiometer for a DVM reading of 500 mVDC ±5 mVDC. Return the BAL/OPR switch to BAL as soon as possible after making the adjustment. Note that when the proper adjustment is made, the Model 911 CONTROL CONDITION meter indicates all the way to the right (blue).
6. Set the GAIN potentiometer fully CCW. Allow the mirror to heat up to above +25°C as indicated by the dew point temperature reading.
7. Set the control switch to OPR. IMMEDIATELY read the DVM and adjust the THK potentiometer (R12) so that the DVM indicates 150±10 mVDC. This adjustment must be made shortly after setting the control switch to OPR, as the DVM reading will drop with time as the system approaches the dew point. Return the switch to BAL as soon as possible after making the adjustment.
8. Short the THK potentiometer by connecting a short jumper from TP3 to TP5 on the Main Circuit Card.
9. Set the control switch to OPR. IMMEDIATELY read the DVM and adjust the GAIN potentiometer (R8) so that the DVM indicates 300 ±10 mVDC. This adjustment must be made shortly after setting the control switch to OPR, as the DVM reading will drop with time. Return the switch to BAL as soon as the adjustment is made.
10. Allow the Model 911 CONTROL CONDITION meter to stabilize at BAL for about 1 minute. Check that the meter is balanced. Readjust the SEN CAL potentiometer (R3) slightly if necessary.
11. Remove the jumper installed in step 9.
12. After the THK potentometer has been adjusted, observe the Model 911 dew point reading. The reading must drop smoothly and then stabilize with less than 5°C overshoot (if aspirating with room air; samples with very low dew points may cause an overshoot of 10°C or more). After 2 minutes, the dew point reading should not fluctuate.
13. If the dew point reading overshoot exceeds 5°C or fluctuates, the system is oscillating. Oscillation may also be indicated by the CONTROL CONDITION meter moving back and forth. Oscillation can be caused by excessive gain or excessively high sample flow rate. If oscillation occurs, reduce the sample flow rate to remove the oscillation.

6.3.3 Adjustment of Analyzer with Automatic Balance Control Option

The Model 911 Digital Humidity Analyzer internal adjustments are factory aligned and generally need not be readjusted unless a component has been changed. The adjustments in this section deal with the hygrometer dew point control loop circuit, CUR LIM, THK, GAIN, and SEN CAL.

The CUR LIM control is used to set the maximum current delivered to the cooler in the Model 911 Sensor. A setting too low will result in inadequate depression capability.

SEN CAL presets the photocell bridge circuit to a proper operating point for the Automatic Balance Control (ABC).

The GAIN control sets the gain of the dew point control circuit. Excessive gain can cause oscillation while insufficient gain will result in sluggish operation.

The THK adjustment sets the light level reduction from the Model 911 Sensor mirror which is required to start cutting off the cooler current; thus it sets the dew layer thickness during normal operation.

NOTE

To expedite the following adjustment procedure, it is suggested that the eight-level switch on the ABC board have only switch numbers 1 and 6 closed. (Refer to paragraph 4.2.7 for the ABC option if necessary.) After the procedure is completed, the switches can be reset to the desired positions.

6.3.4 Adjustment Procedure for Analyzer with Automatic Balance Control Option

1. To set the internal adjustments, start with a clear sensor mirror surface and aspirate the sensor with room air.
2. Remove the cover from the Control Unit and connect a digital voltmeter (DVM), set to read in the vicinity of 3 VDC, between TP4 and TP5 on the Main Circuit Card.
3. Set the Model 911 power to ON. The indicator in the Manual Initiate Switch should come on and be steady, indicating that the system is in the Balance mode.
4. Adjust the SEN CAL potentiometer, if required, to obtain 2.5 VDC ±0.1 on the DVM. The SEN CAL potentiometer is accessed through the Model 911 front panel just above the BAL/OPR and ALARM SET switches.
5. Remove the DVM leads from TP4 and TP5 and put them across the leads of R20 (0.2 ohm) on the Main Circuit Card. The DVM should indicate 0 VDC.
6. Set the GAIN and THK potentiometers, located on the Main Circuit Card just behind the front panel, fully clockwise (CW).
7. Allow the system to go into the Operate mode. (The indicator in the Manual Initiate Switch will start flashing.) As soon as it does, note the DVM. It should indicate 500 MV ±10 MV. If not, adjust the CUR LIM potentiometer (located next to the 0.2 ohm resistor) for 500 MV. Then, as soon as possible, depress the Manual Initiate Switch to put the system back into the Balance mode.
8. Set the GAIN and THK potentiometers fully CCW.
9. Allow the system to go into the Operate mode. Immediately read the digital voltmeter and adjust THK potentiometer R12 so that the digital voltmeter reads 150 ±1.0 mVDC. This adjustment must be made shortly after the system goes into Operate, as the digital voltmeter reading will drop with time. As soon as possible after making the adjustment, depress the Manual Initiate Switch to put the system back into the Balance mode.
10. Connect a short jumper between TP3 and TP5. This shorts out the thickness potentiometer.
11. Allow the system to go into the Operate mode. Immediately read the digital voltmeter and adjust GAIN potentiometer R8 so that the digital voltmeter reads 300 ±10 mVDC. This adjustment must be made shortly after the system goes into Operate, as the digital voltmeter reading will drop with time. As soon as possible after making the adjustment, depress the Manual Initiate Switch to put the system back into the Balance mode.
12. Remove the jumper installed in step 10.
13. Allow the system to go into the Operate mode while observing the dew point reading. The reading must drop smoothly and then stabilize with less than 5°C overshoot (if aspirating with room air; samples with very low dew points may cause an overshoot of 10°C or more°). After 2 minutes, the dew point reading should not fluctuate.

    If the dew point reading overshoot exceeds 5°C or fluctuates, the system is oscillating. Oscillation may also be indicated by the CONTROL CONDITION meter moving back and forth. Oscillation can be caused by excessive gain or excessively high sample flow rate. If oscillation occurs, first reduce the sample flow rate to remove the oscillation. If this is not effective, reduce the gain a small amount at a time by adjusting the GAIN potentiometer in a CCW direction.

6.3.5 Circuit Adjustments for System Using Model 660 S2 Sensor

Adjustments to the special circuits required for using a Model 660 S2 Sensor with the 911 C1 Control Unit are detailed in Section 3, paragraph 3.2.2.7. The following procedure is included so that those adjustments plus the Dew Point Control Loop adjustments (paragraph 6.3) can be integrated into one procedure. In addition, these procedures should be used when the Automatic Balance Control option is used in conjunction with the Model 660 S2 Sensor.

There are some differences in the procedure depending on whether the system has Manual Balance or Automatic Balance. These differences are noted in the specific steps.

1. Clean the sensor mirror.
2. MANUAL BALANCE: Depress the BAL/OPR switch.

   AUTOMATIC BALANCE: Tip the Control Unit on its side and set the switch on the ABC board so that only position 6 is on. Depress the ABC Initiate switch on the front panel every minute to keep the system in the Balance mode. The system must be in the Balance mode for making the following preliminary adjustments.
3. Aspirate the sensor at about 2 SCFH.
4. Set the power to ON.
5. Use a digital voltmeter (DVM) to monitor the voltage across the direct resistor, R21, on the Interface Card.
6. Set the LED potentiometer on the Main Circuit Card fully clockwise. The DVM voltage should indicate +7 to +12 VDC. If it exceeds +12 V, rotate the LED potentiometer counterclockwise until it is +12 VDC.
7. Check the voltage across the Bias resistor, R20, on the Interface Board. It is typically less than the direct voltage, and must be greater than +2 VDC.
8. On the Interface Card, set S1-2 to OFF. Adjust the COMP potentiometer to mid-scale.

NOTE

S1-2 is ON when the number 2 on the switch is depressed and is OFF when the other side is depressed.

9. Connect the DVM between ground and the test point on the Interface Card. Adjust R22 on the Interface Card for 0 VDC ±25 MV.
10. Set switch S1-2 back to ON.
11. MANUAL BALANCE: Adjust the SEN CAL potentiometer (through the front panel) so that the CONTROL CONDITION meter indicates at the white/red junction when the front panel balance control is fully CCW. Then adjust the balance control for a center scale indication on the meter.

    AUTOMATIC BALANCE: Connect the DVM to ground (−) and Main Circuit Card TP (+). Adjust the SEN CAL potentiometer (through the front panel) so that the DVM indicates 2.50 VDC.
12. Connect the DVM across R20 (0.2 ohm located on the Main Circuit Card).
13. Set the GAIN and THK potentiometers on the Main Circuit Card fully CW.

NOTE

THE FOLLOWING STEPS MUST BE DONE QUICKLY AND IN ORDER.
The system will be in the Operate mode, but the mirror must still be dry when the adjustments are made. Therefore, if the front panel display indicates within 15 degrees C of the dew point temperature, the system must be put back into balance and the mirror must heat up again before continuing the procedure.

14. MANUAL BALANCE: Release the BAL/OPR switch. Quickly adjust the CUR LIM potentiometer if necessary to obtain 500 MV ±10 MV on the DVM.

AUTOMATIC BALANCE: Allow the system to go into the Operate mode by NOT depressing the Manual Initiate Switch as before. Quickly adjust the CUR LIM potentiometer if necessary to obtain 500 MV ±10 MV on the DVM.

15. Set the GAIN potentiometer fully CCW. Then rotate the THK potentiometer in a CCW direction until the DVM indicates 150 MV ±10 MV.
16. Connect a short jumper between TP3 and TP5 on the Main Circuit Card. This jumper shorts out the THK potentiometer.
17. Adjust the GAIN potentiometer CW until the DVM indicates 300 MV ±10 MV.
18. Remove the jumper installed in step 16.
19. Allow the system to seek a dew point temperature. The COMP potentiometer can be adjusted if necessary to eliminate any oscillation (see Section 3, page 3-7).

NOTE

Switch S1-2 on the Interface Card should always be left ON except when doing the adjustment above.

6.4 PRT AMPLIFIER CALIBRATION

A Platinum Resistance Thermometer (PRT) is used in the Dew Point Sensor and the Ambient Temperature Accessory. To measure the temperature, the PRT resistance is converted to a voltage by a PRT Amplifier. This amplifier contains controls for ZERO, SPAN, and LINEARITY. By adjustment of these controls, the PRT Amplifier can be made to produce a linear output voltage proportional to the temperature sensed by the PRT. These adjustments are made at the factory and normally do not have to be changed. However, large changes in cable lengths used to mount the dew point or ambient temperature sensors remotely may require readjustment (there is approximately a 0.1°C change in output for a 50-foot change in cable length). Factory adjustments are made based on cable lengths specified at time of purchase. If it becomes necessary to check the operation of the PRT amplifier or if the remote cable length is changed significantly after shipment from EG&G, then the following procedure should be used. A precision calibrated resistance decade box and precision calibrated digital voltmeter (DVM) are required for making these adjustments.

6.4.1 Adjustment Procedure for Basic Analyzer

1. Remove the Model 911 Dew Point Sensor connector at the rear of the sensor. If the sensor is attached to the rear of the Model 911 Control Unit, the sensor need only be removed and the connector will be exposed and can be removed. If the sensor is located at the end of a length of remote cable, then the cable should be unplugged from the sensor at the remote location.
2. Connect a precision decade resistance box between pins 9 and 10 of the connector that normally attaches to the sensor, and short pins 10 and 4 together.
3. Set the precision decade resistance box to 100.00 ohms. Adjust ZERO potentiometer R45 on the Main Circuit Card until the analog output voltage for dew point as measured at P13-14 (+) and P13-11 (Ground −) with the precision calibrated DVM equals 0.000 volts DC.
4. Set the precision decade resistance box to 111.79 ohms and adjust SPAN potentiometer R39 until the DVM indicates 3.000 volts DC.
5. Next, set the precision resistance decade box to 123.48 ohms and adjust LIN (linearity) potentiometer R48 until the DVM indicates 6.000 volts DC.

6. Repeat steps 3, 4, and 5 above until all conditions are met. Since the functions of the adjustments interact to a degree with each other, it may be necessary to repeat these steps several times.
7. Set the precision resistance decade box to 84.11 ohms. The output should indicate −4.000 volts, ±0.005 VDC.

6.5 DIAGNOSTIC TESTING USING THE DVM

The Model 911 has been designed to allow the user to utilize the digital display function of the instrument as a 3-1/2 digit digital voltmeter (DVM). Although this feature should not be used for such precise purposes as calibration of the PRT Amplifier, it can be useful as a troubleshooting aid for those instances when trouble in the instrument may be apparent and a test DVM may not be readily available.

In order to use the digital display as a DVM, it is necessary to remove the cover of the Model 911 by removing the four No. 6 screws attaching it to the instrument chassis. When the cover is removed, a "Grabber" test hook will be seen attached to a test point in the area of connector J3 for the Model 911 BCD Output Module Option. By removing this test hook from its test point, it can be used to attach to other parts of the circuit card to measure voltages that can provide clues to assist in locating the source of any problems that may arise. Following any testing of this sort, the "Grabber" should always be returned to its original location and the chassis cover replaced (Test Point TP6 or TPX).

When attempting to use the digital display as a DVM, the meter display must be set to display dew point in °C and the ALARM SET control junction must not be in operation. In addition, the decimal point must be mentally moved one place to the left to obtain the correct DC voltage reading, i.e., 50.0 = 5.00 volts. This feature is operable only for DC voltages less than 19.99 volts.

It is possible that the only time this feature will be used is when discussing a problem with the factory. During these times, the factory service representative may request that certain voltages be measured and reported as a means of isolating a problem and as an aid in determining if a failed instrument can be repaired in the field or must be returned to the factory for service.

Instrument operating voltages can easily be checked by measuring them with the "Grabber" test hook on output connector J13:

+15 VDC	J13-2
−15 VDC	J13-B
+5 VDC Logic	J13-1
+5 VDC Ref.	J13-C
−4 VDC	J13-M

If an accidental short occurs on the output of any of the DC supplies, they will turn off rather than supply current to the short circuit. When the short is removed, the DC supplies may be reset by turning AC power to the instrument OFF for a few seconds and then turning it ON again.

SECTION 7

GENERAL DEW POINT MEASUREMENT INFORMATION

basic humidity definitions

DALTON'S LAW

John Dalton was the first to surmise that the total pressure, p_m, exerted by a mixture of gases or vapors is the sum of the pressures of each gas if it were to occupy the same volume by itself. The pressure which each gas component of a multiple constituent gas (such as air) exerts is called its partial pressure. If p_x, p_y, and p_z represent the respective partial pressures of gases X, Y, and Z in a mixture, Dalton's Law states:

$$p_m = p_x + p_y + p_z + \ldots$$

Elementary as it may seem, the concept of Dalton's Law is often overlooked in considering problems in humidity, because one forgets that the "water" in a gas is actually a gas itself and must be treated in accordance with the gas laws. Air must be considered a mixture of gases - oxygen, nitrogen, and water vapor (neglecting the minor constituents). All discussions of humidity can then be reduced to discussions of water vapor pressure, and all definitions encountered in humidity can be expressed in terms of vapor pressure.

DEW POINT

Dew Point is that unique temperature to which the air (or any gas) must be cooled in order that it shall be saturated with respect to water.

FROST POINT

Frost Point is that unique temperature to which the air (or any gas) must be cooled in order that it shall be saturated with respect to ice.

The dew point or frost point DEFINES the partial pressure of the water vapor in the gas, from the Smithsonian Meteorological Tables.

RELATIVE HUMIDITY

Relative Humidity is the ratio of the actual vapor pressure (as defined by the Tables) in the mixture to the saturation vapor pressure, with respect to water, at the prevailing dry bulb temperature.

Example 1. (Metric Units)

If dew point = 10°C and dry bulb = 25°C:

$$RH = \frac{\text{Vapor Pressure at } 10^\circ C}{\text{Vapor Pressure at } 25^\circ C} = \frac{12.272 \text{ mb}}{31.671 \text{ mb}} = 38.7\%$$

If frost point = - 45°C and dry bulb = - 40°C:

$$RH = \frac{\text{Vapor Pressure at } -45^\circ C \text{ (Actual)}}{\text{Vapor Pressure at } -40^\circ C \text{ (with respect to water)}} = \frac{0.07198 \text{ mb}}{0.1891 \text{ mb}} = 38.1\%$$

Example 2. (English Units)

If dew point = 50°F and dry bulb = 90°F:

$$RH = \frac{\text{Vapor Pressure at } 50^\circ F}{\text{Vapor Pressure at } 90^\circ F} = \frac{.3624'' \text{ Hg}}{1.422'' \text{ Hg}} = 25.5\%$$

If frost point = - 50°F and dry bulb = - 40°F:

$$RH = \frac{\text{Vapor Pressure at } -50^\circ F \text{ (Actual)}}{\text{Vapor Pressure at } -40^\circ F \text{ (with respect to water)}} = \frac{1.990 \times 10^{-3}'' \text{ Hg}}{5.584 \times 10^{-3}'' \text{ Hg}} = 35.7\%$$

NOTE: RH is arbitrarily defined with respect to water even though it seems that it should be with respect to ice at - 40°C (- 40°F).

PPM BY VOLUME

Parts per million (PPM) by volume is the ratio of the partial pressure of the water vapor to the partial pressure of the dry gas.

Example 1. (Metric Units)

If frost point = - 60°C and system total pressure is 1013 mb (14.7 PSIA)

$$PPM_v = \frac{\text{Parts}}{\text{Million}} = \frac{\text{Vapor Pressure at } -60^\circ C}{\text{Total Pressure} - \text{Water Vapor Pressure at } -60^\circ C}$$

$$= \frac{10.80 \times 10^{-3} \text{mb}}{(1013 - 10.80 \times 10^{-3}) \text{mb}} \times 10^6$$

= 10.7PPM(by volume)

Example 2. (English Units)

If frost point = - 70°F and system total pressure is 14.7 PSIA (29.92"Hg):

$$PPM_v = \frac{\text{Parts}}{\text{Million}} = \frac{\text{Vapor Pressure at } -70^\circ F}{\text{Total Pressure} - \text{Water Vapor Pressure at } -70^\circ F} \times 10^6$$

$$= \frac{4.974 \times 10^{-4}'' \text{ Hg}}{(29.92 - .004974)'' \text{Hg}} \times 10^6$$

= 17PPM(by volume)

EG&G

PPM BY WEIGHT

PPM by weight of dry gas is identical to PPM by volume except that the weight ratio changes with the molecular weight of the carrier gas.

Example 1. (Metric Units)

If frost point = − 60°C, system total pressure is 1013 mb, and the carrier gas is hydrogen:

$$PPM_w = PPM_v \times \frac{\text{Mol. wt. of } H_2O}{\text{Mol. wt of carrier gas}}$$

$$= 10.7 \times \frac{18}{2} = 96.3\text{PPM (by weight)}$$

Example 2. (English Units)

If frost point = − 70°F, system total pressure is 14.7 PSIA, and the carrier gas is hydrogen:

$$PPM_w = PPM_v \times \frac{\text{Mol. wt. of } H_2O}{\text{Mol. wt of carrier gas}}$$

$$= 17 \times \frac{18}{2} = 153\text{ PPM (by weight)}$$

MOLECULAR WEIGHT OF COMMON GASES

Acetylene	26	Helium	4
Air	29	Hydrogen	2
Ammonia	17	Methane	16
Argon	40	Nitrogen	28
CO_2	44	Oxygen	32
CO	28	Sulfur Dioxide	64
Ethylene	28	Water	18

DEW POINT/FROST POINT RELATIONSHIPS

Below 0°C (32°F), dew point hygrometers measure the frost point temperature rather than the dew point. The tables below permit conversion from dew to frost point. For a more accurate conversion, consult Table 102 of Smithsonian Meteorological Tables.

Metric Units (°C)

F.P.	D.P.	F.P.	D.P.	F.P.	D.P.	F.P.	D.P.
0	0	−12	−13.4	−24	−26.6	−36	−39.4
−1	−1.2	−13	−14.5	−25	−27.7	−37	−40.5
−2	−2.3	−14	−15.6	−26	−28.8	−38	−41.6
−3	−3.4	−15	−16.7	−27	−29.9	−39	−42.6
−4	−4.5	−16	−17.8	−28	−30.9	−40	−43.7
−5	−5.6	−17	−18.9	−29	−32.0	−41	−44.7
−6	−6.8	−18	−20.0	−30	−33.0	−42	−45.8
−7	−7.9	−19	−21.1	−31	−34.1	−43	−46.8
−8	−9.0	−20	−22.2	−32	−35.2	−44	−47.9
−9	−10.1	−21	−23.3	−33	−36.2	−45	−49.0
−10	−11.2	−22	−24.4	−34	−37.3	−46	−50.0
−11	−12.3	−23	−25.5	−35	−38.4		

English Units (°F)

F.P.	D.P.	F.P.	D.P.	F.P.	D.P.	F.P.	D.P.
+32	+32	+10	+7.4	−12	−16.7	−34	−40.3
+31	+30.8	+9	+6.3	−13	−17.8	−35	−41.4
+30	+29.7	+8	+5.2	−14	−18.9	−36	−42.4
+29	+28.6	+7	+4.1	−15	−20.0	−37	−43.5
+28	+27.5	+6	+2.9	−16	−21.1	−38	−44.5
+27	+26.4	+5	+1.8	−17	−22.2	−39	−45.6
+26	+25.2	+4	+0.7	−18	−23.3	−40	−46.6
+25	+24.1	+3	−0.4	−19	−24.3	−41	−47.7
+24	+22.9	+2	−1.5	−20	−25.4	−42	−48.7
+23	+21.8	+1	−2.6	−21	−26.4	−43	−49.8
+22	+20.7	0	−3.7	−22	−27.5	−44	−50.8
+21	+19.6	−1	−4.8	−23	−28.6	−45	−51.9
+20	+18.5	−2	−5.8	−24	−29.6	−46	−52.9
+19	+17.4	−3	−6.9	−25	−30.6	−47	−54.0
+18	+16.2	−4	−8.0	−26	−31.7	−48	−55.0
+17	+15.1	−5	−9.1	−27	−32.8	−49	−56.1
+16	+14.0	−6	−10.2	−28	−33.9	−50	−57.1
+15	+12.9	−7	−11.3	−29	−35.0	−51	−58.2
+14	+11.8	−8	−12.4	−30	−36.1	−52	−59.2
+13	+10.7	−9	−13.5	−31	−37.2	−53	−60.3
+12	+9.6	−10	−14.6	−32	−38.2		
+11	+8.5	−11	−15.6	−33	−39.3		

REFERENCE: Smithsonian Meteorological Tables, Sixth Revised Edition, List, Robert J., Publication No. 4014, Smithsonian Institution, Washington, D.C.

PRESSURE CONVERSION

As the total pressure of a gas sample changes, all of the partial pressures comprising the total pressure change in the same ratio.

Example 1. (Metric Units)

If frost point = $-60^{\circ}C$ and system total pressure is 1013 mb ($1.033\ kg/cm^2$), what is the dew point at $21\ kg/cm^2$?

$$\frac{\text{Vapor Pressure at } -60^{\circ}C}{1.033\ kg/cm^2} = \frac{\text{Vapor Pressure at New Dew Point}}{21\ kg/cm^2}$$

$$\text{Vapor Pressure at New Dew Point} = 10.80 \times 10^{-3} mb \times \frac{21}{1.033} = .2195 \text{ mb partial pressure}$$

From the Vapor Pressure Tables (over ice), the Frost Point = $-35.2^{\circ}C$

Example 2. (English Units)

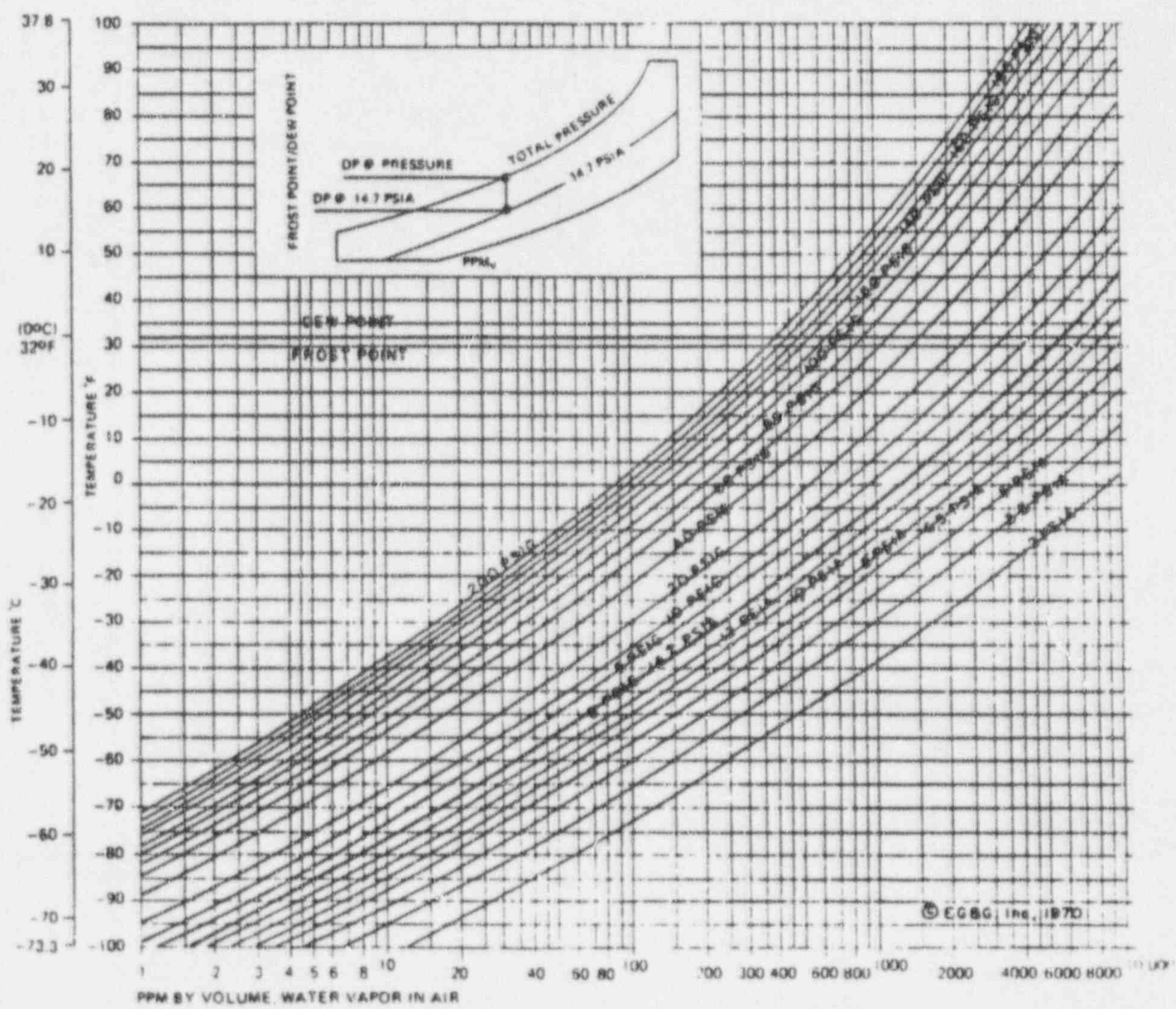
If frost point = $-70^{\circ}F$ and system total pressure is 14.7 PSIA, what is the dew point at 70 PSIG (84.7 PSIA)?

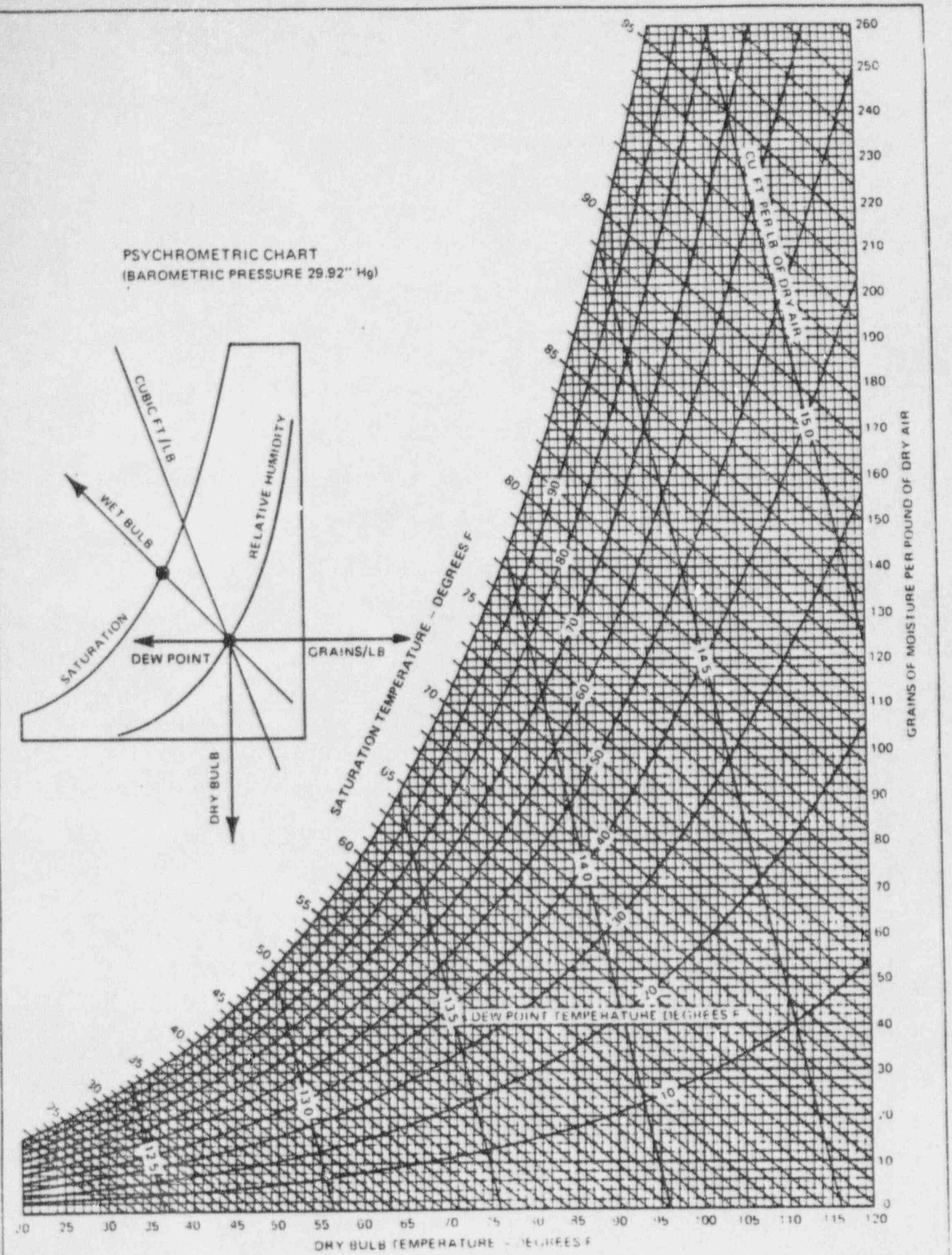
$$\frac{\text{Vapor Pressure at } -70^{\circ}F}{14.7 \text{ PSIA}} = \frac{\text{Vapor Pressure at New Dew Point}}{84.7 \text{ PSIA}}$$

$$\text{Vapor Pressure at New Dew Point} = 4.974 \times 10^{-4''} \text{Hg} \times \frac{84.7}{14.7} = 2.87 \times 10^{-3''} \text{ Hg partial pressure}$$

From the Vapor Pressure Tables (over ice), the Frost Point = $-44.5^{\circ}F$

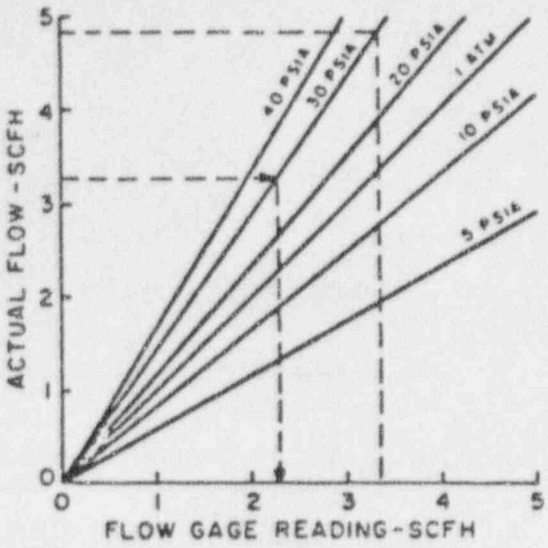
DEW POINT/PRESSURE CONVERSION CHART



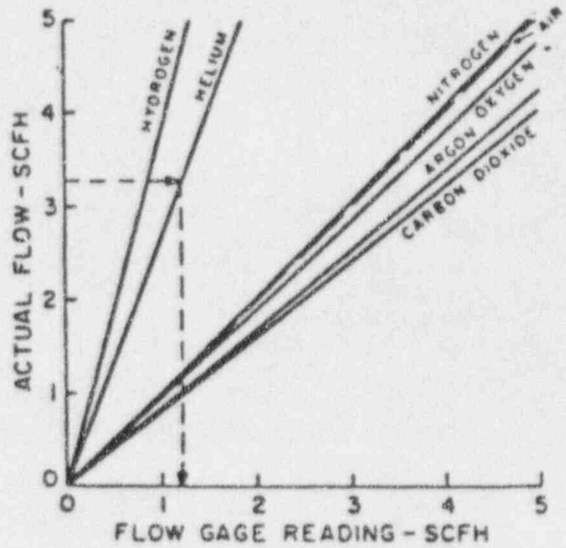


PSYCHROMETRIC CHART
(BAROMETRIC PRESSURE 29.92" Hg)
CUBIC FT/LB
RELATIVE HUMIDITY
WET BULB
SATURATION
DEW POINT
GRAINS/LB
DRY BULB
SATURATION TEMPERATURE – DEGREES F
CU FT PER LB OF DRY AIR
DEW POINT TEMPERATURE DEGREES F
GRAINS OF MOISTURE PER POUND OF DRY AIR
DRY BULB TEMPERATURE – DEGREES F

FLOW RATES FOR DIFFERENT GASES AND PRESSURES



Actual Flow Rate of
Air at Pressures
Other than 1
Atmosphere (14.7 psia)



Actual Flow Rate of
Six Different Gases

RECOMMENDED HARDWARE

Flow Gauges (with valves)

Stainless and Glass	Brooks Sho-Rate "50" No. 1350-V, with 2.65A Glass, range 0.2 - 4.5 SCFH
Brass and Lucite	Brooks-Mite No. 2001V, 0.10 - 4.5 SCFH
Sample Tubing	**Recommended Fittings**
Stainless Steel, 1/4 inch	Flare, or Swagelok
Teflon (or Kel-F), 1/4 inch	Swagelok
Stabilized Polypropyine, 1/4 inch	Swagelok
Pumps	
Iron-Vane Type	Gast Mfg. Co. Model 0406-V102-15C (0.5 cfm)
Diaphragm Type	Dynapump - Neptune Products Model 2 (2.25 cu. in./min)
Filters (General Purpose: In-Line)	
Stainless	NUPRO 4F-316, with 60-micron filter element HOKE No. 632-3F4Y (316SS)
Brass	NUPRO 4F, with 60-micron filter element

USE OF THE GRAPHS ON PAGE 7-7

GRAPH 1

Used to determine sensor mirror temperature depression below the Sensor Base temperature and the minimum dew point temperature attainable for a given Sensor Base temperature.

Step 1 Enter the graph at the bottom with the Sensor Base temperature.

Step 2 Go straight up until the slanted graph line is met.

Step 3 Go to the left and determine sensor depression.

Step 4 Go to the right and determine minimum dew point attainable.

GRAPH 2

Used to determine the minimum % relative humidity that can be measured with the Model 911 S1 Sensor.

Step 1 Enter the graph on the left side with the sample gas temperature (dry bulb temperature).

Step 2 Go right until the intersection of the curve corresponding to the Sensor Base temperature.

Step 3 Go down (or up) to % minimum relative humidity.

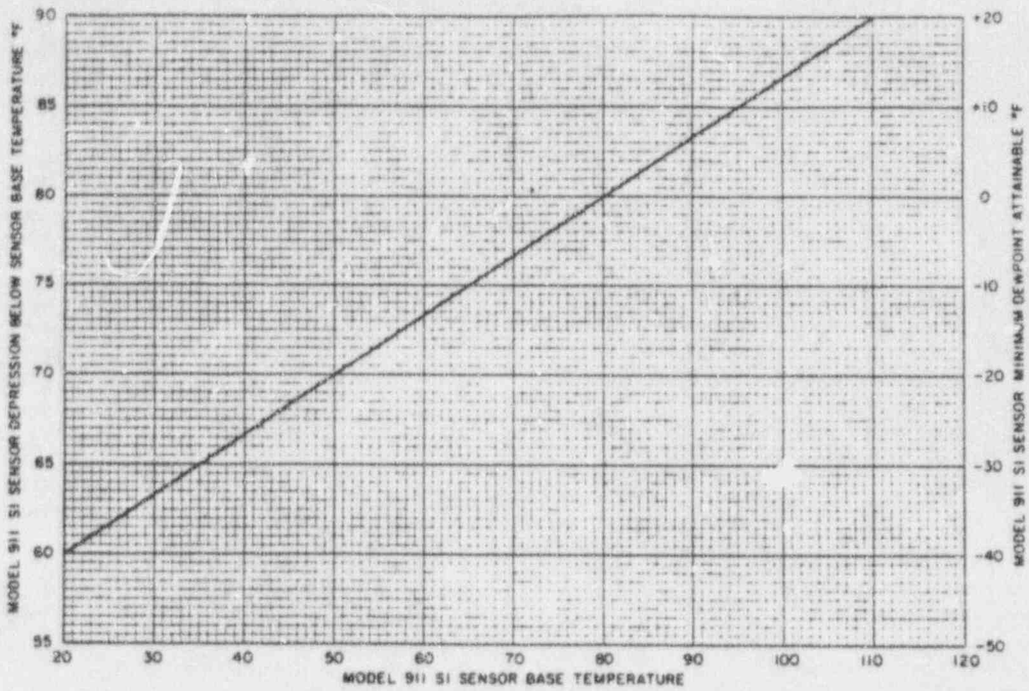
TERMS

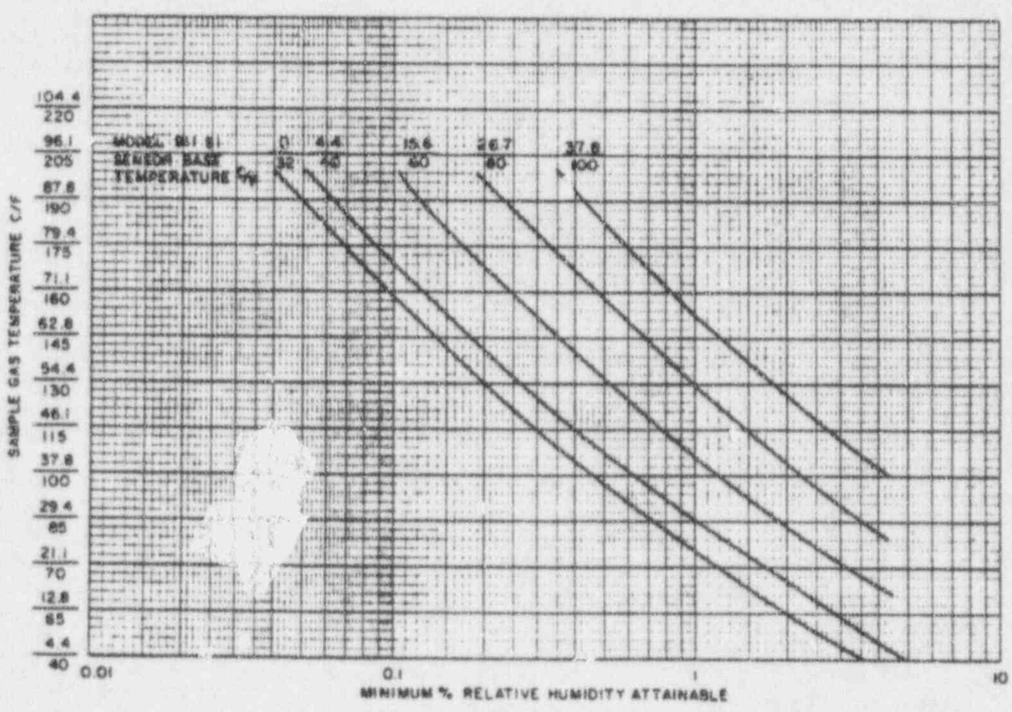
1. **Sample Gas Temperature** -Temperature of the sample gas, often referred to as a dry bulb temperature.

2. **Sensor Base Temperature** - Temperature of the mounting plate of the Model 911 Sensor. This temperature may be the same as the chassis temperature if the sensor is mounted to the chassis or it may be at the coolant temperature if the Model 911-CJ coolant jacket is used.

3. **Sensor Depression** - Minimum number of degrees the mirror surface temperature may be brought below the Sensor Base temperature assuming 0.5 SCFH flow of 80°F air as sample gas across the mirror surface. Higher sample gas temperature or gases with higher thermal conductivities than air tend to reduce this figure.

4. **Sensor Minimum Dew Point Attainable** - Lowest dew point temperature that can be measured with a given Sensor Base temperature given a 0.5 SCFH flow of air across the mirror surface with sample gas (air) at 80°F.


MODEL 911 SI SENSOR DEPRESSION BELOW SENSOR BASE TEMPERATURE °F
MODEL 911 SI SENSOR MINIMUM DEWPOINT ATTAINABLE °F
MODEL 911 SI SENSOR BASE TEMPERATURE
90
85
80
75
70
65
60
55
+20
+10
0
-10
-20
-30
-40
-50
20
30
40
50
60
70
80
90
100
110
120


SAMPLE GAS TEMPERATURE C/F
MINIMUM % RELATIVE HUMIDITY ATTAINABLE
MODEL 911 SI
SENSOR BASE
TEMPERATURE C/F
0/32
4.4/40
15.6/60
26.7/80
37.8/100
104.4/220
96.1/205
87.8/190
79.4/175
71.1/160
62.8/145
54.4/130
46.1/115
37.8/100
29.4/85
21.1/70
12.8/55
4.4/40
0.01
0.1
1
10

EG&G DEW POINT HYGROMETER SAMPLING SYSTEMS

GENERAL

Of all the factors considered in humidity measurement, one of the most important, and that which most often is given the least attention, is the sampling system. Considerations of leakage, pressure and temperature gradients, and moisture absorption/desorption characteristics are often overlooked.

The problem of leakage is relative; i.e., if the dew point being measured is close to the ambient room dew point, leakage into the system may not bias the reading substantially. If the system is pressurized above atmospheric so as to create a leakage out of, rather than into, the system, the error introduced will be less. The degree to which leakage can be tolerated also depends heavily on the actual dew point being measured. As an example, when measuring a dew point of -100°F with a sample flow rate of 4 SCFH, at an ambient or surrounding dew point of 50°F, a leakage in flow of 5 x 10^{-5} SCFH will cause an error of 1°F. However, at a measured dew point of +100°F the same leakage rate would cause an error of only 0.00001°F. The area of leakage becomes significantly more important and the error becomes much larger in systems operating below ambient pressure.

Pre-Heating

If the dew point of the gas under measurement is above the ambient temperature of the installation and the sampling lines, both the lines and the sensor must be heated with some type of heater tape, or the line must be steam-traced in the usual fashion. The approach used will vary widely with the specific nature of the installation, and the user must use his own ingenuity to assure that none of the sampling components be at a temperature lower than the highest dew point anticipated. If electrical heater lines are used, it is desirable to connect these to a variable transformer to adjust the heating level. If the sample lines are long, it may be necessary to wrap them in insulating cloth to minimize the amount of heat required to do the pre-heating. The line should be heated well above the dew point and should not exceed the temperature rating of the sensor. A maximum of 200°F is usually recommended. *Heating above the dew point does not change the dew point of the sample.*

Selection of Sampling Components

Of equal importance is the effect that material absorption/desorption characteristics have on overall system response. Although not true of all applications, stainless steel, glass and nickel alloy tubing are the best possible nonhygroscopic materials and should be used for low dew point applications (0°F to -100°F). Teflon is also satisfactory, but begins reducing system response due to desorption at the lower dew points. Copper and aluminum alloys, as well as stabilized polypropylene tubing, are acceptable above -20°F dew point. Most plastic and rubber tubing is unacceptable in all ranges. Unless attacked by the sample, the effect of the more hygroscopic materials is not of a contaminating nature, but actually one of introducing severe lag into the system during the establishment of an equilibrium condition. For example, plastics such as nylon cannot be used at low dew points simply because the equilibrium condition may actually take days to stabilize. The actual selection of the sample line material should be based on the degree of permanency of the installation, with a minimum of joints, fittings, and other plumbing prior to the hygrometer. Generally, stainless steel is preferred for permanent installations operating at low dew points. On stainless steel lines, either swage or flare-type fittings can be used.

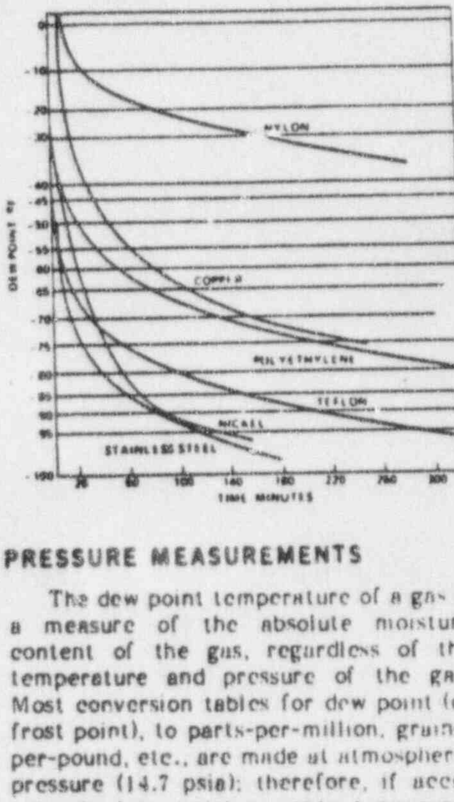
There are three types of pumps generally suitable for hygrometric work. For installations where the sample is not to be returned to the process, the Gast Manufacturing Co. vane pump is acceptable. This pump offers a reasonably high degree of reliability, and can handle large volumes of air. The vane type of pump does tend to contaminate the sample with minute amounts of pump-wear products (iron, carbon), therefore, it should be downstream of the hygrometer.

For general purpose use or for closed loop sampling at atmospheric pressure, any one of several types of diaphragm pumps, such as the Neptune Dynapump, can be used. The Dynapump utilizes a neoprene diaphragm, and the pump housing is aluminum.

For most closed loop sampling where leak tightness is essential, the welded bellows types such as the Metal Bellows MB-21 can be used.

MATERIAL MOISTURE PROPERTIES

All materials will absorb moisture to some extent. The curves relate typical desorption properties of common sampling line materials after being exposed to a "wet" gas such as the ambient atmosphere. The curves illustrate the difficulty of obtaining a fast system response when switching from a high dew point sample to a low dew point sample. Even if the instrument responds instantly, the sampling lines dictate the overall response.



PRESSURE MEASUREMENTS

The dew point temperature of a gas is a measure of the absolute moisture content of the gas, regardless of the temperature and pressure of the gas. Most conversion tables for dew point (or frost point), to parts-per-million, grains-per-pound, etc., are made at atmospheric pressure (14.7 psia); therefore, if accurate absolute moisture content measurements are to be converted to atmospheric-pressure-referenced values, the pressure must be known. A pressure tap after the hygrometer sensor can be fitted with an appropriate pressure gauge. Basic Humidity Definitions are explained in Bulletin 3-050.

CLEANING SAMPLING SYSTEMS

Most types of metal tubing contain oil deposits on the interior walls due to the manufacturing process. This residue must be removed before putting the line into service in a gas sampling system. Trichloroethylene or a similar solvent can be used to clean individual lines and

components before assembly, with a final flushing after assembly. The lines should be purged dry with air or nitrogen before being placed into service. In addition to the initial installation, the process itself may constitute a source of contamination and in many applications these are volatile hydrocarbons. An excellent fluid for purging and cleaning the instrument and/or the sample is Freon 114. This is a suitable solvent since it is capable of holding many hydrocarbons in solution, it is highly volatile, non-toxic, non-explosive, readily available, and will not attack common sampling line materials. EG&G Dew Point Hygrometers are provided with Type A or Type B Cleaning Solution for use in cleaning and conditioning the sensor mirror. Type A is a general purpose cleaner for most applications. Type B is a special purpose cleaner recommended for Heat Treating, or similar applications, where oil vapors are present. This cleaner tends to make the sensor less sensitive to oil vapor condensation.

CONTAMINATION EFFECTS

System contamination and its effect on dew point measurement can be subdivided into two categories – condensibles and noncondensibles. Before proceeding, it is important that one understands that the optical dew point analyzer measures the dew point, hence, the vapor pressure, of any substance that condenses on the mirror surface. Conversely, regardless of concentration, contamination constituents in a sample will not condense on the mirror unless its dew point temperature is reached.

Condensibles

Condensibles can be further subdivided into soluble and insoluble condensibles. If insoluble, and its dew point is at or above that of the constituent being measured, the relative concentration level will mainly determine the effect on the measured dew point. If the concentration level of the contaminant is low, i.e., it has a low partial pressure compared to the water vapor, then the effect of its presence can be standardized periodically before it degrades the primary measurement. This is done by heating the mirror surface to remove the condensate and rebalancing the optical detection system. At high concentration levels the dew point analyzer may measure the dew point of the contaminant rather than the water vapor dew point. This problem is lessened due to the high attenuation characteristics of dew or frost compared to many of the common contaminants. For example: if a water vapor dew point of 0°C was being measured at atmospheric pressure (760 mm Hg) and the ethylene oxide were present as a contaminant at a concentration level of 10% (76 mm Hg), its dew point would be -35°C. Since this is below the water vapor dew point, it will not condense on the sensor mirror. However, this means that there would be interference if the water vapor dew point was below -35°C. If the contaminant is, in addition, soluble in the constituent being measured, it will modify the vapor pressure and, hence, the dew point of the sample. The overall effect will depend on the degree of solubility.

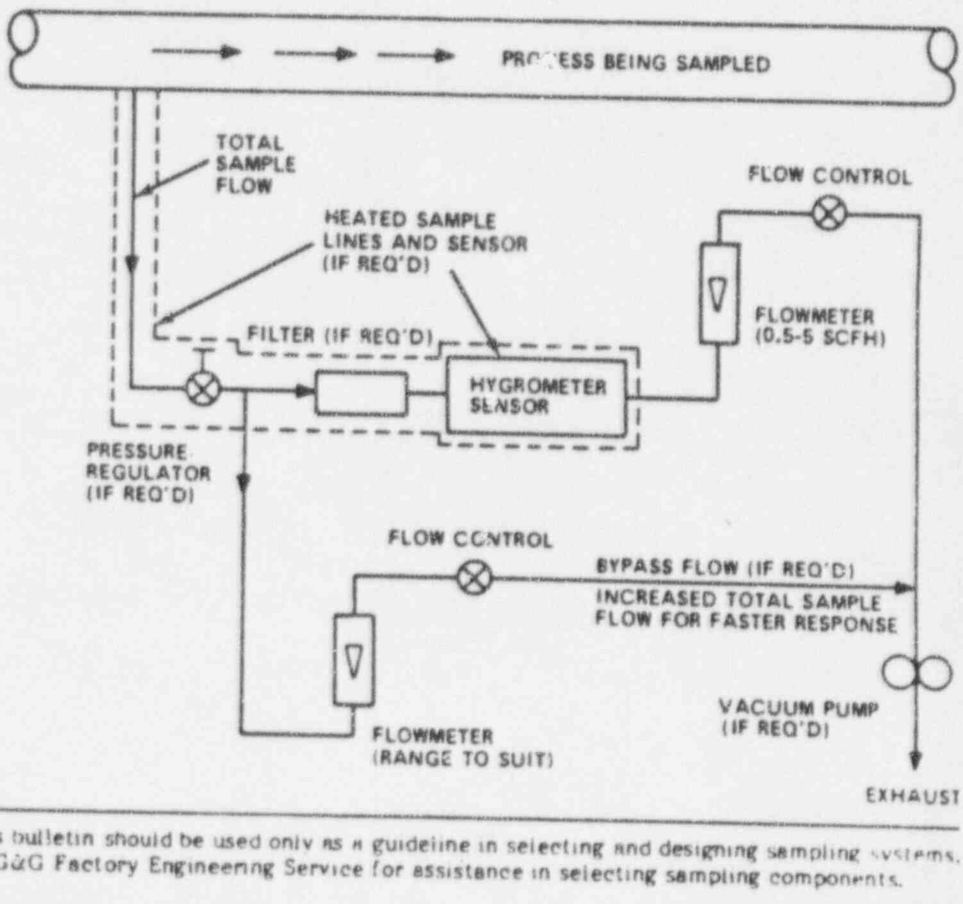
Noncondensibles

The second category of contaminants is the noncondensibles, which can again be subdivided into solubles, primarily salts, and insolubles, consisting of particulate matter. The soluble contaminant similarly will modify the partial pressure, or dew point, being measured. This type of contaminant affects all types of humidity instruments and necessitates frequent cleaning of the dew point mirror, since heating the mirror will not remove the salts. Insoluble matter is most easily avoided through sample line filtration.

SAMPLING CONFIGURATIONS

A suggested sampling system for use with EG&G Dew Point Hygrometers would be one where a portion of the gas line to be sampled is brought to the hygrometer location from a pressure tap either by using a suitably designed vacuum pump, or by expanding the sample to a lower pressure. The flow rate through this main sampling line should be sufficient to ensure continuous flushing of the lines, in order to provide a fast response time for the sampling system. Usually, the flow rate of 2–4 SCFH in a 1/4" line is adequate, however, this number must be adjusted with the length of the line, the level of absolute moisture content of the sample, and the desired response time of the sampling system. A bypass line may be used to increase the main sampling line velocity and improve the overall response time. It is necessary that the sampling line be equipped with a valve for adjusting the sample flow rate. The sample for the hygrometer is obtained from the pressure drop across the bypass as shown. It is desirable to provide the hygrometer input with a filter, especially if the gas under study contains particulate contaminants. Several sintered stainless steel filters are available which are suitable. It must be remembered that the filter element is considered a hygroscopic item, which will contribute some lag to the sampling system. A rule-of-thumb in the design of hygrometer sampling systems is to minimize the number of components, such as valves, tees, and filters prior to the hygrometer input. The hygrometer output is connected to a flowmeter and valve for adjusting the flow rate to the recommended range of 2–4 SCFH.

<u>NOTE</u>: Considerable cost savings can sometimes be made by recognizing that the sample-exhaust lines and related components need not be as high a quality and as non-hygroscopic as those prior to the hygrometer.



The procedures and parts recommended in this bulletin should be used only as a guideline in selecting and designing sampling systems. If your problem is of special nature, call the EG&G Factory Engineering Service for assistance in selecting sampling components.