EdgeTech
A division of Victoreen, Inc
455 Fortune Boulevard, Milford, MA 01757 Tel: (508) 478-9500 Fax: (508) 478-1456

MODEL 660
DEW POINT HYGROMETER SYSTEM
INSTRUCTION MANUAL
TM77-260

We are pleased to inform you that **EG&G Moisture & Humidity Systems** has recently been acquired by Victoreen, Inc., a successful and financially strong instrument manufacturing company. Our new name is **EdgeTech**. Our dedicated management and staff will remain the same.

We want to assure you that our high level of quality and service will be maintained.

As you may already know, **EdgeTech** has also relocated its facility from Burlington, MA to a newer, more modern plant in Milford, Massachusetts, about fifty miles from our old location. Our present address, telephone and fax numbers are as follows:

Address: **EdgeTech**
455 Fortune Boulevard
Milford, MA 01757

Telephone: (800) 276-3729
or
(508) 478-9500

Fax: (508) 634-3010

We are pleased to be a part of Victoreen and trust that you will share our enthusiasm for these very positive changes. If you have any questions or would care to visit our new facility, please call us.

Best regards,

EdgeTech
Moisture and Humidity Systems

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

CONTENTS

SPECIFICATIONS FOR MODEL 660 DEW POINT HYGROMETER

Dew Point Range	-50°C to +100°C
Dew Point Accuracy*	± 0.3°C (± 0.54°F) nominal at 0°C
Depression	60°C (108°F) nominal at ambient temperature of 25°C (77°F)
Depression Slew Rate	2°C (4°F) second maximum
Dew Point Sensitivity	± 0.06°C (± 0.1°F)
Sample Flow Rate	0.25-2.5 liters/minute (0.5-5.0 scfh)
Sample Pressure	0-21 Kg/cm^2 (0-300 psia)—Standard Housing 0-3 Kg/cm^2 (0-40 psia)—Mirror Microscope Housing
Ambient Temperature Range	-40°C to +100°C (-40°F to +212°F)— Sensor 0°C to +50°C (32°F to +120°F)—Control Unit
Auxiliary Coolant	Water (or other)—2 liters/minute (0.5 gallon/minute) at 100 psig maximum, to augment cooling capability of Sensor when necessary.
Dew Point Temperature Sensor	3-wire platinum resistance thermometer (PRT) 100 ohms, nominal at 0°C.
Dew Point Outputs(s)	Standard: (1) -5 to +10 VDC over range -50°C to +100°C. (2) 100 ohms nominal (Cannot be used with above analog output.) Optional: (1) 3 1/2 digit 8-4-2-1 parallel BCD digital data. T^2L compatible. (2) 4-20 MA DC
Display	3 1/2 digit digital data display, -50°C to +100°C, resolution 0.1°C
Alarm	DPDT contact closure rated at 3 amps at 28 VDC or 115 VAC with resistive load. Adjustable over entire range.
Remote Sensor	Up to 150 meters (500 feet).
Sensor Materials	Gold mirror, glass, epoxy, anodized aluminum.
Balance	Automatic self-standardization at 6, 12, or 24 hours. Factory set at 6 hours for 1.4-minute duration (both adjustable).
Power Requirements	115/230VAC 10%, 50-60 Hz, 60 watts max.
Weight	6.8 Kg (15 pounds)

*A detailed error analysis discussing the nature and relative magnitude of errors is available on request.

INTRODUCTION

This manual has been prepared to serve as both an instruction book for operation and maintenance, and as a source of general information on the Model 660 Dew Point Hygrometer and its functions and features. For ease in use, all information needed for placing the instrument in service, and for performing routine maintenance, is given in the first part of the manual. Servicing instructions, given in Part II will, of course, be consulted as the need arises. Part III describes the basic characteristics of the instrument and, by contributing to your understanding of its capabilities and limitations, should aid in its proper application. Part IV contains information on Options and Accessories for use with the Model 660 Dew Point Hygrometer, and supplementary general dew point hygrometry information.

IMPORTANT

When requesting Information about this instrument, always furnish the Control Unit and Sensor Serial Numbers. The Control Unit number is marked on the tag in the upper left-hand corner of the rear panel. The Sensor serial number is stamped into the metal on the top surface of the Sensor housing.

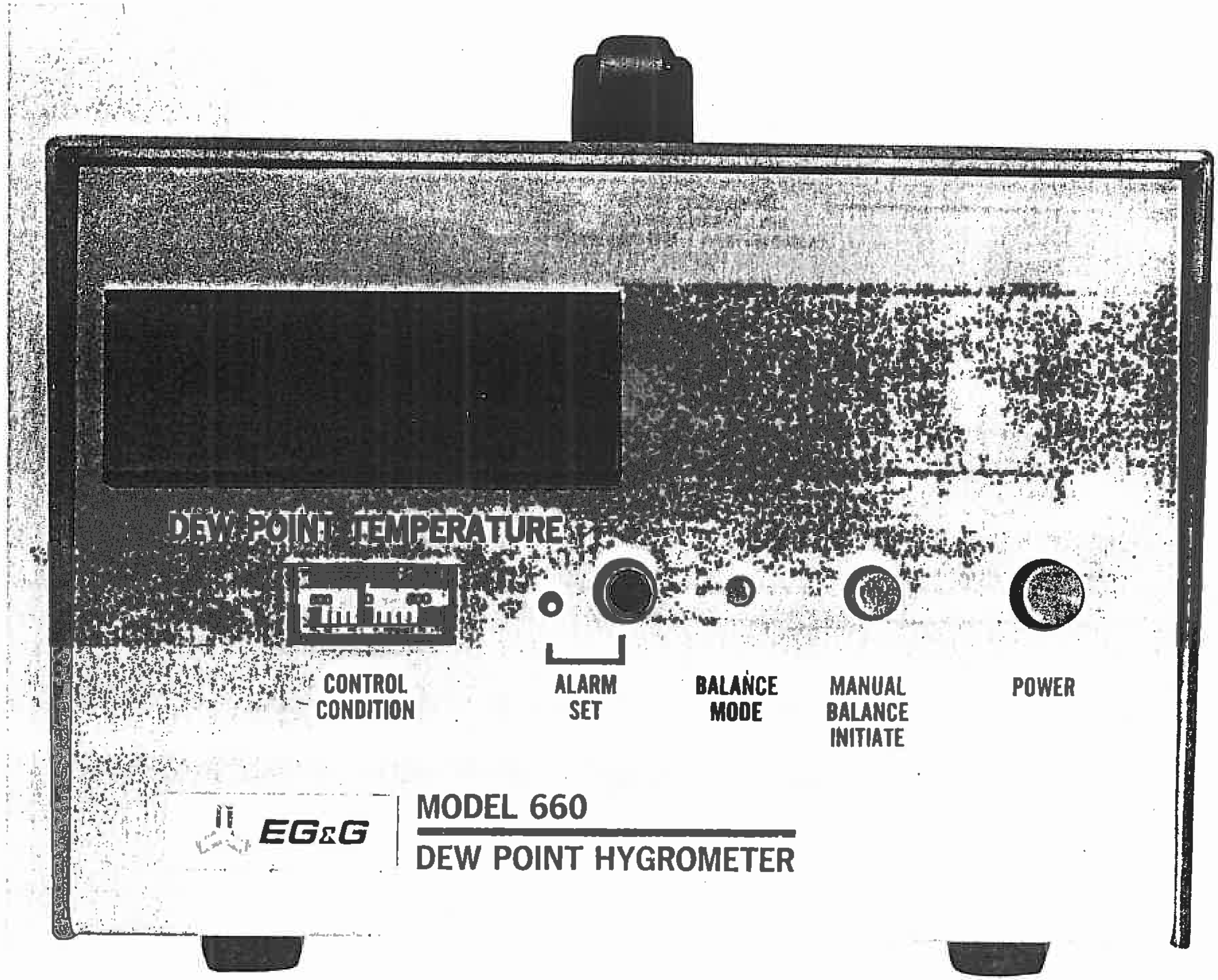

Figure A1 — Model 660 Control Unit - Front View

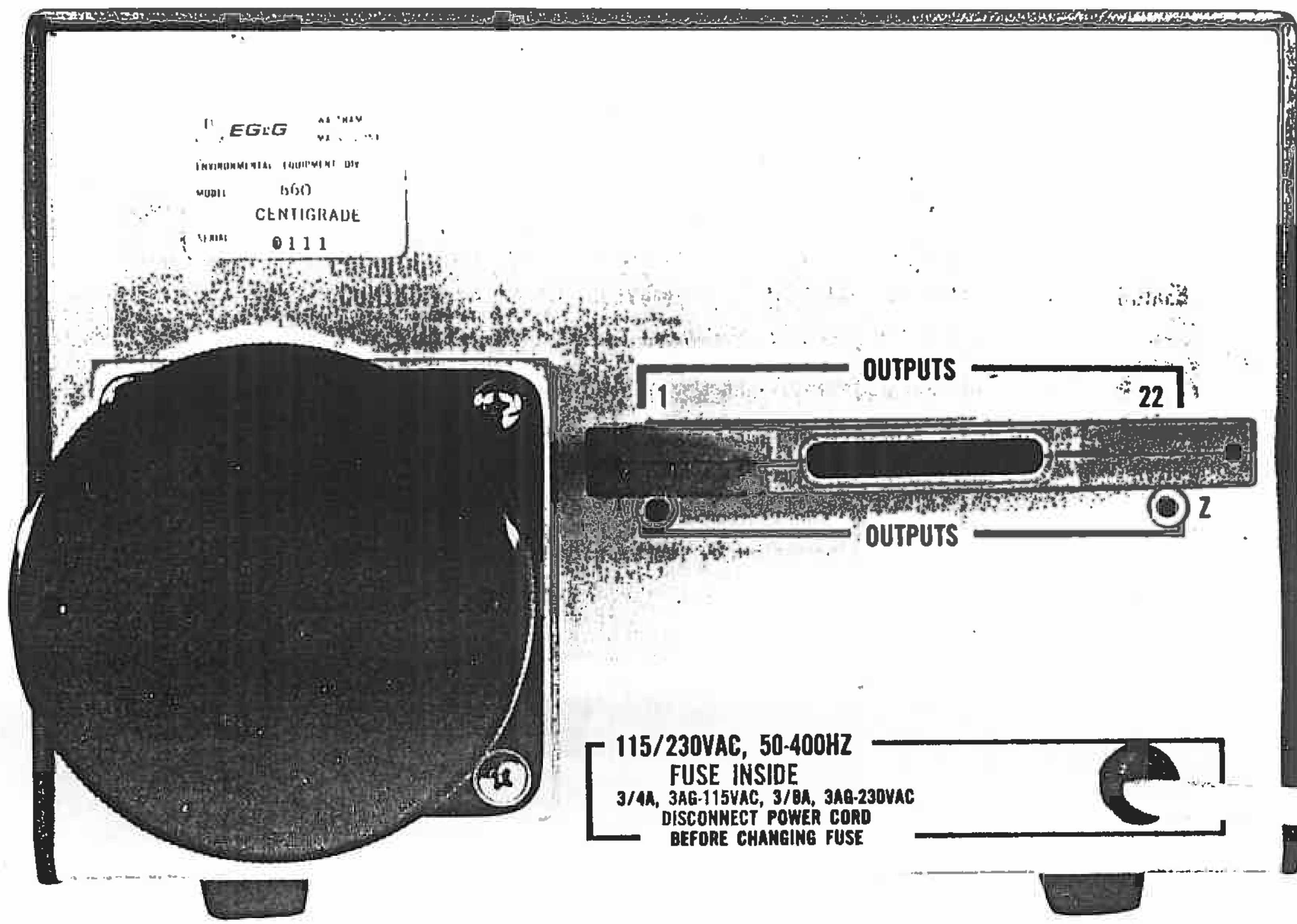

Figure A2 — Model 660 Control Unit - Rear View

PART I — INSTALLATION AND OPERATION

Section A — *INSTALLATION*

UNPACKING

Remove the instrument from its shipping carton and remove any shipping ties, clamps or packing material. Save the Certificate of Traceability, etc., shipped with this manual. Locate and save the small box containing the Cleaner Kit included in the shipping carton. The Model 660 Sensor normally is attached to the Model 660 Control Unit, except in those cases where the Optional Remote Mounting Kit is ordered.

GENERAL MOUNTING

The standard Model 660 Dew Point Hygrometer is designed primarily for bench mounting. However, an optional Panel/Rack Mounting Kit makes it possible for mounting the instrument in either a panel or rack, at least 19 inches wide. The Sensor may be remotely mounted from the Control Unit by means of the Remote Mounting Kit.

BENCH MOUNTING

For bench mounting the Model 660 Control Unit, it is necessary to place the instrument on a clean, flat surface. Care should be taken to ensure that there are no obstructions to the free convection of air underneath and around the sides of the Control Unit.

PANEL/RACK MOUNTING

For panel or rack mounting, the optional Panel/Rack Mounting Kits must be used. This kit includes a 19 inch rack panel that can be attached directly to standard EIA 19 inch cabinets. The Model 660 Control Unit attaches to a hinged door and the Sensor is then attached to a support bracket behind the rack panel. This allows the Control Unit to swing out, and provides access to the Control Unit electronics as well as to the Sensor. The instrument is panel mounted in much the same manner as it is rack mounted. A template is provided that can be attached to a larger panel area. This template is used to position the hole cutouts that the Panel Mounting Kit will be fastened to. As with the bench mounting plan, no obstructions should be placed around the Control Unit mounted in a panel or rack configuration that would impede the free convection of air around and under the instrument.

The details of the Panel/Rack Mounting Kit are included in Section O of this manual.

REMOTE SENSOR MOUNTING

When it is desired to remote-mount the Sensor from the Control Unit, the optional Remote Mounting Kit must be used. This kit consists of the necessary mounting hardware, connectors, and cable for locating the Sensor up to 150 meters (500 feet) from the Control Unit. The actual length of cable required should be specified in the Purchase Order as the Control Unit must be adjusted for the specific length of cable used. Details of the Remote Mounting Kit are included in Section P of this manual.

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 since the heat load on 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 anti-freeze 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, and the coolant pressure maximum rating is 100 psia (70 Kg/ cm^2). Connections for the coolant are made to the brass coolant jacket of the Sensor by means of the 1/8-27 NPT fittings (see Figure A3).

NOTES

In those instances 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 will prevent 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.

TEMPERATURE LIMITS

Install the Model 660 Control Unit in locations where the ambient temperature will not exceed the range, 0°C to +50°C (32°F to 122°F).

The Model 660 Sensor will operate over the range of -40°C to +100°C. When the anticipated operating range of the Sensor is expected to be outside of the operating temperature range of the Control Unit, the Sensor should be removed from the Control Unit and connected to the Control Unit by means of the Remote Mounting Kit. Always maintain the Sensor temperature at least 5°C above the dew point temperature of the gas being measured.

WIRING CONNECTIONS

Operation of the Model 660 Dew Point Hygrometer requires a power source of 115/230 VAC, 50-400 Hz. When the instrument is received and *before* attaching it to a source of power, remove the cover from the Control Unit and check the position of the 115/230 VAC selector switch. Ensure that the switch is indicating the desired voltage range. The fuse located beside the switch should be 3/4 amp slow blow for 115 VAC operation and 3/8 amp slow blow for 230 volt operation.

WARNING

Removing the Model 660 Control Unit cover exposes the line operating voltages to the user when the unit is plugged into the power source. Be sure that the power cord is *disconnected* whenever checking or changing the fuse. If the Control Unit is plugged in when performing any circuit adjustments or tests, extreme care must be taken not to come in contact with the high voltage present on the Printed Wiring Board (PWB) in the area of the

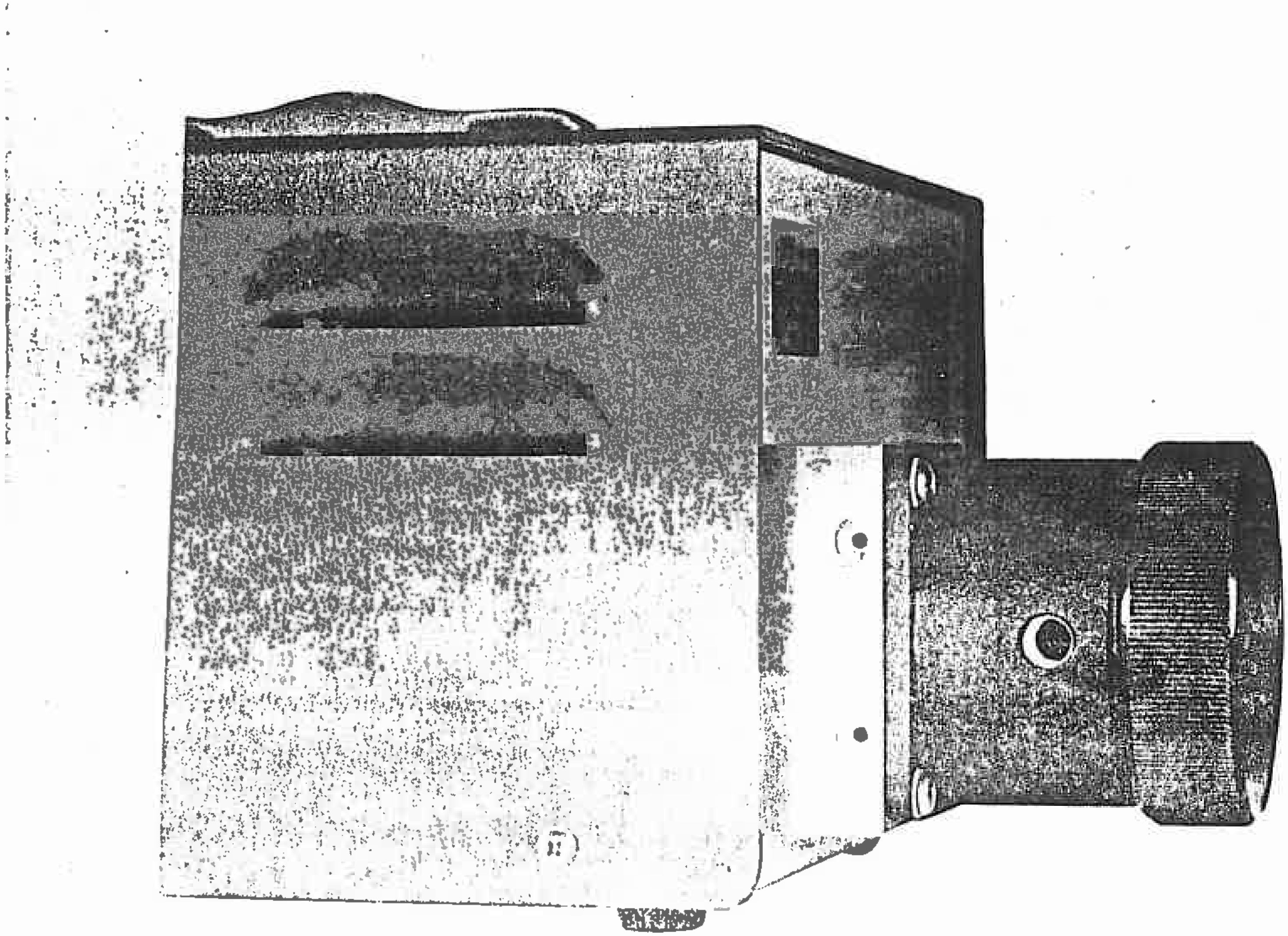

Figure A3 — Rear View of 660 Control Unit Showing Coolant Connection Parts

POWER ON-OFF switch, the fuse, and the input voltage range selector, S1.

When the line voltage selector switch position and the fuse rating have been checked, the cover can be put back on the Control Unit.

The Model 660 Dew Point Hygrometer provides visual display of the dew point temperature of the gas sample being processed by the Sensor, on a front panel digital display. In addition, the same information, and more, is available at the rear panel connector, P1 (PWB output pins). J1, the mating connector for P1, is provided with the Control Unit for attaching to P1 for electrical connections. A cable support hood is also provided. Connector J1 is a 44 pin connector, ELCO 00-6007-044-450-012. The top side of the connector is designated consecutively 1 through 22; the bottom side of the connector is designated consecutively A through Z with G, I, O, and Q missing. Table A1 lists the pin connections to J1 and the appropriate output or function associated with each. Be sure when attaching J1 to P1 that J1-1 and P1-1 are properly aligned.

The following is an explanation of the outputs and functions appearing at the output, P1:

1. Pin 3 +15 VDC
   Pin 5 -15 VDC
   Pin 22 +5 VDC
   Pin L +2.5 VDC

These power supply voltages are present on the output connector for use with the optional 4-20 mA and BCD output options, and for other monitoring purposes. *They are not* to be used for energizing external instrumentation. The +2.5 VDC should be measured with respect to analog ground, Pin 10. The ±15 VDC and the +5 VDC supplies should be measured with respect to digital ground, Pin 20.

2. Pin 1 PRT, 1
   Pin 2 PRT, 100 ohm
   Pin A PRT, 2

These pins present the Sensor Platinum Resistance Thermometer (PRT), in a three wire configuration, for the measurement in ohms of the Sensor mirror dew point temperature by the user with external measuring equpment. When any external measuring equipment is attached to any of these three pins, jumpers L-K, M-N, and P-R on the Control Unit printed wiring board *must* be removed (refer to Figure C1 for the location of these jumpers).

NOTE

When these three jumpers are removed, the temperature measuring circuitry of the Control Unit is disabled such that the front panel display and Pin S and Pin P analog outputs *are not functional.* Any readings on the front panel meter or at Pins S and P should be ignored.

3. Pin D Alarm Relay K2B-NC
   Pin E Alarm Relay K2B-NO
   Pin F Alarm Relay K2A-Common
   Pin H Alarm Relay K2B-Common

These pins connect to the double pole-double throw alarm relay contacts. The relay contacts shown indicate the position of the relay when the dew point temperature being measured by the Sensor and the Control Unit is less than the dew point temperature indicated by the Alarm Set output on the front panel meter.

TA3LE A1

MODEL 660 — P1/J1 PIN DESIGNATIONS

Top Side, Left to Right	*Bottom Side, Left to Right*
1 PRT, Common 1	A -PRT, Common 2
2 PRT, 100 ohm	B
3 +15 VDC	C
4	D Alarm Relay, K2B-NC
5 -15 VDC	E Alarm Relay, K2B-NO
6	F Alarm Relay, K2A-Common
7	H Alarm Relay, K2B-Common
8 Clean Mirror Logic	J Alarm Relay, K2A-NO
9	K Alarm Relay, K2A-NC
10 Analog Ground	L +2.5V Reference
11	M
12	N
13	P -5 to +10V, Track and Hold Output, °C
14	R Balance Mode Indication
15	S -5 to +10V, Direct Output, °C
16	T Hold Mode Indication
17	U 24 Hour Self-Standardization Period
18	V 12 Hour Self-Standardization Period
19 -.4 to +2.12V°F Analog Output	W 6 Hour Self-Standardization Period
20 Digital Ground	X Remote Self-Standardization Period Initiate
21	Y Self-Standardization Period Input
22 +5 VDC	Z

When the dew point, measured by the Sensor and Control Unit, exceeds the Alarm Set output, the relay arm positions will reverse. Relay contacts are rated at 28 VDC or 115 VAC, 3A, with resistive load.

4. Pin S -5 to +10 VDC

Analog direct output voltage corresponding to the temperature of the mirror surface in the Sensor at all times when the Control Unit is turned on and the Sensor is attached. The -5 VDC to +10 VDC corresponds directly to -50°C to +100°C. This is the direct temperature output. This voltage should be referenced to analog ground, Pin 10.

5. Pin P Track and Hold Output

Analog output voltage comparable to the data on Pin S in Item 4. above, except that this output does not track the mirror termperature during the Automatic or Manual Self-Standardization (Balance) Cycle* when the mirror is being heated to remove any condensate. This output essentially "masks" the temperature excursions of the mirror during self-standardization so that process control equipment, computers, analog recorders, etc., that may be attached to this output, will not be affected by the self-standardization process. This voltage should be referenced to the analog ground, Pin 10.

6. Pin R

Pin R has on it a digital representation of the balance mode condition for signaling to external devices. This output is normally high at +15 volts. When in the self-standardization mode however, this output will go to ground (saturated transistor). Following the self-standardization period, this output will alternate between +15 volts and ground for the period that the Track and Hold output is still in the Hold condition. This output should be referenced to digital ground, Pin 20.

7. Pin T

Pin T output indentifies the self-standardization period as well as the hold period that follows and is called the Mold Mode Indication. In normal operation, this output is at +5 volts. When a self-standardization cycle is initiated from any source, this output will go low (CMOS output) and will remain low until after the cycle is completed and the dew layer is re-established on the mirror surface. As long as this signal

*Patented

output remains low, near ground, the output voltage on Pin P, the Track and Hold Output, will be presenting the dew point temperature prior to initiation of the self-standardization cycle. This output should be referenced to digital ground, Pin 20.

8. Pin X

An Automatic Self-Standardization (Balance) Cycle is initiated automatically on power turn-on to the Control Unit, on a 6, 12, or 24 hour interval, or manually by means of a push-button (MANUAL BALANCE INITIATE) on the front panel of the Control Unit. In addition to the normal automatic or manual initiation, this self-standardization cycle can be activated remotely through Pin X. Normally, Pin X should be left open or with a load no greater than 1 megohm. When Pin X is brought low momentarily, to digital ground, Pin 20, the instrument will begin a cycle. Pin X should not be held low continually, but may be held low to initiate a cycle for a minimum of 1 millisecond and a maximum of 1 minute.

9. Pin Y

If no connections are made, the Model 660 will perform an automatic self-standardization (balance) cycle approximately every 6 hours. If it is desired to extend this period to either 12 or 24 hours, the following connections should be made at mating connector J1:

a) For 12 hour self-standardization intervals, connect J1-V to J1-Y.
b) For 24 hour self-standardization intervals, connect J1-U to J1-Y.
c) Connections should be made with No. 24 AWG Wire.

If it is desired to disable automatic initiation of the self-standardization cycle on 6, 12, or 24 hour intervals, a jumper can be added from J1-Y to J1-20 (digital ground). This disables the automatic initiations but does not disable the MANUAL BALANCE INITIATE pushbutton function on the front panel.

10. Pin 16, 19

Analog output voltage corresponding to °F output of -0.4 to +2.12V (-40°F to +212°F). The Model 660 FC option must be installed for this output to be available.

11. Pin 8

Pin 8 is the CLEAN MIRROR logic signal. It is normally low (less than 0.5 volt). When high (about + 5 VDC), it indicates that the Sensor Mirror requires cleaning.

PLUMBING CONNECTIONS

A basic requirement of accurate dew point measurements is the proper design of the gas sampling system. In order that the Model 660 Dew Point Hygrometer measures the actual moisture content of the gas, it is essential that the sampling components neither contribute nor absorb moisture from the gas under study. Also, the sampling components must not modify the pressure or temperature parameters of the gas in a way that would affect the moisture content of the sample. When dew point measurements are to be made, it is also essential that the temperature of sampling components not be allowed to drop below the dew point temperature of the sample, in order to prevent condensation from occurring within the line, causing an erroneous measurement. *Sampling lines and the Model 660 Sensor must be properly preheated when measuring dew points above ambient atmospheric temperature.* (Refer to Preheating Sensor and Sample Lines below.)

Generally, for dew point temperatures above -18°C (about 800 PPMV at 1.02 Kg/cm^2 (14.7 psia), no special precautions need be taken in the selection of sampling line materials, other than assuring that they have temperature and pressure ratings necessary to handle the sample and that all connections are gas tight. The problems associated with the hygroscopic nature of sampling hardware worsen as the absolute moisture content decreases; that is, as the dew point lowers. For dew point temperaturs below -18°C, some attention *must* be given to the selection of non-hygroscopic sampling materials. (Refer to Selection of Components at Low Dew Points below.)

In general, the most common problem areas that will affect the moisture of a sampled gas are:

a) Length of process line and sample line.
b) Leaks in the process line and sample line.
c) Adsorption or absorption of moisture in the process and sample lines due to materials of construction.
d) Excessive elbows, tees, valves or other fittings.
e) Back diffusion of moisture into a pressurized system, particularly at low dew points.
f) Condensation within the process line and sample line at high dew points.
g) Diffusion through the sampling materials.

The procedures and parts recommended in this manual should be used only as a guide in selecting and designing sampling systems. If your problem is of a special nature, feel free to call EG&G's Factory Engineering Service for assistance in selecting sampling components.

SAMPLING CONFIGURATIONS

A suggested sampling system for use with the Model 660 Dew Point Hygrometer is shown in Figure A4. A portion of the gas line to be sampled is brought to the hygrometer location from a pressure tap, either by using a suitable vacuum pump or by returning the sample to a lower pressure point. 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 times for the sampling system. Usually, a flow rate of 0.5 to 5 scfh (14 to 142 lph) in a 1/4-inch 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 to improve the overall response time. It is necessary that the main sampling line be equipped with a valve for adjusting the sample flow rate. The sample to the hygrometer is obtained from the pressure drop across the bypass as shown in Figure A4. It is desirable to provide the hygrometer input with a filter, especially if the gas under study contains particulate contaminants. Several sintered stainless steel types of filters are available which are suitable. They are listed at the end of this section. It must be remembered that the filter is considered a hygroscopic element which will contribute some lag to the sampling system. In the design of hygrometer sampling systems, *minimize* the number of components, such as valves, tees, and filters, prior to the Sensor input. The Sensor output should be connected to a suitable flow measuring device, such as a rota-

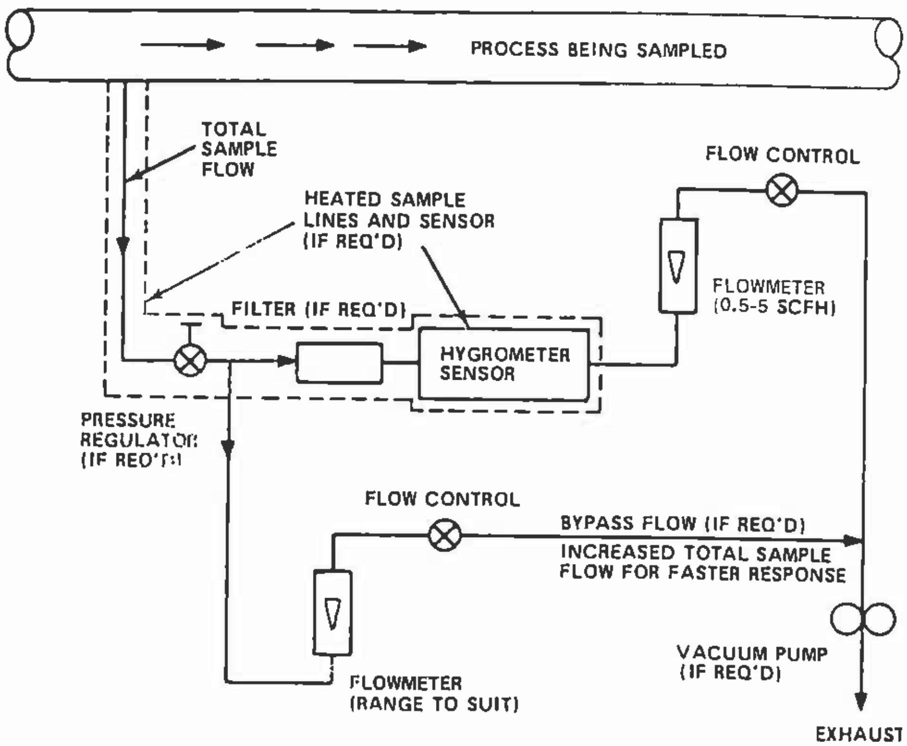

Figure A4 — Suggested Sampling System

meter and valve for adjusting the flow rate to the recommended range of 0.5 to 5.0 scfh (14 to 142 lph).

NOTES

1. Excessively high sample flow rates may cause a loss in the depression capability and unstable operation of the system.

2. Considerable savings can be made by recognizing that the sample exhaust lines and related components need not be of as high a quality and as non-hygroscopic as those prior to the hygrometer.

The gas to be sampled must be furnished to the 1/8-27 NPT male ports on the Model 660 Sensor. Flow may pass through the Sensor in either direction. A sample shut-off valve may be used ahead of the Sensor to remove the sample. This would be especially useful when working with samples as high pressures (300 psia max) (211 Kg/cm^2) and it is desired to open the Sensor for routine mirror cleaning.

PREHEATING — SENSOR AND SAMPLE LINES

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 preheated. The sample lines must be furnished with some type of heater tape, or they can be steam-traced. The Sensor must be located in a heated enclosure or also wrapped with heater tape, so that condensate will not form on the optical components or other parts of the Sensor. The approach used will vary widely with the specific nature of the installation, and the user must use his own ingenuity to ensure that no portion of the sample line is at a temperature lower than the highest dew point anticipated. If electrical heater lines are used, it is usually sufficient to connect them to a variable transformer to adjust the heating level. If the sample lines are long, it may be desirable to wrap them in insulating cloth to minimize the amount of heat required to do the preheating. The Sensor temperature must always be maintained at least 5°C above the dew point temperature of the gas sample. The temperature of the Sensor *must not exceed +100°C*. Heating the Sensor and sample lines above the dew point of the gas sample does not change the dew point of the sample.

SELECTION OF COMPONENTS AT LOW DEW POINTS

When measuring dew points below -18°C, increased attention to sampling details must be made as the dew point is lowered.

Rubber, neoprene, tygon and most plastic tubings are undesirable for use ahead of the Sensor in hygrometer systems. Specifically, non-hygroscopic tubing, such as stainless steel, Teflon, or KEL-F is recommended, with a minimum of joints, fittings, and other plumbing prior to the hygrometer. The actual selection of the sample line material should be based on the degree of permanency of the installation, and the type of fittings and connections to be used. 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. Leaks in the sampling system must be avoided, particularly for installations operating below atmospheric pressures, since leakage of ambient air into the sampling system will seriously bias the readings obtained.

MATERIAL MOISTURE PROPERTIES

All materials will absorb moisture to some extent. The adjacent curves shown in Figure A5 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 were to respond instantly, the sampling lines would dictate the overall response.

SELECTION OF SAMPLING PUMPS

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 tends 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 type such as the Metal Bellows MB-21 can be used. These pumps are available from EG&G as well as from their respective manufacturers. (The optional Model 660-SS Sample System Kit utilizes the Neptune Dynapump Model No. 2).

RECOMMENDED HARDWARE

Pumps

Iron-Vane Type	Gast Mfg. Co. Model 0406-V102-15C (0.5 cfm)
Diaphragm	Dynapump - Neptune Products, Model 2 (2.25 cu. in./min)
Bellows Type	Metal Bellows Co. MB-21

Filters (General Purpose - In-Line)

Stainless Steel	NUPRO 4F-316, with 60 micron filter element
	HOKE No. 632-3F4Y (316SS)
Brass	NUPRO 4F, with 60 micron filter element

Flow Gauges (with valves)

Stainless Steel 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, ¼ in.	Flare, or Swagelok
Teflon (or Kel-F) ¼ in.	Swagelok
Stabilized Polypropylene, ¼ in.	Swagelok

PRESSURE MEASUREMENTS

The dew point temperature of a gas is a measure of the absolute moisture content of the gas, at a given pressure, regardless of the temperature 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) (Kg/cm^2); therefore, if accurate absolute moisture content measurements are to be converted to atmospheric-pressure-referenced values, the pressure must be known. If it is desired to measure dew points at sample operating pressures other than atmospheric, the hygrometer Sensor should be fitted with an appropriate pressure gauge. (A dew point pressure conversion chart is shown in Section 1; Basic Humidity Definitions.)

CLEANING THE SAMPLING SYSTEM

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 lines 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 lines is Freon 114. This is a suitable solvent since it is capable of holding many hydrocarbons in solution, and it is highly volatile, non-toxic, non-explosive, readily available, and will not attack common sampling materials.

The Model 660 Dew Point Hygrometer is provided with a Type A Cleaner Solution for use in cleaning and conditioning the Sensor mirror surface. Type A is a general purpose cleaner for most applications, and is provided in the Mirror Cleaning Kit shipped with each instrument. A Type B Cleaner Solution is a special purpose cleaner that is also available from EG&G. It is recommended for Heat Treating or similar applications, where oil vapors are present. This mirror surface cleaner tends to make the Sensor less sensitive to oil vapor condensation.

SAMPLE FLOW RATE INFORMATION

When setting sample flow rates at other than 1 atmosphere (1.03 Kg/cm^2 or 14.7 psia), or when gases other than air are employed Figures A6 and A7 must be used to convert the indicated sample flow rate reading to the actual flow rate.

Figure A6 gives the actual flow rate of air at pressures other than 1 atmosphere (14.7 psia). For example, the actual flow rate of air at 30 psia when the sample flow rate reading is 2.3 scfh is 3.3 scfh.

Figure A7 gives the actual flow rate of six different gases. The actual flow rate of helium, for example, when the sample flow rate indicates 1.2 scfh is 3.3 scfh (at 1 atmosphere). When gas pressures other than 1 atmosphere are used, use Figure A6 to convert the "actual" flow rate reading obtained from Figure A7 to the true flow rate. Using 30 psia, rather than 1 atmosphere in the helium gas example above, apply the 3.3 scfh "actual" flow rate obtained from Figure A6 as the Flow Gauge Reading on Figure A6, and read 4.8 scfh as the actual flow rate of helium at 30 psia.

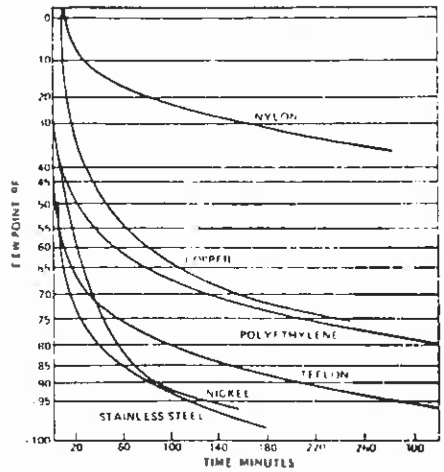

Figure A5 — Typical Sample Line Material Response Characteristics

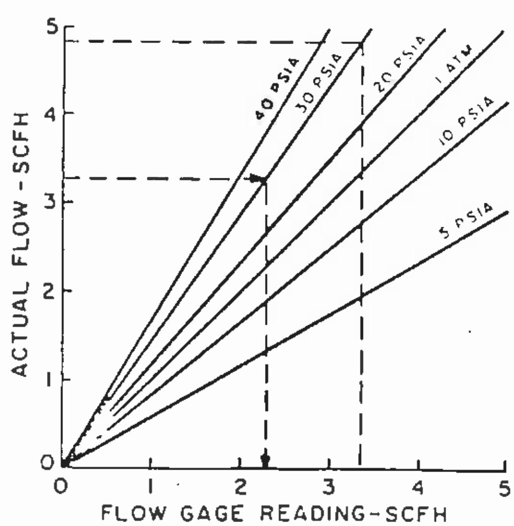

Figure A6 — Flow Corrections for Various Flow Pressures

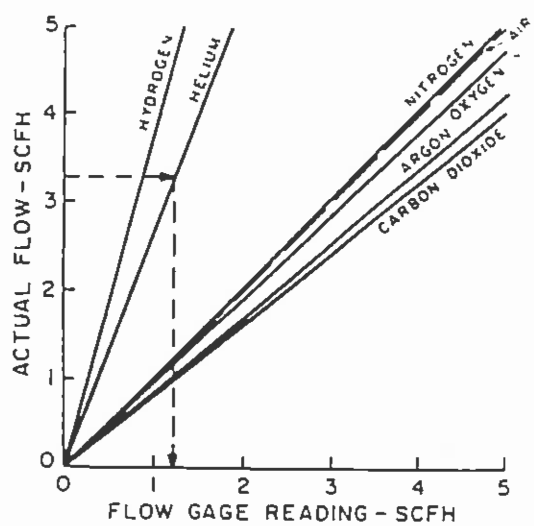

Figure A7 — Flow Corrections for Various Gases

Section B — *PREPARATION FOR OPERATION*

The Model 660, as shipped, is already set up for operation on 115 VAC, and has been tested in this configuration. However, prior to using the equipment, certain checks should be made to ensure that the Model 660 is set up properly for your particular application.

AC INPUT VOLTAGE SELECTION

Select the input voltage planned for your installation, either 115 VAC or 230 VAC. Switch S1 makes this selection easy after the cover of the Model 660 has been removed. When shipped, the 660 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. (See Figure C1.)

CAUTION

> When changing the fuse *for any reason* ensure that the Model 660 power cord has been disconnected from the source of AC power, as the fuse will be electrically energized otherwise.

Access to the fuse is gained by removing the two retaining nuts on S1 that are securing the plastic protection shield. Reinstall the plastic shield after the fuse has been changed.

FLOW RATE

Proper operation of the Model 660 is dependent upon proper plumbing of the sample to the Sensor. Reference should be made to Part 1, Section A, Plumbing Considerations. When the system is plumbed, the flow rate may be adjusted. (See Figure B1.)

SETTING ALARM SET POINT

If it is desired to use the ALARM SET feature of the Model 660, the set point should be selected prior to operation. This is accomplished by depressing the ALARM SET switch on the 660 front panel so that the yellow indicator is visible. Then digital Panel Meter (DPM) will be indicating an alarm set point temperature selection in degrees Centigrade. (Also, this is only true if the test jumper on the 660 printed wiring board is connecting TP10 to TP11.) By using a small blade screwdriver (provided in the mirror cleaning kit), the alarm set point may be adjusted to any point over the range -50°C to +100°C. When the instrument is returned to normal operation, the alarm DPDT relay, the contacts of which are brought to the rear panel connector, will remain de-energized as long as the actual dew point temperature is below the alarm set point selected. When the dew point increases above the selected alarm set point, the alarm relay will become energized and give an indication to any externally connected alarm indicators. No external alarm indicators are provided with the Model 660. (See Figure B2.)

OPERATING POINT SELECTIONS

As shipped from the factory, the Model 660 is set to perform an Automatic Self-Standardization (Balance)* cycle every 6 hours during continuous operation. A cycle is also automatically initiated whenever the instrument is turned on. Options of 12 and 24 hours for this automatic self-standardization cycle are also possible by connecting two pins on the output data connector J1, as follows:

Frequency of Automatic Self-Standardization (Balance) Cycle	*Connections on J1*
6	None
12	V to Y
24	U to Y

*Patented

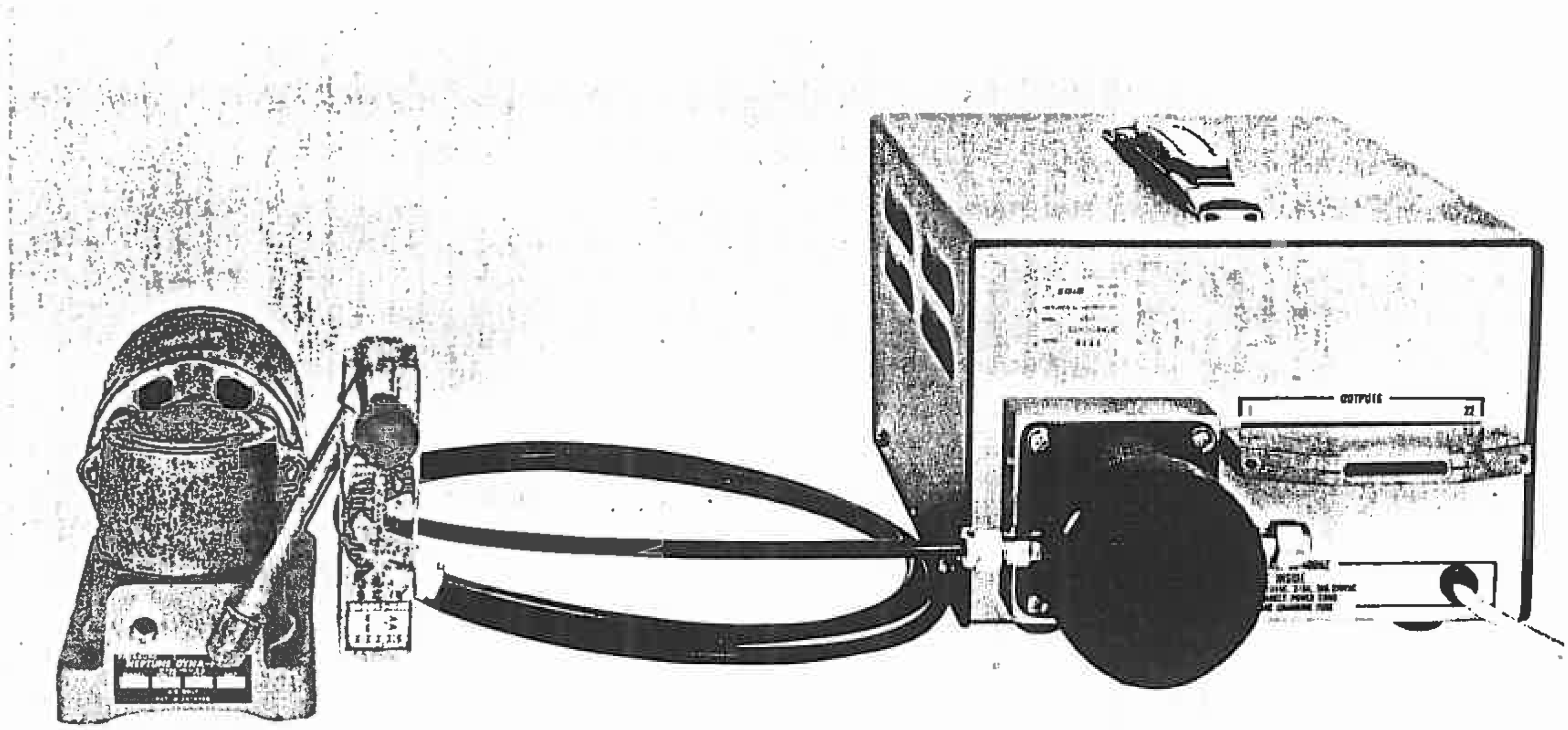

Figure B1 — Sample System Kit Attached to Model 660 Sensor

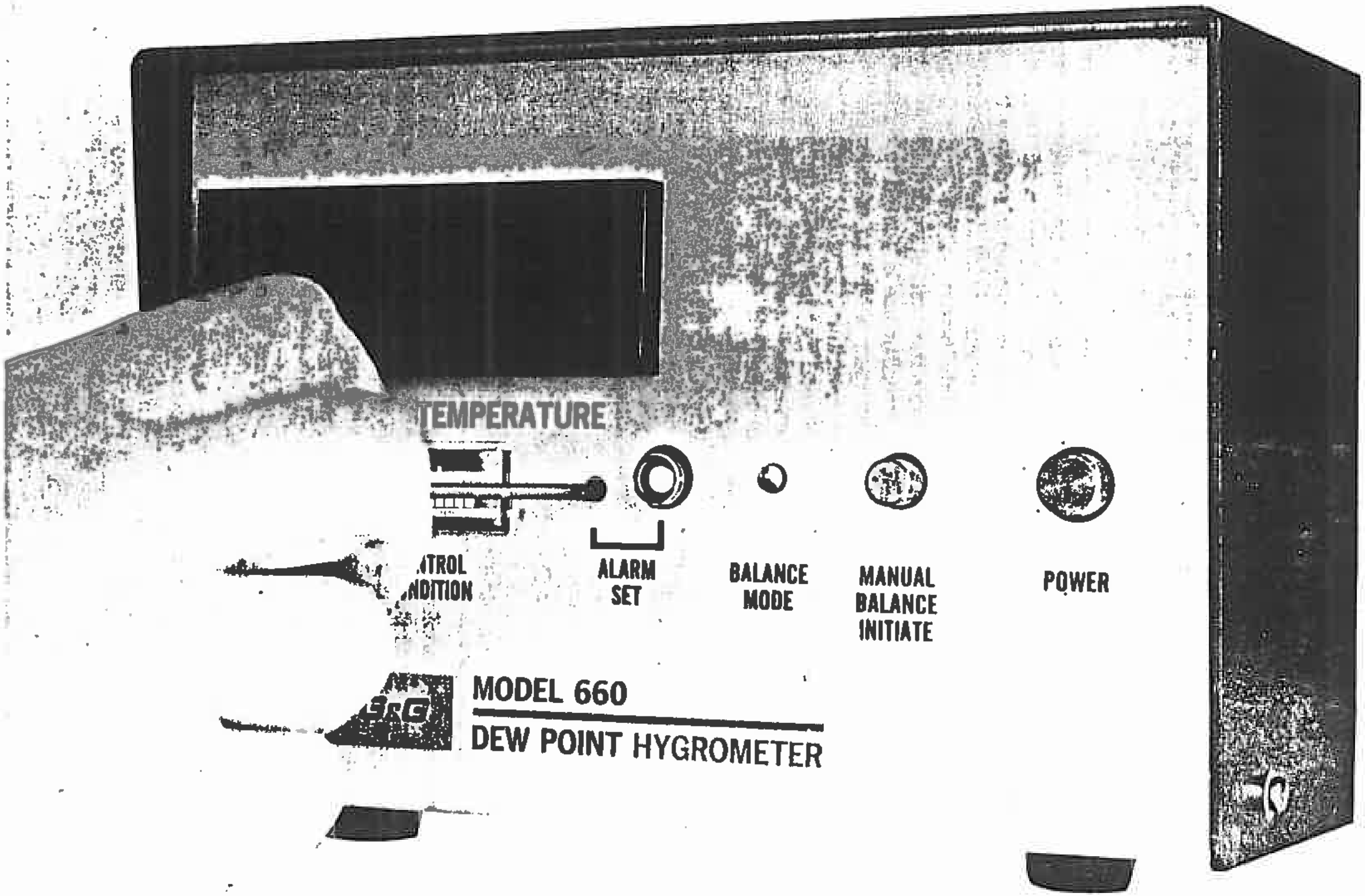

Figure B2 — Adjusting the Alarm Set Point

When an automatic self-standardization (balance) cycle is initiated, the time required to perform the self-standardization may also be varied depending on the operating conditions. Each cycle consists of a period of time that the Sensor mirror is heated to remove any condensate from it, followed by a period of time required to re-establish control on the actual dew point again. In between these two time periods, the instrument automatically and electronically compensates for any change in the reflectivity of the Sensor mirror due to the build up of contaminants on the mirror surface. The heat time period, selected at the factory, is 1.4 minutes. Other time periods available are 2.8 minutes and 5.6 minutes. When low dew points are being measured, a longer amount of time is required to heat the mirror surface to remove any condensate prior to automatic self standardization taking place. Therefore, the following time periods for the anticipated operating range are:

Dew Point Range (°C)	*Heat Time Period (Minutes)*	*PWB Jumper See Figure C1*
-50 to -25	5.6	A to H or J
-25 to +0	2.8	A to F or G
0 to +100	1.4	A to D

During an automatic self-standardization cycle, the dew point output is held by a Track and Hold circuit to maintain the analog dew point output at the level it was prior to initiation of the cycle. This output will be held at its previous level following automatic self-standardization until the instrument has had time to re-establish control on the dew point. The time required to re-establish control will vary with the actual dew point temperature. The lower the actual dew point, the longer it will take. The time period selection for the output to be held at its previous level *after* the mirror heat period selected can be made in accordance with the following:

Dew Point Range (°C)	*Output Hold Time Following Balance Initiate Period (Minutes)*	*PWB Jumper See Figure C1*
-50 to -25	11.2	B to E
-25 to +0	5.6	B to H or J
0 to +100	2.8	B to F or G

One other feature, the Digital Panel Meter display or non-display of mirror temperature during automatic self-standardization, is operator selectable. Selection of this operating mode should also be made during this initial period of preparation for operation. This selection determines whether the Digital Panel Meter (DPM) on the 660 front panel will indicate the direct Sensor mirror temperature or the output of the Track and Hold circuitry that does not "see" the Sensor mirror heat up during the automatic self-standardization cycle. As shipped, the DPM is connected to indicate the direct mirror temperature *at all times*. Therefore, it will indicate the heating of the Sensor mirror during an automatic self-standardization cycle as the mirror surface is heated to remove condensate, and then cooled to re-establish the dew point temperature. This operational mode is accomplished by a jumper on the printed wiring board which connects S to U (normally factory installed). If instead of reading mirror temperature during auto self-standardization, it is desired to have the DPM indicate the output of the Track and Hold circuitry, i.e, the last actual dew point monitored before auto self-standardization, then S should be connected to T. At times *other than* Automatic Self-Standardization, the direct output and the output of the Track and Hold circuitry indicate the same value.

When the °C to °F option is used with the 660, it is necessary to connect S to T to obtain a "Hold" output for the °F analog. This means that the displayed values will be held also. Although the °C analog hold output occurs simultaneously with the direct °C output, this is not true for the °F analog outputs.

POWER TURN-ON

Once the foregoing checks and any necessary jumper changes have been made, the cover can be put on the 660 Control Unit, and the power cord plugged into the source of AC power. Depressing the POWER switch will cause the DPM to illuminate and the BALANCE MODE light (yellow) to be on steady. The BALANCE MODE light being on indicates that an automatic self-standardization cycle has been initiated at power turn-on, as it should. The Sensor mirror surface is now being heated in accordance with the time period selected. The CONTROL CONDITION meter at this time will be indicating a dry mirror surface condition and will be near the center of the scale. (Normally there is no dew on the mirror surface when the instrument is turned on.) If the ALARM SET switch is in its operate position (NO yellow indicator visible), the DPM will indicate either the Sensor mirror temperature or the output of the Track and Hold circuitry, depending on the jumper option selected.

NOTE

At power turn-on, the output of the Track and Hold circuitry is to be ignored since there was no previous dew point data available to remember.

When the Sensor mirror heat period has elapsed, the instrument electronics will automatically compensate for any contaminants on the Sensor mirror, and then will begin to cool the Sensor mirror surface to establish control at the dew point of the gas passing through the Sensor. At this time, the yellow BALANCE MODE light will begin to blink instead of being steady. This blinking BALANCE MODE light indicates that (1) the mirror surface is being cooled, (2) the dew point is still being established, and (3) that the Track and Hold circuitry is still in the Hold mode. The Track and Hold output will switch to Track only when the BALANCE MODE indicator light is off completely.

At the same time that the BALANCE MODE indicator switches from a steady to a blinking condition, the CONTROL CONDITION meter will swing to the right. This indicates that the Sensor mirror is being cooled at its maximum rate. As dew or frost forms on the mirror surface, the CONTROL CONDITION meter will eventually move back toward center scale.

The CONTROL CONDITION meter gives a quick, visual indication of the status of the control loop at all times. Indications to the right of center indicate that the Sensor mirror surface is being cooled. The lower the dew point temperature, the more the needle of the CONTROL CONDITION meter will indicate to the right. Inversely, if the dew point temperature of the gas sample to the Sensor should experience a step change to a higher dew point temperature, the needle of the CONTROL CONDITION meter will indicate to the left as the Sensor mirror is heated to raise the mirror temperature to the higher dew point reading. When the dew point temperature of the sample gas is steady, the CONTROL CONDITION meter will indicate a steady reading to the right of center after control of the dew point has been achieved.

The front panel CLEAN MIRROR indicator should normally be off. It will only come on when, at the end of an automatic self-standardization cycle, the system cannot return to the operate mode. This is typically due to excessive contamination on the mirror surface. See Page D1 for mirror cleaning instructions. A CLEAN MIRROR logic signal is present at the rear connector Pin 8. This signal is normally near zero volts and rises to +5 VDC when the CLEAN MIRROR indicator is on.

Section C — *OPERATING ADJUSTMENTS*

The Model 660 is designed to operate without operator control. Although there are several potentiometers in the printed wiring board of the 660, all are factory set, and normally, it is not necessary to adjust them. However, certain adjustments may be made by the customer, when a knowledge of the instrument and its capabilities has been achieved, and when familiarity with the instrument has been gained. One of these adjustments affects the static setup of the instrument, and the other three affect the dynamic response of the instrument to changes in the dew point temperature of the gas sample in the Sensor. These adjustments are BALANCE, THICKNESS, GAIN, and COMPENSATION.

BALANCE

The BALANCE control, potentiometer R10 (Figure C1), is used to make the needle of the CONTROL CONDITION meter read near center scale when the BALANCE MODE lamp is steadily illuminated. It performs the same functions as the automatic self-standardization circuitry and determines a starting point for the self-standardization circuitry. It is particularly useful to adjust this BALANCE control when a new Sensor is attached to the Model 660 Control Unit.

BALANCE ADJUSTMENT

When the Model 660 Control Unit has been on for more than one hour, depress the MANUAL BALANCE INITIATE pushbutton on the front panel (Figure C2). This causes the BALANCE MODE indicator to light steadily. If there is a dew layer on the Sensor mirror, the CONTROL CONDITION meter needle will deflect to the left of center, and then as the dew evaporates, the needle will swing back to the right and stop. When the needle stops moving and the BALANCE MODE light is still in a steady condition, BALANCE potentiometer R10 can be adjusted to make the CONTROL CONDITION meter indicate as close to the center of the scale as possible. It is preferable to make this adjustment after the Sensor mirror surface has been cleaned (Section D). Once set, as contaminants build up on the Sensor mirror surface, the CONTROL CONDITION meter will begin to indicate more to the left of the center whenever the instrument is in its automatic self-standardization (balance) mode, and whenever the BALANCE MODE lamp is on steadily and the Sensor mirror is dry. If the mirror surface is known to be clean, and the CONTROL CONDITION meter indicates to the far left or right with a dry mirror and a steady BALANCE MODE light, then R10 should be adjusted. After R10 is adjusted, and contaminant build-up causes the CONTROL CONDITION meter to indicate to the far left under the same conditions of dry mirror and BALANCE MODE lamp steady, the mirror should be cleaned in accordance with the standard practice outlined in Section D.

THICKNESS

The THICKNESS control, R9, varies the thickness of the dew layer on the Sensor mirror surface when the dew layer on the mirror surface is in equilibrium with the moisture in the air sample passing over the mirror. The THICKNESS control has only a minimal effect on the dew point temperature. Any setting of this control represents a compromise between fast dynamic response of the Sensor and insensitivity to contaminants on the mirror surface. The Model 660, as shipped, has been set for optimum response with mirror cleaning intervals in excess of 90 days for normal gas sample environments. (The time between mirror cleaning periods is determined largely by the quality of the filtering of particulate matter from the gas sample.) If a faster response to changes in dew point temperatures is required, the dew layer thickness can be reduced. Conversely, if longer periods between mirror cleanings is

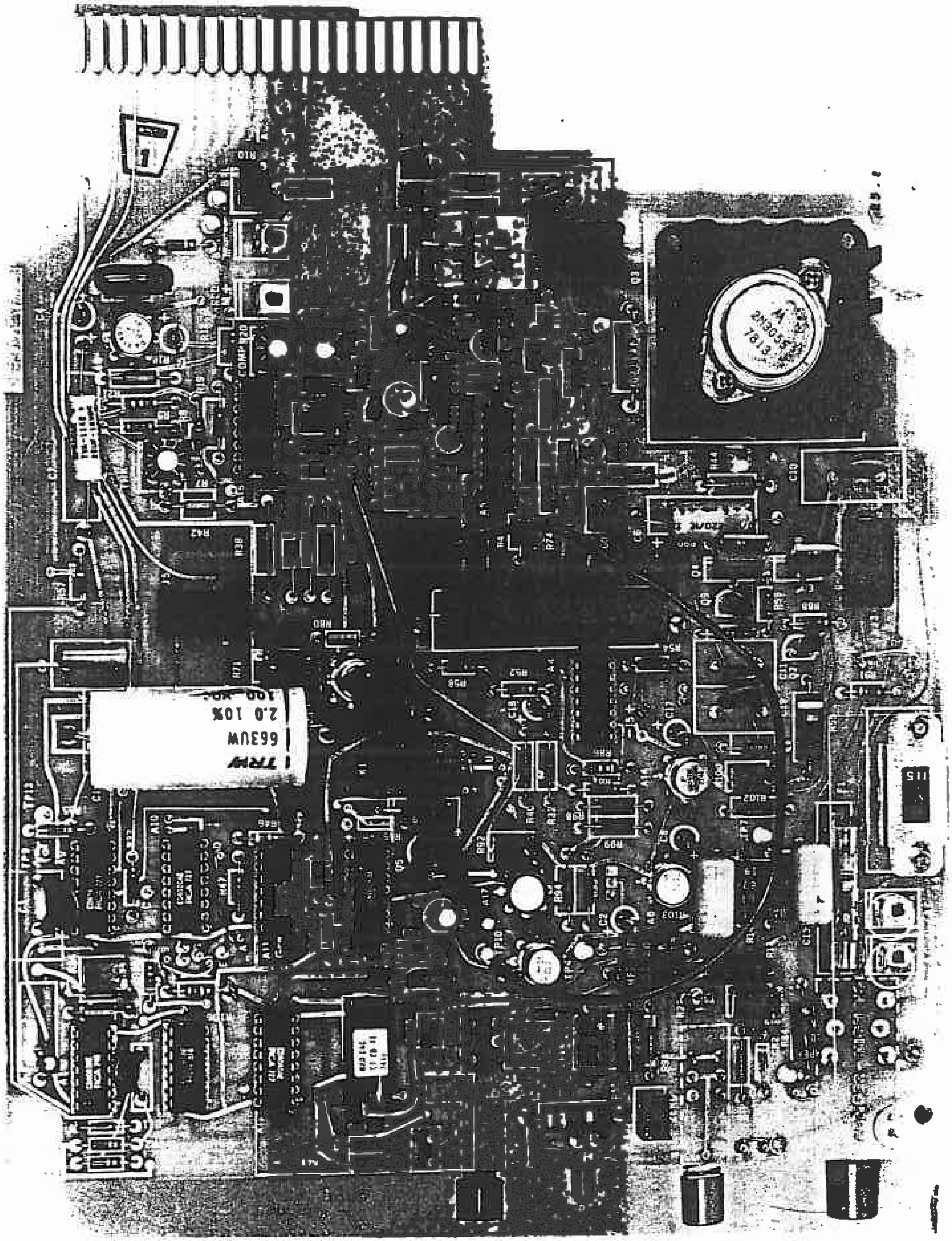

Figure C1 — Model 660 Printed Wiring Board Detail

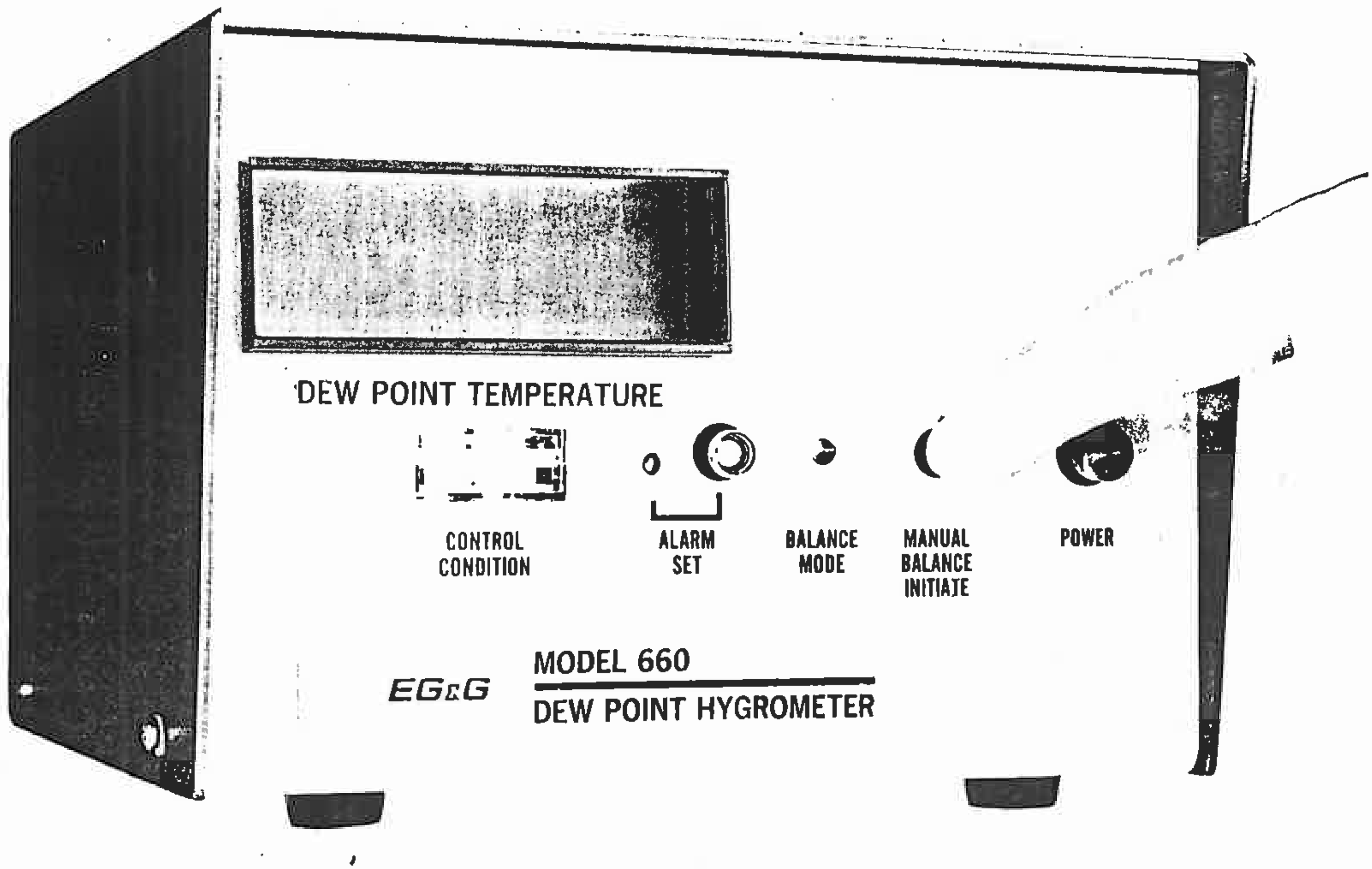

Figure C2 — Manual Initiation of Automatic Self-Standardization Cycle required for the operating conditions being experienced, the THICKNESS control can be increased.

The THICKNESS control potentiometer, R9, is a single-turn device with a position indicator attached having positions from 1 to 9. Before changing this control, *always record its factory set position* for ease in returning to the original position at a later date, if desired.

If the THICKNESS control is set too thin, i.e., lower numbers on the control setting indicator, this will be indicated by the Sensor mirror temperature not depressing to the dew point temperature. If set too thick, the Sensor will not control on the dew point temperature, but rather will continue to cool until a dew point temperature, approaching the maximum Sensor mirror depression from ambient temperature capability, is reached.

Whenever the THICKNESS control is adjusted, always depress the MANUAL BALANCE INITIATE pushbutton on the front panel to cause the Control Unit to perform on automatic self-standardization cylce, before returning to normal operation.

GAIN

The GAIN control potentiometer, R25, is a single-turn control similar to the THICKNESS control. The GAIN control functions to adjust the overall gain of the Model 660 control loop that controls the proper dew point temperature. The overall gain of the control loop is dependent on the electric gain of the control loop circuitry, *and* the gain of the condensation phenomenon on the dew point Sensor mirror surface. The gain of the condensation phenomenon is related to the mobility of the condensate which is both a function of the absolute temperature and the state of the condensate (water or ice), being high for high temperatures and water deposits, and low for low temperatures and ice deposits. The GAIN adjustment is used to compensate for this change in gain of the condensate phenomenon.

The GAIN control is set at the factory to provide stable operation over the range of the operation of the instrument. However, if dynamic performance must be optimized for a particular operating dew point, the GAIN control may be adjusted clockwise as far as possible until unstable operation is experienced, as noted by oscillations in the dew point temperature and in the operation of the CONTROL CONDITION meter. When oscillation occurs when making this adjustment, *slowly* turn the control counterclockwise until stable operation is achieved at the higher gain setting.

Before making adjustments to the GAIN control, *always record the factory set position* to aid in returning to the original position at a later date if desired. Before returning to normal operation, always depress the MANUAL BALANCE INITIATE pushbutton on the front panel of the Model 660 after making changes to the GAIN control to cause the instrument to perform on automatic self-standardization (balance) cycle.

COMPENSATION

The COMPENSATION control, R20, is provided to introduce phase lead into the amplifier circuit to compensate for the thermal phase lag characteristics of the thermoelectric cooler in the dew point 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 only at dew points of 0°C and above.

The COMPENSATION control has been set at the factory for optimum dynamic response when operating at high dew points and should not have to be adjusted. However, the proper adjustment of the COMPENSATION control may be achieved by introducing a gas sample into the sensor at the highest dew point anticipated. With the instrument operating normally on this dew point, rotate the COMPENSATION control full counterclockwise and advance the GAIN control until a steady oscillation is obtained. If oscillation occurs, rotate the COMPENSATION clockwise slowly noting the change in response for each increment of change until the oscillation ceases. If no oscillation occurs it is permissable to operate at max GAIN.

Section D — *ROUTINE MAINTENANCE*

To ensure the maximum in accurate and reliable operation of the Model 660 System, a periodic maintenance program should be established. The first area of interest in this regard is to ensure that items do not get placed near or under the Model 660 Control Unit that will impede the normal flow of air by natural convection around the instrument.

MIRROR CLEANING SCHEDULE

Contrary to what might be expected, the mirror surface in the Sensor need not be spotless for proper operation. In fact, mirror surface contaminants act as nuclei for thé condensate, thus hastening formation.

The build-up of contamination on the mirror surface normally occurs very slowly. Dust and other matter borne by the sample gas adheres to the mirror surface as it is collected by the dew layer on the mirror surface. Also, particulate matter that may be passed by any system line filters employed can also be deposited on the mirror surfáce. The net result of the build-up of contaminants of any kind on the mirror surface is to reduce the reflectivity of the mirror surface. This is the same effect that is caused by the presence of dew on the mirror. Therefore, it becomes necessary to compensate the circuitry occasionally to account for the change in reflectivity of the mirror surface due to contaminants.

This compensation for the change in the mirror reflectivity is accomplished automatically in the Model 660 with each self-standardization cycle. This patented feature adjusts the circuitry automatically for any reduction in mirror surface reflectivity that occurs when the mirror is dry, and ensures that normal operation of the Model 660 will be proper even after long periods of continuous unattended operation.

Eventually, however, the build-up of contaminants on the Sensor mirror surface may become so great that it is necessary to clean the mirror surface. Normally, intervals of 90 days between routine mirror cleanings can be easily achieved, but if gas sample operating conditions are particularly severe, more frequent mirror cleanings will be required. Whenever the instrument cannot electronically adjust for contamination, the automatic self-standardization (balance) cycle cannot be completed. This is indicated by the fact that the BALANCE MODE indicator lamp remains *on steadily* after the time period selected for the self-standardization cycle (1.4, 2.8, or 5.6 minutes), and does not blink. Also the CLEAN MIRROR indicator will come on. When this occurs, the mirror surface and optical parts should be cleaned. Then the MANUAL BALANCE INITIATE pushbutton on the 660 front panel should be depressed to allow the circuitry to readjust for the clean mirror surface, before returning to normal operation.

MIRROR CLEANING

To clean the mirror surface in the Sensor, remove the spinoff cover from the Sensor to expose the mirror as shown in Figure D1.

CAUTION

If operation with a pressurized sampling system, be sure to 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 660. 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. (Figure D2.)

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

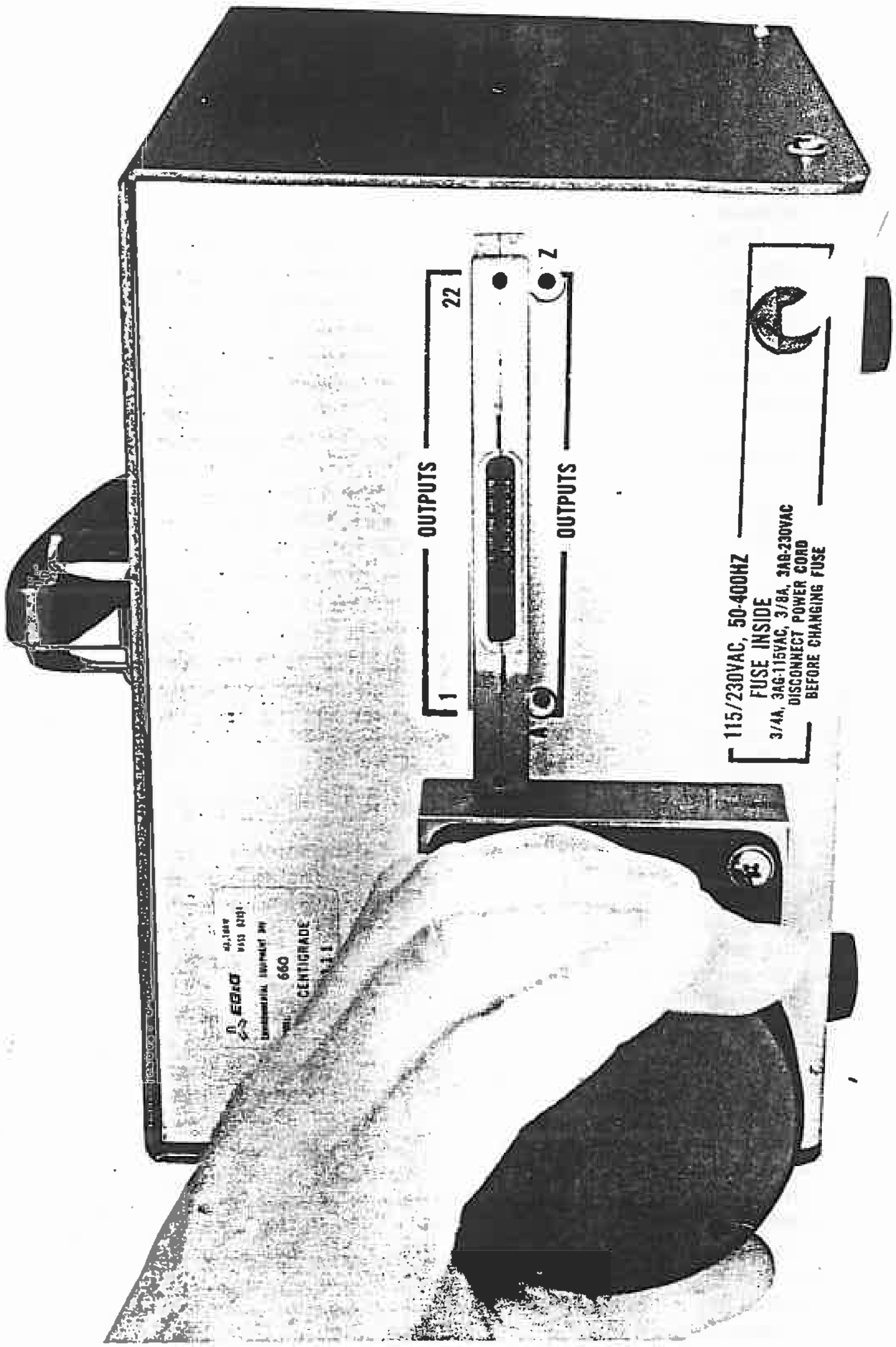

Figure D1 — Sensor Cover Removal

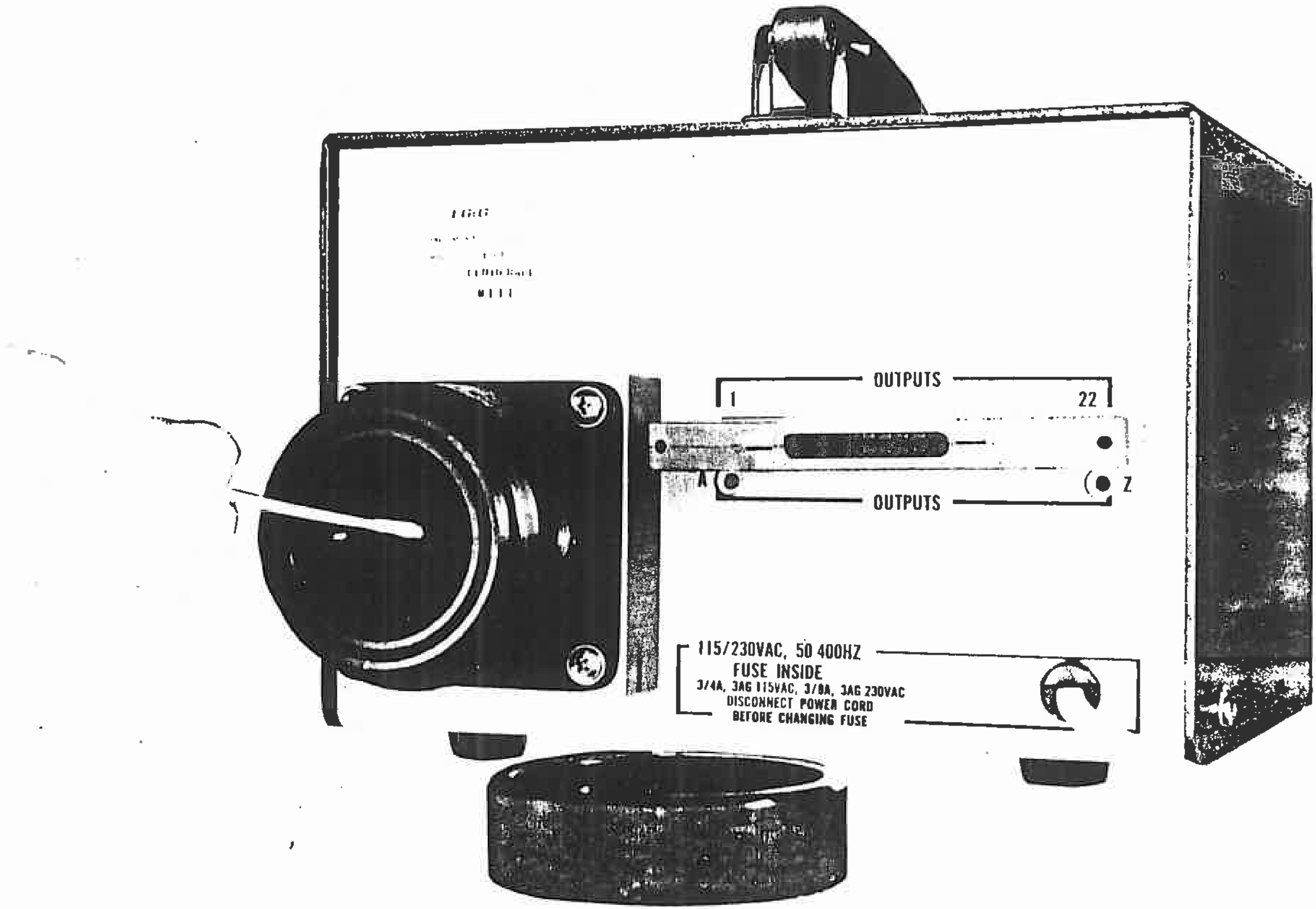

Figure D2 — Cleaning the Sensor Mirror Surface around the mirror surface and it is desired to remove it, use a clean, dry Q-tip, not Type A Cleaner, for this purpose.

For those applications where the Type A Cleaner appears to be ineffective in removing hard deposits or varnishes, a polishing paste — Simichrome Polish — (Competion Chemicals, Iowa Falls, Iowa 50125) may be used sparingly. To prevent excessive eroding of the gold-plated mirror surface, this material *must not* be used unless necessary.

PART II — SERVICING AND TROUBLESHOOTING

Section E — *REMOVAL AND INSTALLATION OF PARTS*

The Model 660 is designed to provide reliable operation without the need for adjustment or repair. If, however, it is desired to make adjustments to (1) optimize performance, (2) to change jumper options, (3) to change cable length from the Control Unit to the Sensor in the field thereby requiring field calibration, or (4) if troubleshooting has to be performed for any reason, these procedures will assist you in performing these functions.

TOOLS

A small Phillip's-type screwdriver is all that is required to remove the Control Unit cover, the Digital Panel Meter (DPM), the Printed Wiring Board (PWB), or the Sensor from the base of the Control Unit.

REMOVAL OF CONTROL UNIT COVER

To gain access to the input power voltage select switch, the fuse, or any other parts within the Control Unit, it is necessary to remove the Control Unit cover. This is accomplished easily by removing the four screws, two on each side, securing the cover to the base of the Control Unit (Figure E1). The cover then simply lifts off. Be sure to save the screws and their finish-protecting washers for reassembly. Reassembly is just the reverse of the procedure used to remove the cover.

REMOVAL OF DIGITAL PANEL METER (DPM)

When changes are to be made to the jumpers that control the operating times of the Automatic Self-Standardization and Track and Hold Circuitry, or if it becomes necessary to remove the printed wiring board (PWB), it is necessary to remove the DPM. This is accomplished by first removing the two small screws that attach the support bracket to the DPM. The DPM may now be removed through the front panel of the Control Unit by squeezing the side clips located on the DPM near the rear surface of the front panel (Figure E2). The cable attaching the DPM to the PWB should be removed at the PWB side, P5, by removing the retaining clip over the 14 pin connector and unplugging the P5 connector. It is not necessary to remove the connector from the rear of the DPM. Remove DPM and cable attached to it through the front of the Control Unit. Reassembly of the DPM is the reverse of the disassembly procedure.

PRINTED WIRING BOARD (PWB) REMOVAL

Whenever it becomes necessary to remove the PWB for replacement, or to gain access to the power supplies beneath the PWB, removal is easily accomplished by following the procedure listed below. *Be sure to disconnect the Model 660 from the source of AC power before performing these steps!*

1. Remove the Control Unit cover.
2. Remove the DPM.
3. Unplug the two AC input power leads located near the fuse.
4. Remove the retaining clip over P3/J3 and unplug P3. This cable connects to the power supplies beneath the PWB.
5. Remove the retaining clip over P4/J4 and unplug P4 from J4. This is the cable that attaches the PWB to the Sensor.
6. Unplug the two leads marked M+ and M- from the PWB. These are located near the rear panel connector exten-

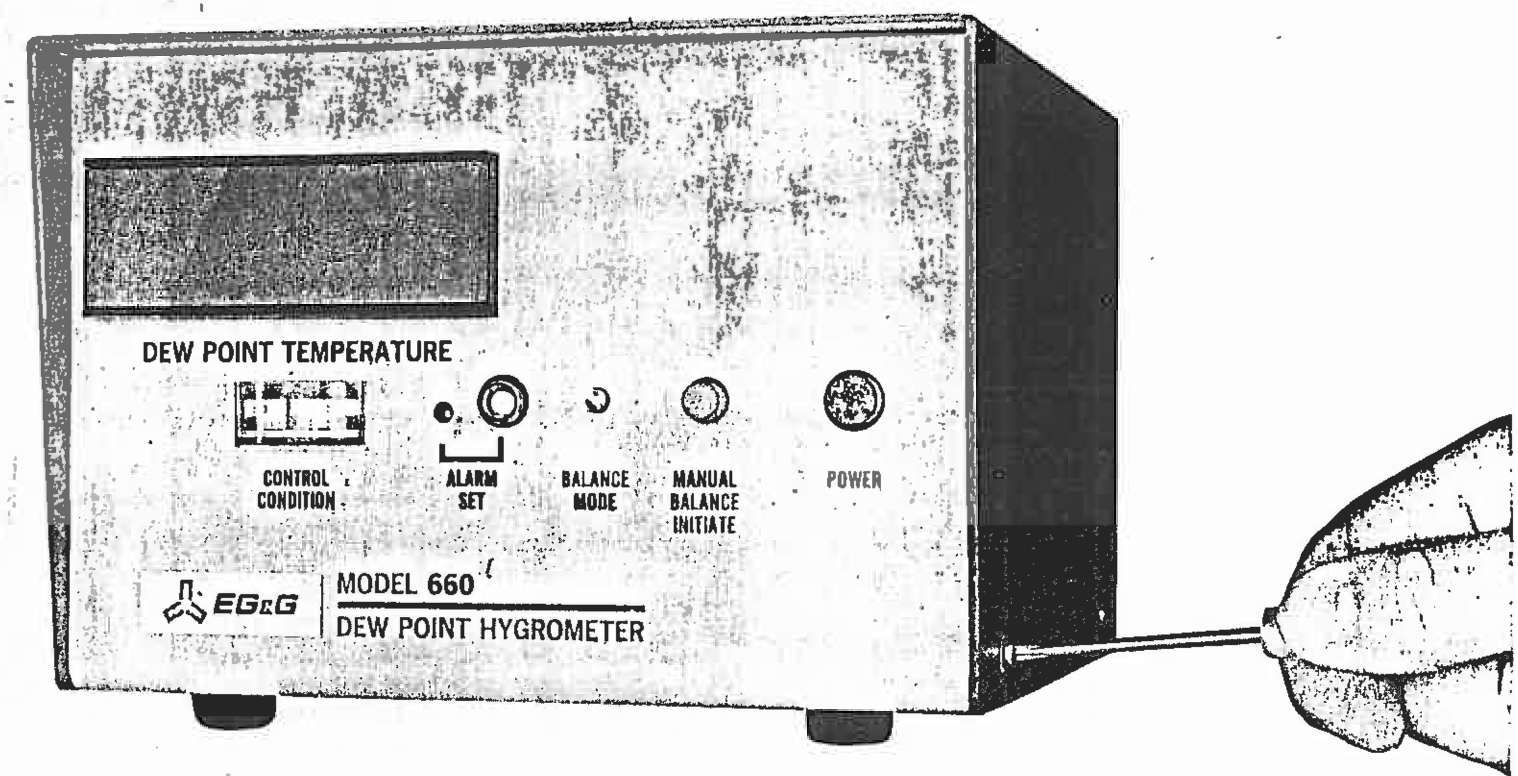

Figure E1 — Removal of Control Unit Cover

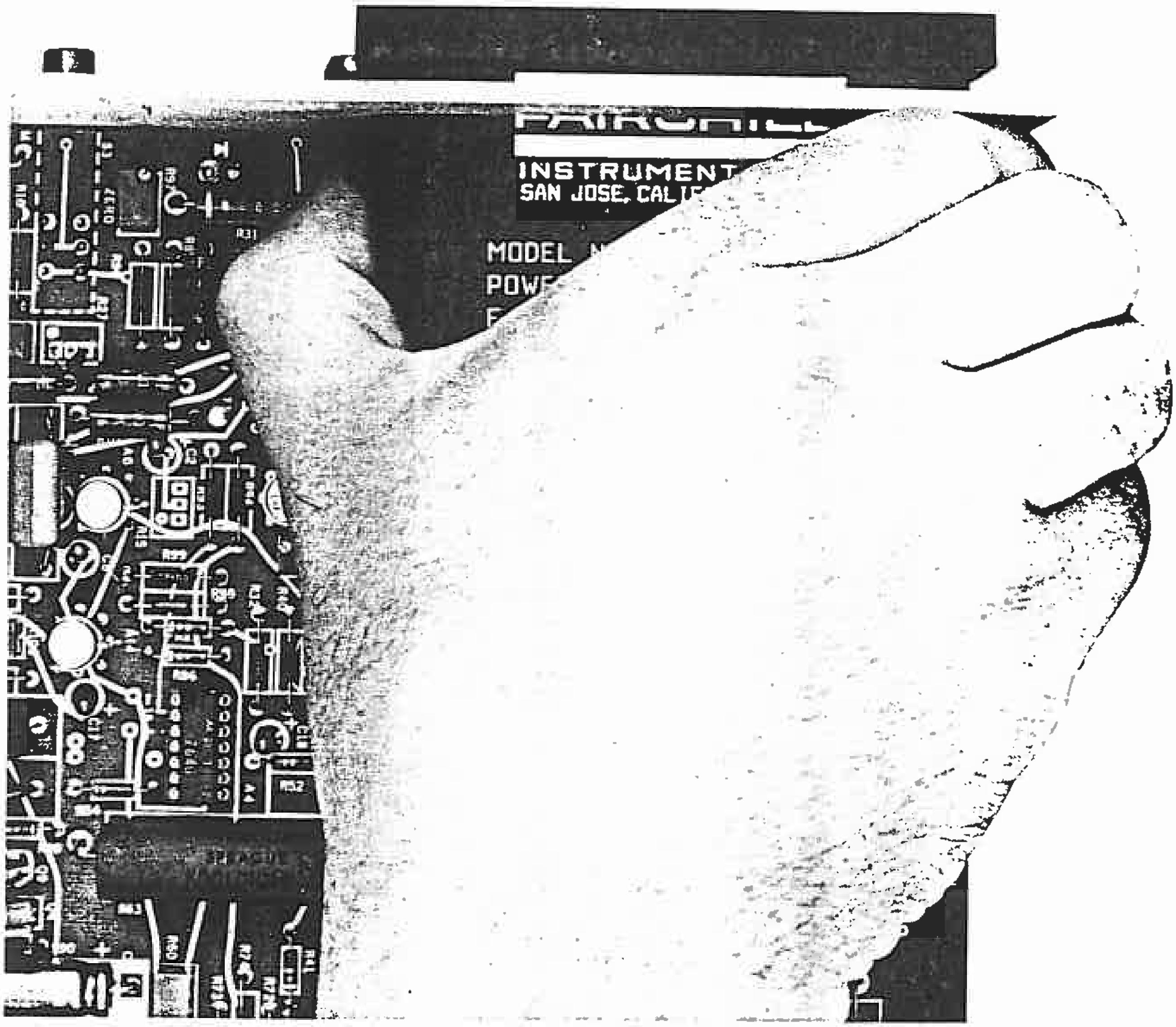

Figure E2 — Removal of Digital Panel Meter sion on the PWB. The read lead should be attached to M + and the black lead to M-.

7. Remove the four screws that attach the PWB to the four stand-offs which position this PWB over the power supplies. These four screws are located in each of the four corners of the PWB.
8. Carefully lift the PWB slightly and move it toward the rear panel of the Control Unit. As soon as the switches located on the front edge of the PWB clear the rear surface of the front panel, lift the front edge of the PWB and remove the PWB from the Control Unit. (Figure E3.)
9. Reassembly is the reverse of the disassembly procedure just described.

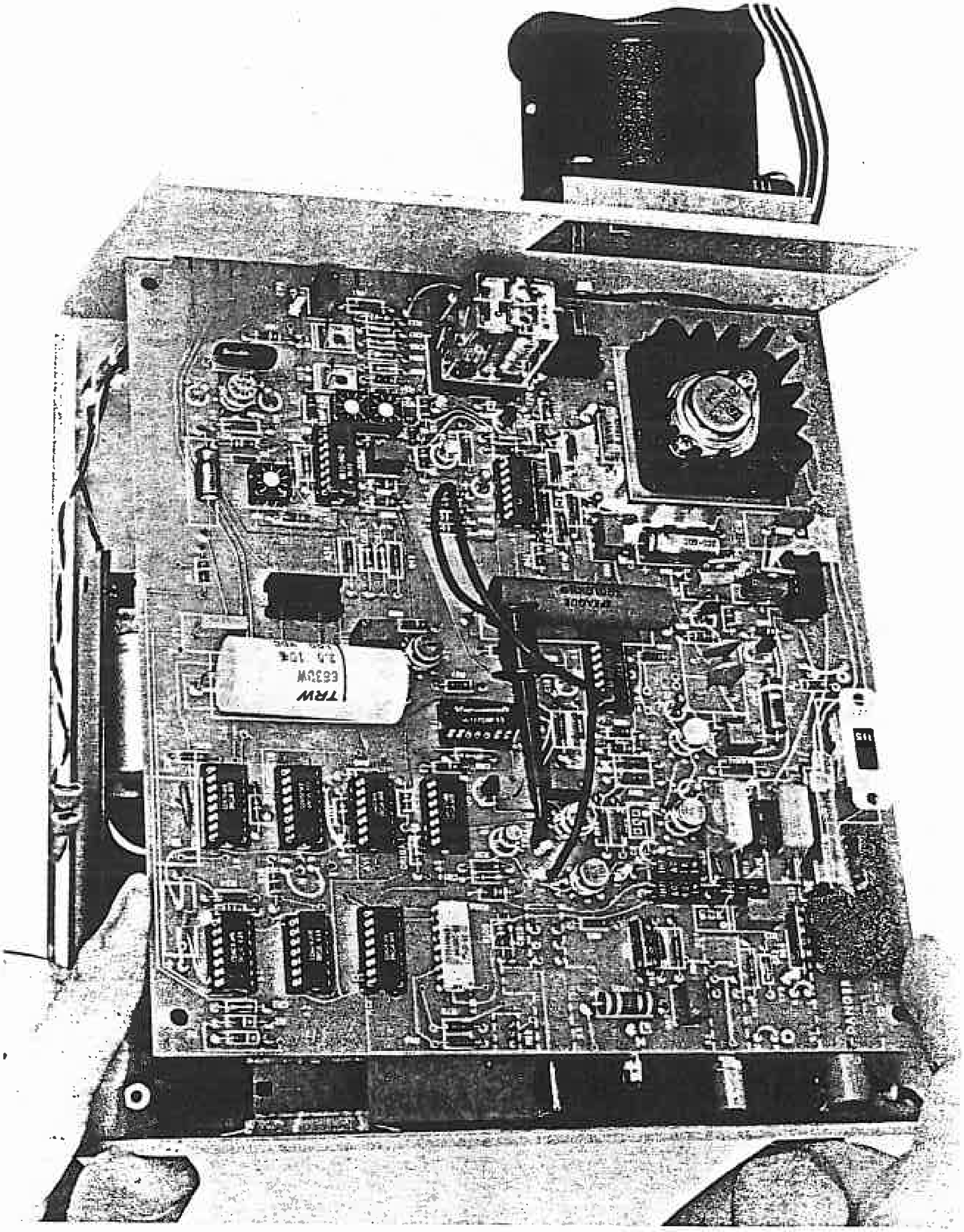

Figure E3 — Model 660 PWB Removal

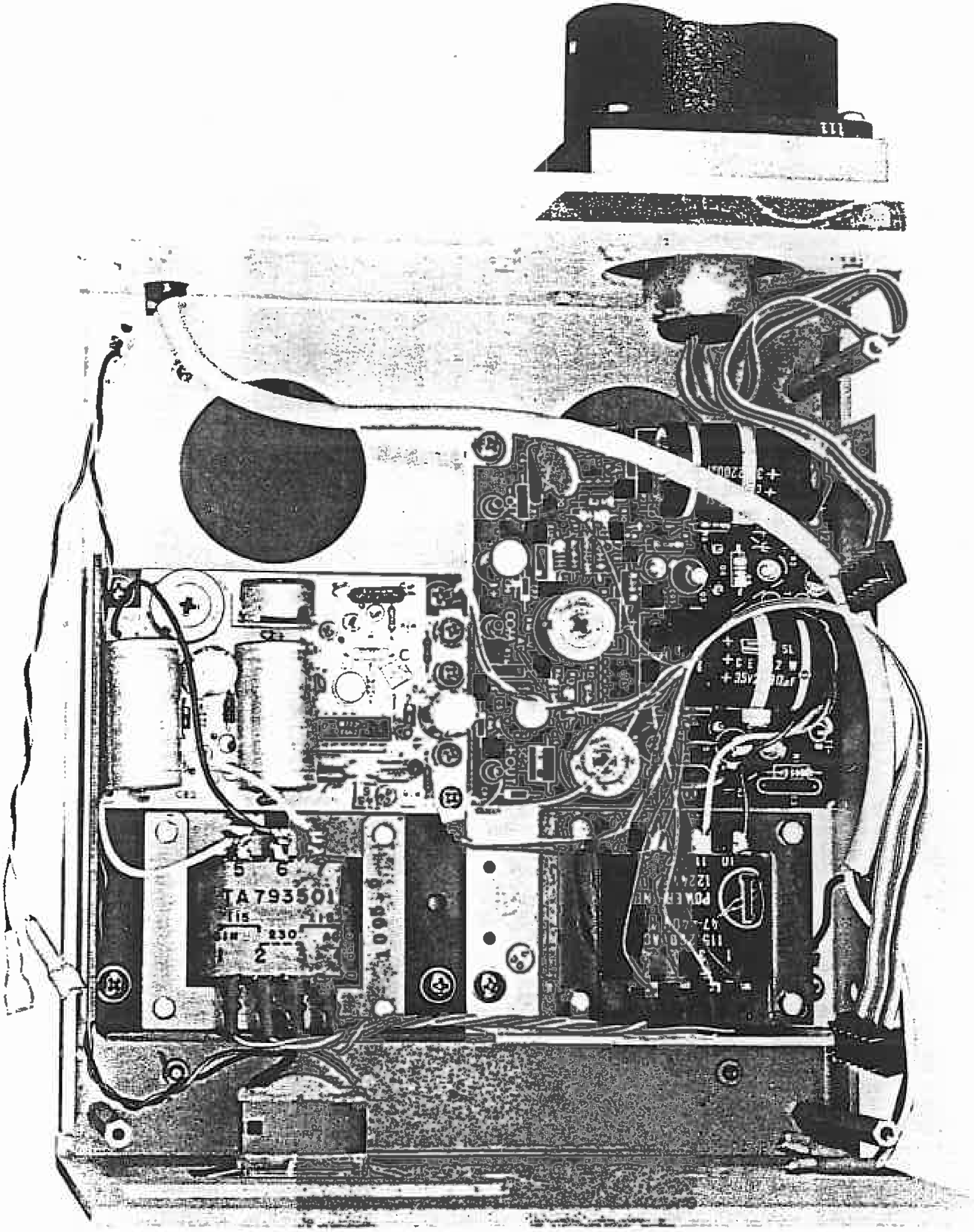

Figure E4 — Model 660 Control Unit with PWB Removed

Section F — *CALIBRATION*

A Platinum Resistance Thermometer (PRT) is used in the Dew Point Sensor. 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, larger changes in cable lengths used to mount the dew point sensor remotely may require readjustment (there is approximately a 0.1 degree Celsius 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 Volt Meter (DVM) are required for making these adjustments.

CALIBRATION OF THE PRT AMPLIFIER

There are two types of PRTs which may be used in the dew point sensor, each having slightly different characteristics. The PRT type used in a given sensor can be identified by the sensor serial number. If the serial number is prefixed with an "S" (e.g., S3604K), it is a Type 2 PRT. Otherwise, it is a Type 1. In performing this recalibration procedure, attention must be given to the PRT type in order to achieve optimum results.

When the recalibration is to be attempted for the reasons discussed above, the following procedure is recommended.

1. Remove the Sensor from the end of the cable (either long or short) and prepare a precision resistance Decade Box to be used to simulate the PRT in the Sensor.
2. Turn power on to the Control Unit and wait ½ hour to ensure that all the electronics has reached an equilibrium condition.
3. Remove the top cover from the Control Unit by removing the four retaining screws, two on each side.
4. If available, attach a precision calibrated Digital Volt Meter (DVM) across pins S and 10 on rear panel output data connector J-1. If a DVM is not available, the front panel Digital Panel Meter (DPM) may be used for this calibration.
5. Set the resistance Decade Box to 100.00 OHMS.
6. Connect Pins 4 *and* 10 of the connector removed from the Sensor together and to one terminal of the Decade Box. Connect the other terminal of the Decade Box to Pin 9 of the Sensor cable connector.
7. Observe the output of the DVM attached to J-1. It should read 0.000 volts. The DPM should also be reading 00.0°C at this time. R97, the ZERO potentiometer on the PWB, should be adjusted until this reading is attained.
8. Set the resistance Decade Box to 119.59 (Type 1) or 119.40 (Type 2) and adjust R13, SPAN, until the DVM reads +5.000 volts. The DPM should read +50.0°C at this time.
9. Set the resistance Decade Box to 138.89 (Type 1) or 138.50 (Type 2) and adjust R100, LIN (Linearity), until the DVM reads +10.000 volts. The DPM should now read +100°C.
10. Repeat steps 7, 8, and 9 as often as required to bring each voltage reading to within ±0.010 volt of the values given. Each adjustment interacts slightly with the others so it is sometimes necessary to repeat these steps several times.

11. By setting the resistance Decade Box to 80.10 (Type 1) or 80.31 (Type 2), the lower end of the scale at −5.000 volts (−50.0°C) can be checked.
12. Once calibration has been completed, the resistance Decade Box can be removed and the Sensor reattached to the end of the cable. After the Sensor is reconnected, the MANUAL BALANCE INITIATE pushbutton on the front panel of the Model 660 should be pressed and the Control Unit cover reattached to the chassis.

The resistor values to be used for calibration purposes listed in the procedure given above are nominal values that serve for most Model 660 Sensors. This allows for correct interchangeability of sensors without recalibration. If, however, the calibrations values for a particular sensor are different from those listed here, the correct values will be included on a separate document shipped with the sensor and certificate of calibration.

Section G — *LOCATING TROUBLE*

In some cases of faulty instrument operation the source of trouble will be immediately apparent. In others, this will not be the case since a given sympton may often be due to any one of several causes. In locating and eliminating such faults, two methods are recommended:

1. When trouble arises, a number of simple preliminary checks, listed later in this section, should be made before proceeding with more elaborate tests. These simple checks, which can be performed without disturbing any components of the system, are designed to detect or correct those troubles most likely to occur.
2. If the trouble is not located or remedied by the simple preliminary checks, a series of tests, described later in this section, can be used to isolate the fault to one of the major sections of the system. When this is done, the faulty section can then be replaced or checked systematically to locate the particular component causing trouble.

THE DIGITAL PANEL METER (DPM) AS A TEST AID

The Model 660 has been designed in a manner that allows the DPM to be used as a digital voltmeter to test for certain voltages and test signals. For instance, power supply voltages can be checked as well as the currents flowing in certain circuits. This section explains how to use the DPM as a test tool to aid in locating trouble.

The DPM used to display the dew point temperature on the front panel of the Model 660 is, in reality, a ± 19.99V full scale reading digital voltmeter. However, the decimal point has been moved one place to the right to enable it to present +10.00 volts DC as 100.0°C, a representation of the dew point temperature in engineering units. Therefore, when actually using the DPM as a digital voltmeter test tool, mentally move the decimal point one place to the left to read volts DC directly.

In order to use the DPM as a test tool, the ALARM SET pushbutton must be depressed so that the YELLOW indicator on the button is visible. Normally, when in this position, the DPM is indicating an ALARM SET point in degrees Centigrade (°C). However, if the cover of the 660 Control Unit is removed, notice that a test hook, called a "Grabber," is used to connect two test points, TP 10 to TP 11. When the "Grabber" is in this position, the DPM will, in fact, be indicating an ALARM SET point so that whenever testing is completed, the "Grabber" should always be returned to TP 11. However, if the "Grabber" is removed just from TP 11 it can then be used to measure DC test voltages less than ± 19.99 volts throughout the Printed Wiring Board (PWB) of the Model 660.

PROCEDURE FOR USING THE DPM AS A TEST AID

The following procedure will ensure that the DPM is removed from performing its normal functions and used properly to assist in locating trouble.

1. Remove the top cover of the 660 Control Unit by removing the four screws, two on each side, that attach it to the 660 Control Unit Chassis. Save the screws and washer hardware removed for later reassembly. Lift the Top Cover off, exposing the PWB.
2. Depress the ALARM SET pushbutton on the front panel to the position so

that the YELLOW indicator on the button is visible.

3. Remove the "Grabber" from TP 11 and use it as an input lead to the DPM which now operates as a DVM.
4. When measuring voltages, be sure to mentally move the decimal point location one place to the left to read DC volts directly. For instance, +15.00 VDC will appear as +150.0 VDC and +5.00 volts will appear as +50.0 VDC. By moving the decimal point to the left under these circumstances, of course, the correct values of +15.00 VDC and +5.00 VDC, respectively, can be obtained.
5. Use caution to ensure that the "Grabber" is not connected to any of the input AC voltage points. *DO NOT USE THE DPM TO MEASURE ANY AC VOLTAGES.* The DPM is strictly a DC device.
6. When all tests and checks have been made, be sure to return the "Grabber" to TP 11, as this will complete the circuit to enable the DPM to read the ALARM SET point when the YELLOW indicator is visible on the ALARM SET switch.
7. Reattach the Top Cover of the 660 by following the reverse of the removal procedure outlined in Step 1 above.

In the troubleshooting aids that follow, reference will be made several times to measuring of certain DC voltages to see if they are proper. The use of the DPM as described above is suitable for these purposes. No other test equipment is necessary. However, a few simple checks that can be made quickly with the DPM as a DVM are listed here.

Parameter to be measured	*Point of "Grabber" Attachment*	*What you should find at this point*
+5.0 VDC	Can of large transistor located on heat sink.	5.00 VDC ±0.2 VDC. This voltage should also appear on Pin 14 of A1, A2, A3, A11 and Pin 16 of A9, A10, A12. If this voltage is too far from being correct, the DPM may not operate properly. (The DPM operates from the +5 VDC Supply.)
+15 VDC	Near A4, a point on the PWB is designated +15.	+15.00 VDC ±0.2 VDC. This voltage should also be present on Pin 7 of A6, A7, A8, A13, A14.
-15 VDC	Near A4, a point on the PWB is designated -15.	-15.00 VDC ±0.2 VDC. This voltage should also be present on Pin 4 of A6, A7, A8, A13 and Pin 12 of A13.
+1 to +2 VDC	TP2	The voltage on this test point is directly related to the current flowing through the Sensor LED light sources. TP 2 volts ÷ 0.050 = LED CURRENT in milliamps.

PRELIMINARY CHECKS

Symptom	*Recommended Checks and Replacements*
1. Instrument is completely inoperative including DPM and CONTROL CONDI-meter.	Check 115/230 volt switch for proper position for input AC voltage being used. Check the fuse. If fuse is good, check for line voltage across the AC terminals on the PWB. (Unplug power cord before checking fuse.)
2. Line voltage and fuse are good, but still no indication of equipment operation.	Check to see that all cables connecting to the PWB are intact. For instance if P3 is not plug-ged into J3, no operation will occur.
3. Fuse blows when replaced and power is turned on again.	Check to see that the proper fuse is being used. The fuse value should be 3/4 amp rating for 115 VAC operation and 3/8 amp rating for 230 VAC operation. Either fuse should be of the SLO-BLO design.
4. DPM always reads near zero when at-tempting to adjust ALARM SET.	Check to see that the "Grabber" on the PWB has been returned to TP 11.
5. The +5 volts seem fine, but the +15 and -15 voltages are much lower than they should be.	This usually occurs when operating on 115 VAC and the 115/230 input voltage selector switch is set to 230 VDC.
6. CONTROL CONDITION meter is too far left or too far right during the time the BALANCE MODE indicator is on *steady*.	This indication can occur if the Sensor is not plugged in, if the Sensor has been changed, or if the Sensor Mirror surface is very dirty. (A dirty mirror only causes the CONTROL CON-DITION meter to indicate more to the left.) Adjustment of BALANCE potentiometer, R10 can usually bring this indication back to center scale if a new Sensor has been attached. Clean-ing a dirty Sensor mirror has a similar effect.
7. CONTROL CONDITION meter and dew point temperature output do not settle out to a steady reading.	First check to see that the dew point sample flowing through the Sensor is from a uniform source and that there are no plumbing leaks. If these inputs to the Sensor check out, then either the GAIN or COMPENSATION controls may be set too high, or the sample flow rate may be too high.
8. Sluggish response to changes in dew point experienced.	This could be due to the THICKNESS setting being too high or the GAIN setting being too low.

9. Dew Point reading is always too high.	THICKNESS setting is too low or GAIN setting is too low.
10. DPM does not indicate dew point temperature but rather a steady reading at all times.	Check to see that the ALARM SET pushbutton has been pushed to the position where there is *no* YELLOW indicator visible.
11. Operating at high Sensor ambient temperatures near +100°C, the DPM appears to be indicating ambient temperature rather than the dew point temperature.	If the Sensor base temperature has been allowed to exceed +105°C the themostat in the Sensor will open, preventing the mirror from cooling to the dew point. The mirror temperature will now rise to ambient. The Sensor temperature must be reduced to +80°C or below to reset the Sensor thermostat.

FAULT ISOLATION

Test procedures to be used when trouble is not located by means of any of the Preliminary Checks. Reference should be made to the Block Diagram Figure H1, and the circuit explanation of Sections H through N.

Symptom	*Recommeded Checks and Replacement*
1. Not all the three power supply voltages, +5, +15, and -15, are present.	This is probably caused by a failure in one of the power supplies or a breakdown in the cabling from the PWB to the power supplies. It can also be caused by an overload in one of the circuits. Turn the equipment off and in a few minutes, turn it back on. This causes the overload protection circuits on the power supplies to reset and, if the overload were temporary, the fault will clear.
2. +15 and -15 are fine, but +5 goes down when the 660 attempts to cool to the dew point after an automatic self-standardization cycle.	This is sometimes caused if the CURRENT LIMIT potentiometer R56 is adjusted to a point other than that set at factory. If this potentiometer position has been changed, it should be put back to its original position. Again, turning the instrument off and on will allow the power supply to reset itself.
3. Sensor Mirror does not heat above ambient temperature during a self-standardization cycle, but operates on dew point readings.	Measure voltage at TP 1 during the time the BALANCE MODE and indicator is on steady, as during the self-standardization cycle. This voltage should be -0.04 volts ±0.01 volts.
4. Mirror temperature cools below the actual dew point and large amounts of dew or frost builds up on mirror surface.	Place instrument in self-standardization mode and clean mirror surface with type A cleaner. Make sure no detergents are allowed on mirror surface. If trouble persists, which may be caused by dirty optics, clean optics with isopropyl alcohol and pipe cleaner. Clean optics is determined by voltage drop across R4. (Should be greater than 5V)

PART III — TECHNICAL INFORMATION

This part of the manual contains the principles of operation for each of the major circuit areas of the Model 660 Dew Point Hygrometer. Figure H1 serves as a block diagram for all circuit discussions.

Section H — *THERMOELECTRIC DEW POINT TEMPERATURE CONTROL CIRCUITS*

The thermoelectric dew point temperature control circuit, described in Figure H1, serves the purpose of heating and cooling the mirror surface of the dew point Sensor to the temperature necessary to have a layer of dew on the mirror that is in equilibrium with the moisture in the sample gas in the Sensor, and to maintain that equilibrium condition even though the temperature necessary to do so may vary. To accomplish this, an LED light source shining on the mirror surface of the Sensor is driven from a Constant Current Source. This circuit maintains the LED current constant regardless of changes in cable resistance, cable length, temperature, etc. The light reflected from the mirror surface in the Sensor is detected by a direct phototransistor. A separate LED and phototransistor are also located in the Sensor and serve 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 Control Amplifier Circuit. If the mirror surface is dry, this Control Amplifier Circuit instructs the Cool/Heat Power Amp to cool the mirror surface. When too much dew forms on the mirror surface, the Cool/heat Amp is instructed to reduce the cooling level or even be instructed to heat the mirror surface, if necessary. This circuitry, i.e., the phototransistor sensing the reflectivity of the Sensor mirror surface, the Control Amplifier Circuit, and the Cool/Heat Amp, are connected together to form a servo controlled loop. When operating, it adjusts itself automatically to control the Sensor mirror surface at the temperature required to maintain a layer of dew on the mirror surface in equilibrium with the gas sample around it.

When the Model 660 is in the self-standardization cycle mode, the servo loop described above is interrupted, and the Cool/Heat Amp is forced to heat the mirror surface to evaporate any dew or frost present so that the circuitry may automatically compensate for any changes in mirror reflectivity, should they occur for any reason. Once this compensation has been achieved, the loop is reconnected together and allowed to control on the dew point temperature once more.

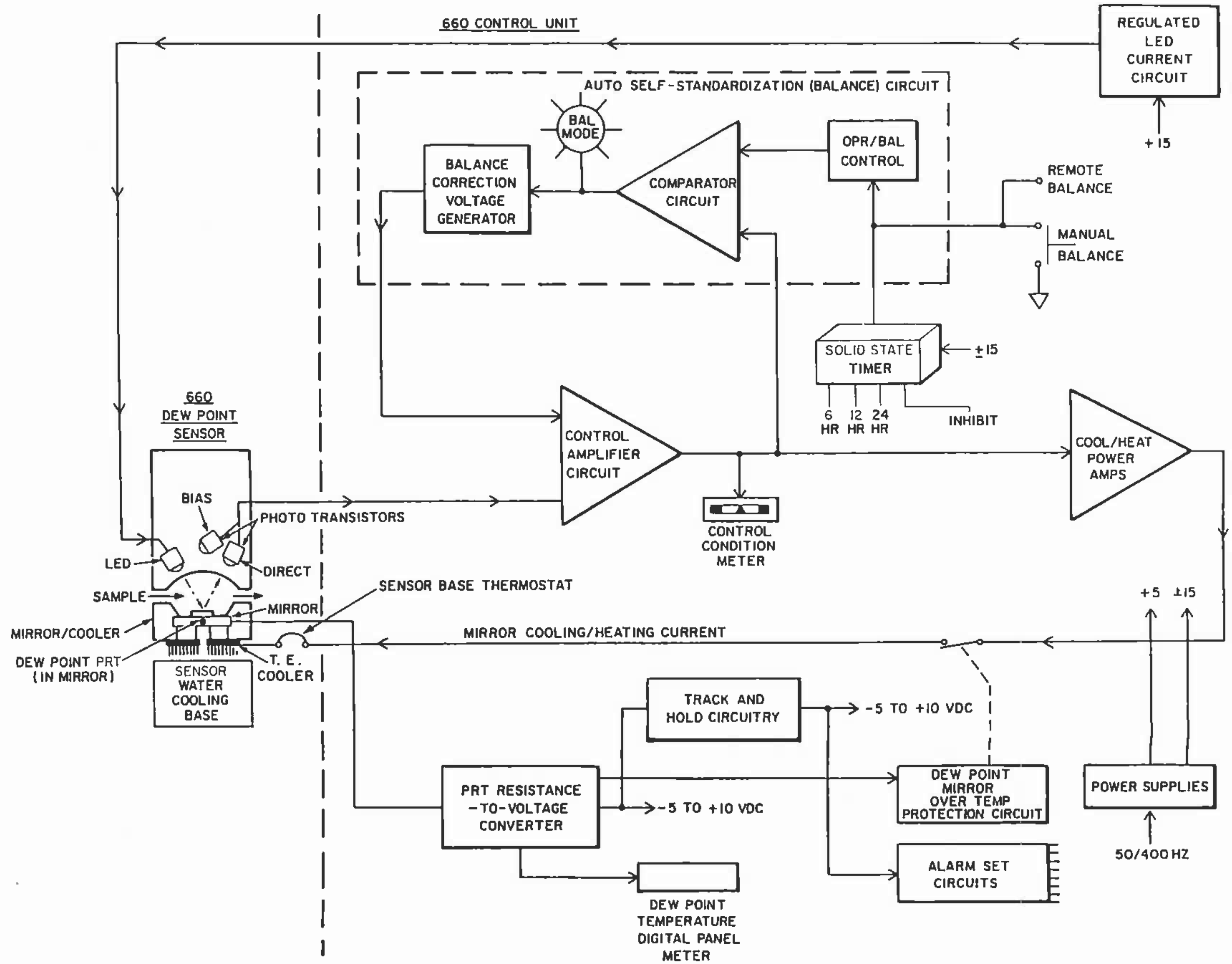

Figure H1 — Model 660 Block Diagram

Section J — *SENSOR PRT RESISTANCE TO VOLTAGE CONVERTER*

The temperature of the mirror surface is measured by means of a Platinum Resistance Thermometer (PRT) embedded beneath the mirror surface. The resistance of the PRT device varies almost linearly with change in temperature. The circuitry in this section interfaces with the PRT with adjustmens for ZERO, SPAN, and LINEARITY. The output is an analog voltage of -5 VDC to +10 VDC that varies with temperature over the range of -50°C to +100°C.

Section K — *AUTOMATIC SELF-STANDARDIZATION (BALANCE) CIRCUITS**

The Model 660 automatically verifies its own performance on a timed sequential basis by means of an automatic self-standardization circuit. This circuit adjusts for changes in the condition of the mirror surface, or for changes in any of the circuitry associated with the Sensor optical system and control loop. Automatic self-standardization is initiated upon instrument turn-on. In addition, the self-standardization cycle can be initiated automatically at 6-, 12-, or 24-hour intervals, user selectable. Model 660 Control Units are shipped prepared to initiate an automatic self-standardization cycle every 6 hours.

An automatic self-standardization cycle may also be initiated manually at any time by depressing the MANUAL BALANCE INITIATE pushbutton on the Control Unit, or remotely by momentarily shorting Pins X and 20 of the Output Data connector. It should be noted that whenever an automatic self-standardization cycle is initiated either manually by the pushbutton provided, or remotely by means of the Output Data connector, the internal timer for the interval selected is reset and the selected internal period, either 6, 12, or 24 hours, will elapse before another self-standardization cycle is automatically initiated.

Associated with the automatic self-standardization cycle is the time required to complete the cycle. The bulk of the cycle time is made up of a period of time when the dew point sensor mirror surface is being heated above the ambient temperature to remove any condensate on it, either dew or frost. This heat time period is adjustable to 1.4 minutes, 2.8 minutes, or 5.6 minutes. Model 660 Control Units are set to 1.4 minutes at the factory. When operating at dew point temperatures greater than +10°C, short heat time periods still allow all condensate to be evaporated from the mirror surface prior to allowing the adjustment circuitry to compensate for the mirror surface condition and any component changes. Longer heat times are required when operating at lower dew point temperatures. At the end of the selected time period, the circuit will automatically balance the optical bridge and control loop and return to normal operation.

Logic level signals are made available at the Output Data connector for remote indication of the operation of the Control Unit. The BALANCE MODE digital output signal on Pin R of J1 is normally high or +15 volts DC when the Model 660 is operating and is not in the automatic self-standardization mode. When an automatic self-standardization cycle is initiated from any source, the signal out on Pin R of J1 will go low or very close to 0 volts DC. This signal will remain low as long as the Control Unit is in the automatic self-standardization cycle.

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Section L — *ALARM SET AND PROTECTION CIRCUITS*

With the Model 660 electronics, it is possible to use the DPM to establish a set point for operation of an alarm relay. Once the set point has been established, between -50°C and +100°C, the alarm relay remains de-energized as long as the actual dew point is below the alarm set point, and energizes as soon as the actual dew point increases to and above the alarm set point.

The outputs of the alarm relay, a set of double pole, double throw (DPDT) contacts, are all brought to the output data connector for use in customer provided alarm indicator circuits. The analog temperature input signals to the alarm set point circuitry are obtained from the output of the Track and Hold circuitry to prevent false alarms from possibly occurring during automatic self-standardization cycles as the mirror temperature is increased above the actual dew point.

Included in this section is a description of the protection circuits that have been incorporated into the Model 660 electronics to prevent damage to the Sensor from over-heating caused by normal circuit operations. The first of these circuits is a thermostat installed in the base of the Sensor to shut down Sensor thermoelectric current in the event that the Sensor base temperature exceeds +105°C. Since the Sensor is designed to operate in ambient temperatures to +100°C, it is possible, if attempting to read very low dew points under these conditions, that the energy dissipated in the thermoelectric cooler can raise the temperature of the Sensor base above +100°C, if it is not attached properly to a sufficient heat sink. If this should occur, the thermostat in the Sensor base will open rather than risk damaging the Sensor.

The second of these protection circuits also relates to the high temperature operation for which the Model 660 has been designed. This protection circuitry monitors the Sensor Mirror temperature continuously and automatically shuts off any current flow to the Sensor thermoelectrics should the mirror temperature exceed +100°C. The possibility of this occurring is primarily when the Sensor is at a high ambient temperature, +50°C to +100°C, and an automatic self-standardization cycle is initiated which heats the mirror surface. This heating could cause the mirror temperature to exceed +100°C and damage the Sensor, but this circuitry protects against this possibility.

Section M — *DISPLAY CIRCUITRY*

The Model 660 is equipped with a Fairchild Model 70 Digital Panel Meter (DPM). This meter has been modified to move the decimal point from its normal position to one located one place to the right. This modification allows the DPM to display a -5 VDC to + 10 VDC input as a -50.0°C to + 100.0°C output, thereby presenting the Model 660 dew point temperature in engineering units.

All technical data concerning the Fairchild DPM are contained in the DPM Manual, which is shipped as part of the Model 660 data package.

Section N — *TRACK AND HOLD CIRCUITRY*

The purpose of the Track and Hold Circuitry is (1) to provide an analog dew point temperature output that is identical to the direct dew point temperature output as long as the system is controlling on the actual dew point temperature, and (2) to provlde a steady output corresponding to the actual dew point value *just prior* to an automatic self-standardization (balance) cycle, during the entire cycle. The time when the two outputs are identical is called the Track mode, and the time spent during the self-standardization cycle is called the Hold mode. By attaching process control instrumentation to the output of the Track and Hold circuitry, rather than to the direct output of the Sensor mirror PRT readout circuitry, the mirror temperature increase and decrease that occur during the self-standardization cycle can be effectively "masked" during this period.

A single-pole, Form B relay is used to disconnect the input to the Track and Hold circuitry during the self-standardization cycle. Previous information of analog dew point temperature is "remembered" during this time by a large, low leakage capacitor. This capacitor is buffered by an amplifier to isolate the capacitor from the output.

During the self-standardization cycle initiated automatically at power turn on, the output of the Track and Hold circuitry should be ignored since there was no previous dew point data to be retained.

PART IV — APPENDIX

Section O — *OPTIONS AND ACCESSORIES*

The Model 660 was designed as a basic dew point measuring instrument incorporating many features as standard as Automatic Self-Standardization (Balance),* Track and Hold output, and an Alarm Set Point, making the basic Model 660 directly suitable for most applications. However, if your application requires features not available in the standard configuration, the following options and accessories are offered to supplement the operational capability of the instrument.

MIRROR MICROSCOPE OPTION — MODEL 660-M

A Mirror Microscope option is offered for applications requiring a view of the actual dew layer established on the Sensor mirror surface. This is particularly useful when attempting to obtain an NBS certified calibration when it must be determined if the system is controlling on the actual frost point at temperatures below 0°C, or on super-cooled dew. Since the relationship between dew point and frost point for temperatures below 0°C is well known, it is easy to convert from one to the other once it is verified if control has been established on dew or frost below 0°C. This can be determined by visually observing the mirror surface using this Mirror Microscope option.

To incorporate this option, it is only necessary to remove the non-microscope compatible Sensor housing provided with the standard instrument and replace it with the one provided in the Microscope Option Kit. Use the same screws that were removed from the non-microscope Sensor housing to retain the new microscope Sensor housing, since these screws are especially strong and will ensure that the pressure integrity of the Sensor is maintained. (Figure O1.)

WARNING

The microscope provided for this option has been pressure tested to 1800 psi, six times the allowable working pressure of the Sensor, to ensure its integrity. However, with the microscope installed, it is recommended that maximum Sensor internal pressure not exceed 25 psi. The reason for this is the nature of a gas under pressure, that should the microscope become dislodged for any reason, it could become a projectile that might inflict injury to someone observing the dew layer at the time of dislodgement.

4-20 MA AND BCD OUTPUT OPTIONS — MODEL 660-MA AND 660-BC

For applications requiring outputs other than the standard analog voltages, this option is offered. It is available equipped as a 4-20 MA option or a BCD option. (Figure 02.)

The 4-20 MA option provides an output current loop in which the output current varies in proportion to the analog input voltage of -5 to +10 VDC. At an analog input of -5 VDC corresponding to -50°C, the output is 4 MA. At an analog input of +10 VDC corresponding to +100°C, the output is 20 MA. Maximum loop resistance is 1,000 ohms.

The BCD output provides 3 ½ digits of parallel BCD data corresponding to the analog voltage input of -5 to +10 VDC. The 16 parallel

*Patented

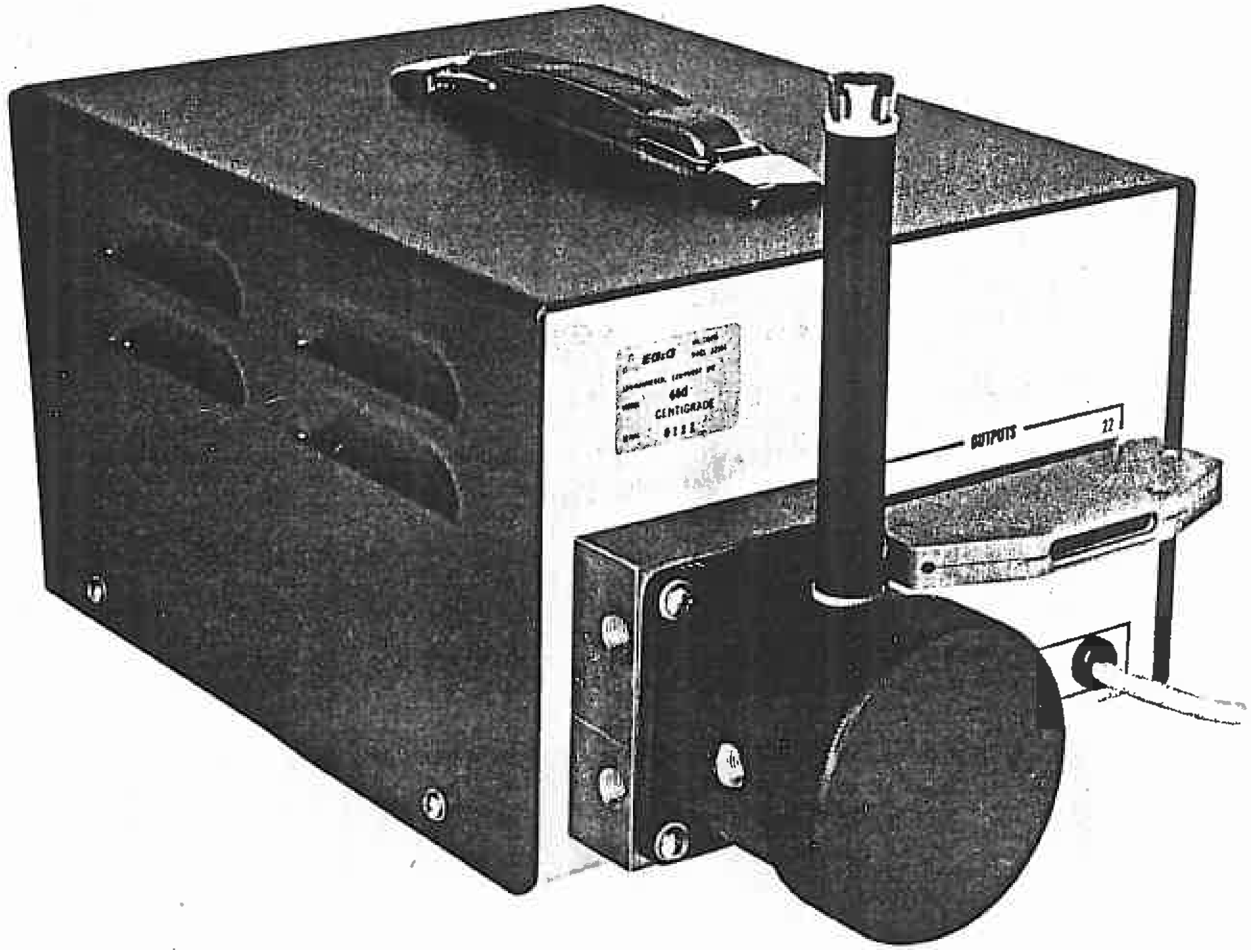


Figure O1 — Model 660 Sensor with Mirror Microscope Option

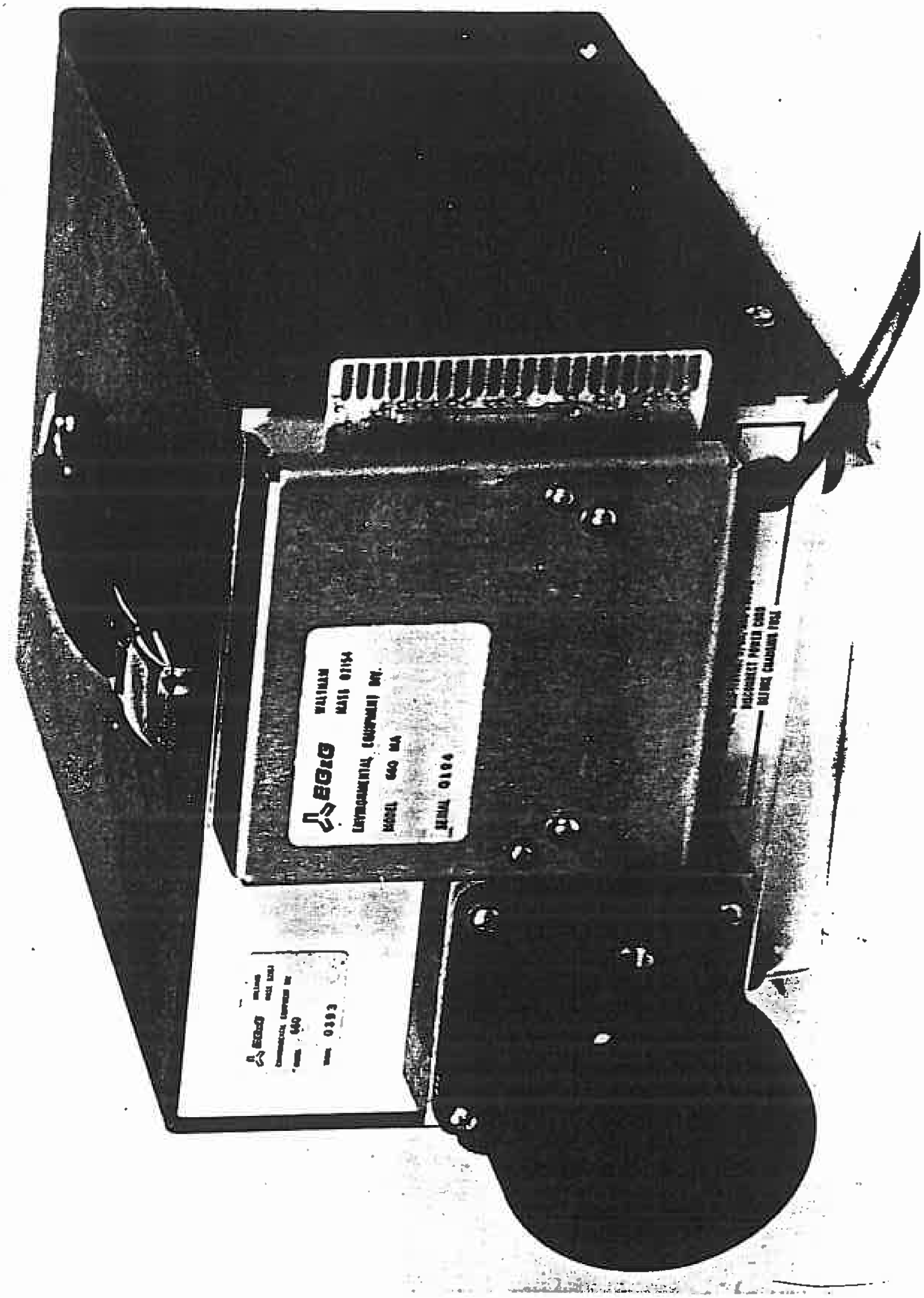


Figure O2 — 4-20 and BCD Option Module Attached to Rear of Control Unit output data lines associated with the BCD data are TTL compatible and memory is employed to give stable output data for the maximum amount of time. An End of Conversion (EOC) pulse is provided to alert external equipment that the output data are being updated. This data update occurs on the leading (positive transition) edge of the EOC pulse.

The normal output data connector on the rear of the 660 is replaced with a comparable output data connector on the output of the 4-20 MA and BCD option module. All data and output signals present on the Model 660 rear panel output data connector are maintained on the duplicate connector on the output of the 4-20 MA or BCD option module. The spare pins on the 660 output connector are used to provide outputs for the 4-20 and BCD options. See Table O1 for a list and explanations of each output pin on the output data connector.

Installation of the 4-20 MA or BCD options is accomplished by following the procedure listed below:

1. Remove existing Model 660 output data connector with connector hood.
2. Plug the 4-20 MA or BCD option module into the Model 660 output data connector such that the output data connector of the optional module extends beyond the cover of the 660 Control Unit. Use the two screws provided with the module to secure the optional module to the rear panel of the 660 Control Unit.
3. Attach any new wires desired to the output data connector removed in Step 1 (see output pin designations).
4. Replace the output data connector wired in Step 3 to the output connector of the optional module.

This module when attached extends behind the rear panel of the Model 660 1.25 inches. The height is 5 inches and the width including the output connector is 6 inches.

REMOTE MOUNTING KIT — MODEL 660-RK FIGURE 03

When it is desired to mount the Model 660 Sensor in a location different from the location of the Model 660 Control Unit, it is necessary to make use of the Remote Mounting Kit. Use of the Remote Mounting Kit allows for distances between Sensor and Control Unit to be as much as 500 feet. (For distances greater than 250 feet, a Power Booster Module is also required, as discussed below.) Instructions for installing the Remote Mounting Kit are included with the kit. It should be noted that if a Remote Mounting Kit is ordered with the Model 660 Control Unit, the Control Unit and Remote Mounting Kit and Sensor are checked out and calibrated at the factory as a system. However, if a Remote Mounting Kit is ordered separately for field installation, then field calibration of the PRT Resistance to Voltage Converter will be necessary to compensate for the slight resistance changes introduced by the change in cable length. The procedure for accomplishing this recalibration is described in Section F of this manual. (Figure O3.)

CELSIUS TO FAHRENHEIT CONVERTER OPTION — MODEL 660-CF

This option is used when it is desired to obtain dew point data in a form that can be related directly to degrees Fahrenheit rather than the standard degrees Celsius outputs. The Model 660-CF option is mounted on the rear of the Digital Panel Meter (DPM) in place of the normal DPM connector. (Figure 04). A switch on this option selects whether the DPM will display °C or °F.

A specially modified DPM is required to operate the Model 660-CF option. This special modification provides an additional digit that indicates the alpha character C when Celsius data is being displayed and the alpha character F when Fahrenheit data is being displayed. The analog data related to Fahrenheit temperature is -0.4V to +2.12 VDC corresponding to the range of -40°F to 212°F (-40°C to +100°C). The DPM, however, will not indicate a degree Fahrenheit temperature any greater than +199.9°F although the analog output is valid to 212°F.

When switching the Model 660-CF option from C to F and vice versa for displaying purposes, the full scale adjustment of the DPM may have to be trimmed for maximum accuracy. °F analog outputs are not affected by what is being displayed. The DPM has been adjusted at the factory to present °F information. If it is

TABLE O1

MODEL 660 — 4-20 MA AND BCD MODULE

OUTPUT PIN DESIGNATIONS FOR P1A/J1A

Number Side	*Letter Side*
1 PRT, Comon 1	A PRT, Common 2
2 PRT, 100 ohm	B
3 +15 VDC	C Alarm Relay, K2B-NC
4 Alarm Relay, K2A-Common	D Alarm Relay, K2B-NO
5 -15 VDC	E Alarm Relay, K2B-Common
6 Alarm Relay, K2A-NO	F Alarm Relay, K2A-NC
7 Balance Mode Indication	H -.4 to +2.12V, °F Analog Output
8	J Hold Mode Indication
9 *End of Conversion (EOC)	K 24 Hour Self-Standardization Period
10 Analog Ground	L 12 Hour Self Standardization Period
11 Remote Self-Standarization Initiate	M 6 Hour Self-Standardization Period
12 *Digit 4, 3 (8)	N Self-Standardization Period Input
13 *Digit 4,0 (1)	P -5 to +10 V, Track and Hold Output, °C
14 *Digit 4, 1 (2)	R Digit 4, 2 (4)
15 *Digit 1, 0 (Not used, Over Range)	S -5 to +10V, Direct Output, °C
16 *Digit 1, 1 (Not used, Under Range)	T *Digit 1, 3, ½ Digit Low for Digit 1, High for Digit 0.
17 *Digit 2, 0 (100)	U *Digit 1, 2 Polarity, "1" = Positive, "0" = Negative
18 *Digit 2, 2 (400)	V *Digit 2, 3 (800)
19 *Digit 3, 0 (10)	W *Digit 2, 1 (200)
20 *Digital Ground	X *Digit 3, 3 (80)
21 +4-20 MA Loop	Y *Digit 3, 1 (20)
22 *Digit 3, 2 (40)	Z 4-20 MA Loop

*Denotes an output associated with the BCD option. Digit 4 is the least significant digit.

NOTE: Not all outputs of P1A/J1A above have the same pin designations as P1/J1 as shown in Table A1.

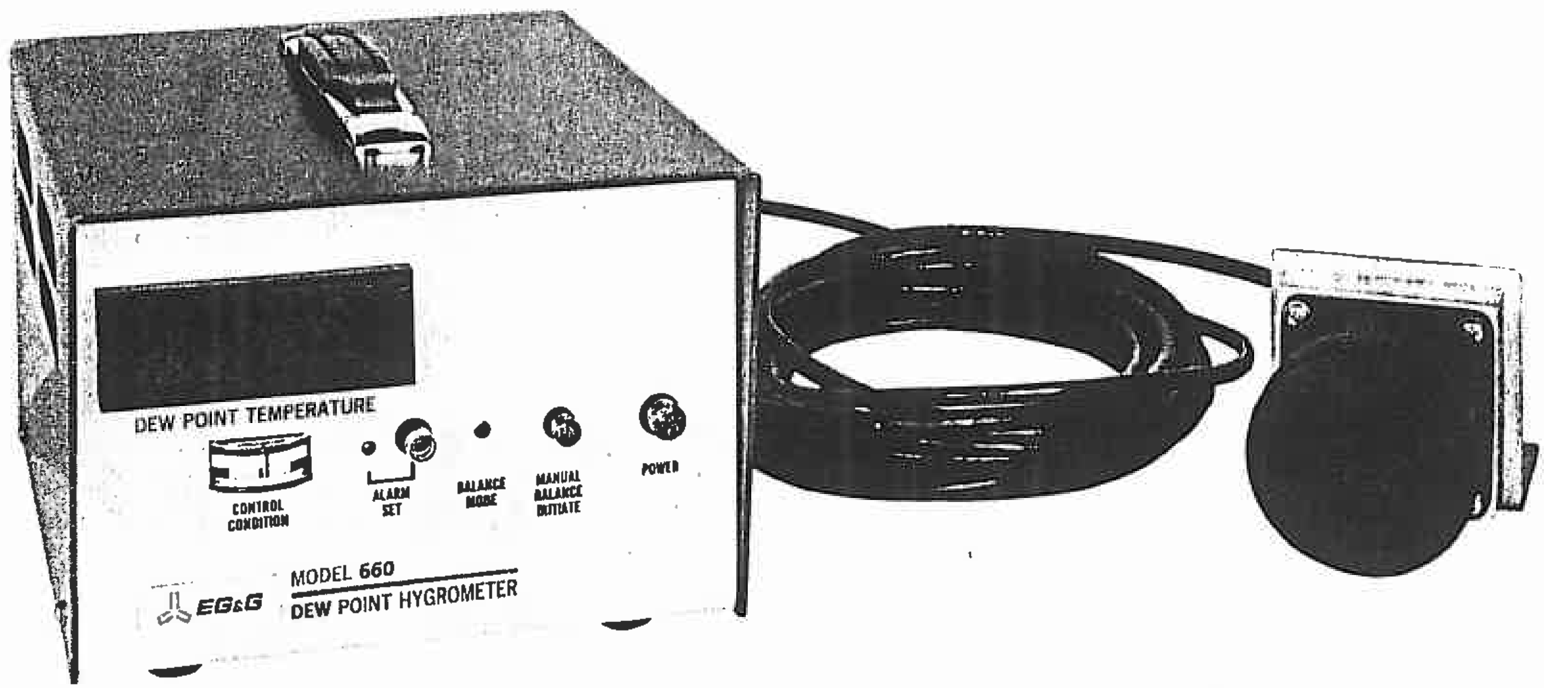


Figure O3 — Model 660 with Remote Mounting Kit desired to display °C data on the front panel at maximum accuracy, measure the °C analog output (P1-S) with a good Digital Volt Meter (DVM) and adjust the DPM F.S. adjust potentiometer (located behind the DPM front bezel) to make DPM display equal the °C analog output. This should be done at a temperature as high as possible (as in the Automatic Self-Standardization Mode) since zero correction in the DPM is automatic.

NOTE

The °C to °F conversion circuitry is physically located at the input to the DPM. Therefore, whatever analog °C signal is presented to the DPM for display will be converted to its °F equivalent. This is true, for instance, when the ALARM SET pushbutton is in position to display the alarm set point, then the alarm set point will also be displayed in °F. However, when the alarm set point is being displayed in °F, the °F analog output also becomes equal to the alarm set point voltage. (°C analog outputs are uneffected when the alarm set point is displayed on the DPM). If the 660 is being utilized in an application, such as a closed loop control system, where it is undesirable to allow inadvertent display of the alarm set point (the process being controlled by the °F analog output), then the test hook "Grabber" should be moved from its normal position on TP11 to the output of the track and hold amplifier found on terminal T. This allows the alarm function to continue to operate while essentially disabling the front panel ALARM SET switch.

Also note that, in order to have the °F analog output operate in the track and hold mode, the DPM must be connected to measure the °C analog track and hold output. This is accomplished by connecting a jumper on the main printed wiring board from terminal S to terminal T.

SAMPLE SYSTEM KIT — MODEL 660-SS

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 660 Sensor. Figure 05 shows this kit attached to a Model 660 Sensor.

PANEL AND RACK MOUNTING KIT — MODEL 660-PR

The Panel and Rack Mounting Kit Option allows the Model 660 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 E1A 19 inch rack is required. Panel height required is 7.0 inches. When mounted in this configuration, the Model 660 extends behind the front panel 10 inches.

Installation instructions are as follows:

1. Unpack the Panel and Rack Kit and layout 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 Cover
   - 1-Mirror Microscope Option Patch
   - 1-Sensor Suppor Bracket, Top
   - 1-Sensor Support Bracket, Bottom
   - 1-Cable, Sensor to Control Unit
   - 1-Cable Clamp
   - 1-Panel Cutout Template for Panel Mounting Only
   - 1-Lot Hardware
2. If the Model 660 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 660 bench mount cover with handle and replace with the unpainted handle-less cover provided in the kit.
4. Remove the Model 660 Sensor from the rear of the Control Unit, saving the hardware, and also remove the cable connecting the Sensor to the PWB.
5. Attach the longer cable provided with

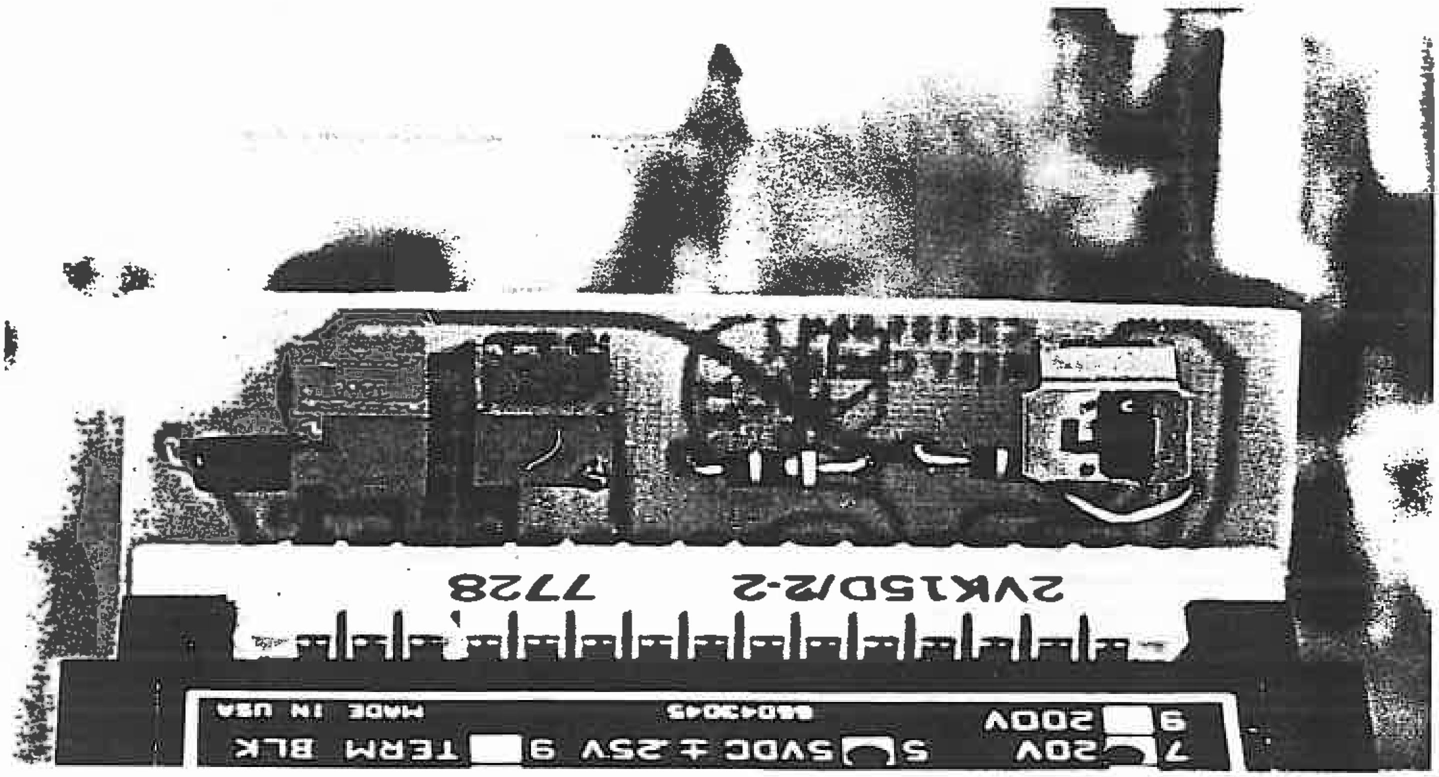


Figure O4 — Model 660 °C to °F Module

the kit from the Sensor to the Control Unit.

6. Remove the two front rubber feet from the base of the Control Unit and attach the bottom angle support bracket to the bottom front of the Control Unit using the screws of the rubber feet removed above.
7. Attach the bracket secured in Step 6 to the 19 inch front panel of the kit with four #8 flat head screws (black).
8. 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 #8 flat head screws (black).
9. Attach one side of the hinge to the 19 inch front panel using the 1/4-20 hardware.
10. Mount the two Sensor support brackets to the Sensor as shown in Figure O6. The Sensor may be rotated as desired for ease of plumbing.
11. 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 as shown in Figure O6.
12. Using the cable clamp provided, secure the cable underneath the Control Unit.
13. If the Mirror Microscope Option is not used, attach the hole patch to cover the microscope hole as shown in Figure O7.
14. The Model 660 is now mounted on a swinging hinged door that will allow it to be swung out for access to the electronics and also for access to the Sensor for mirror cleaning. Note that in this configuration, the sample lines to the Sensor are stationary. The latch (Figure O8) will keep the swinging door shut during normal operation.

Note that Sensor orientation *is* important when using the Mirror Microscope Option so that the microscope will extend through the front panel.

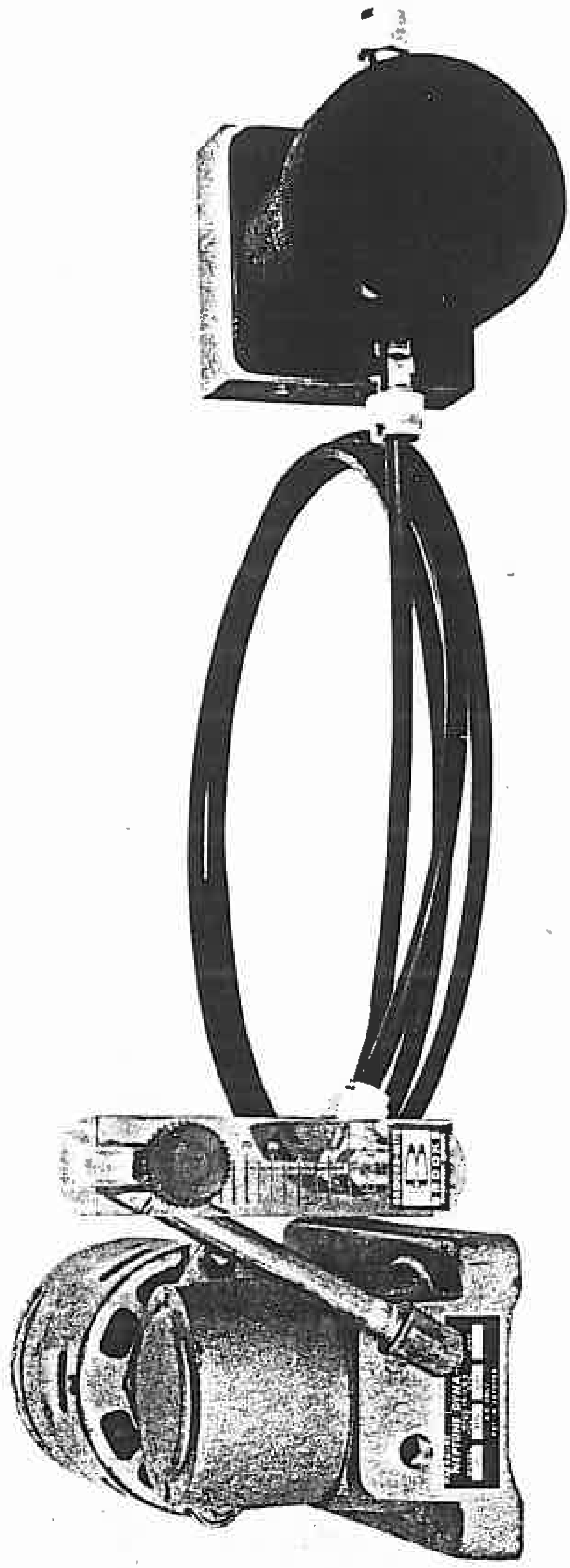


Figure O5 — Sample System Kit with 660 Sensor

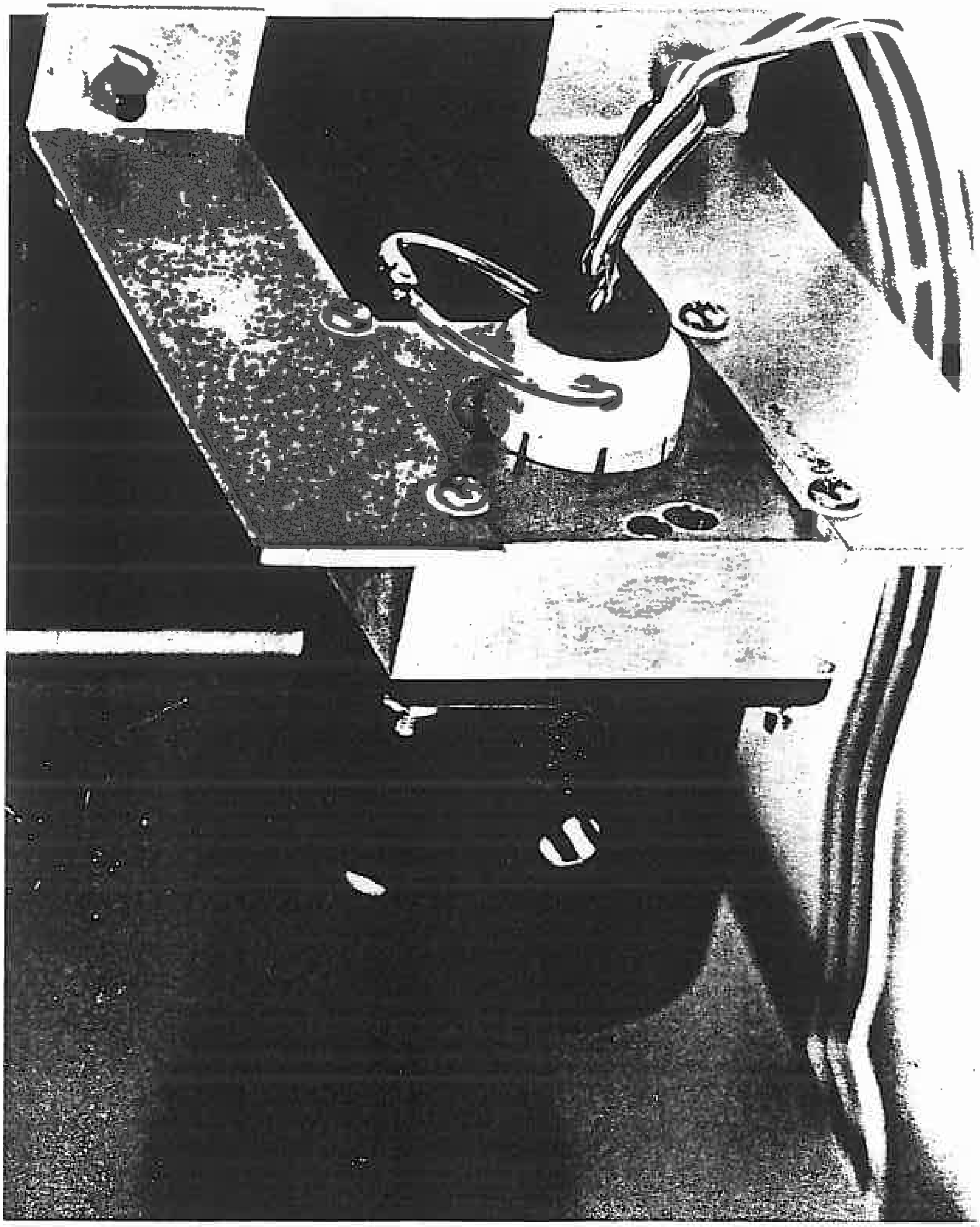


Figure O6 — Panel Mounted 660 Control Unit Rear View Showing Sensor Mounting Detail

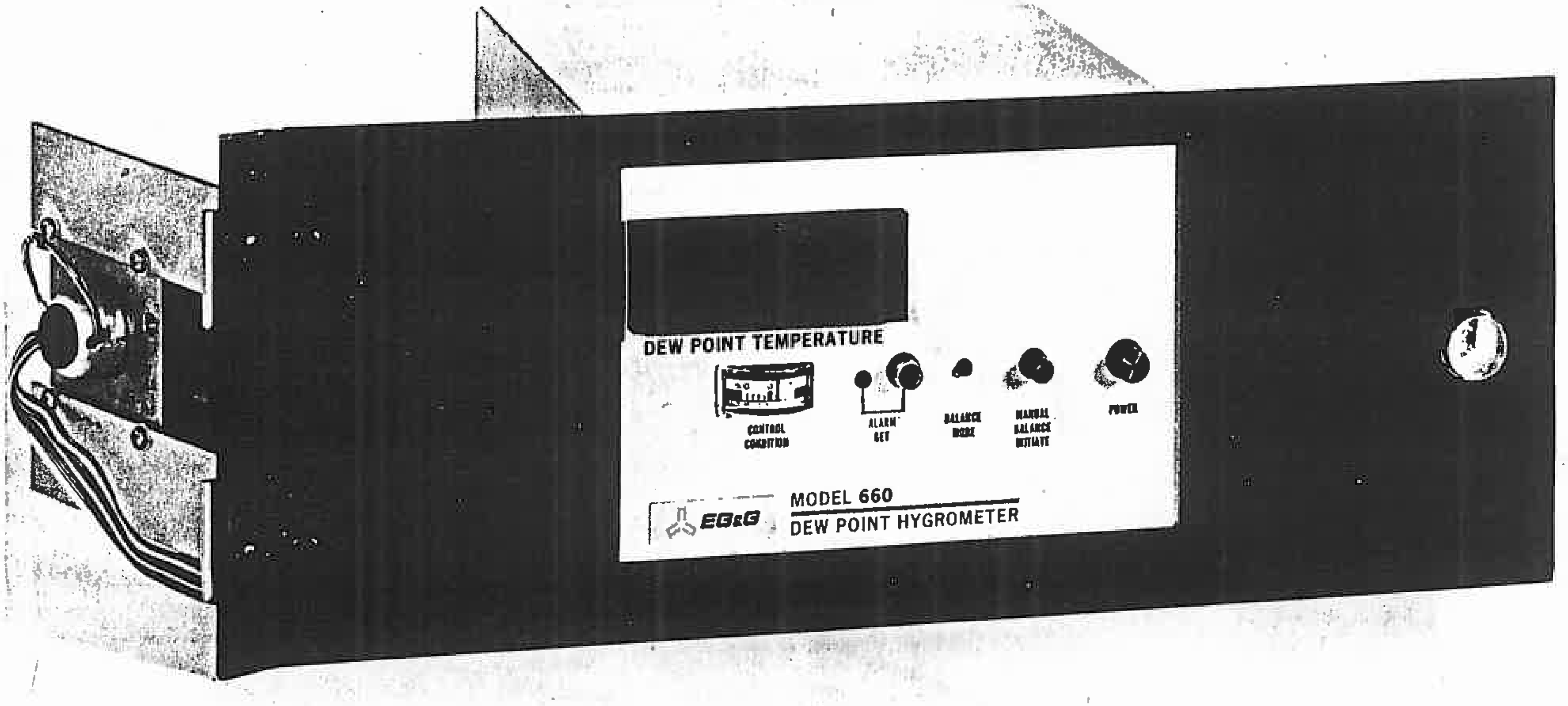


Figure O7 — Panel Mounted Model 660 Control Unit Front View

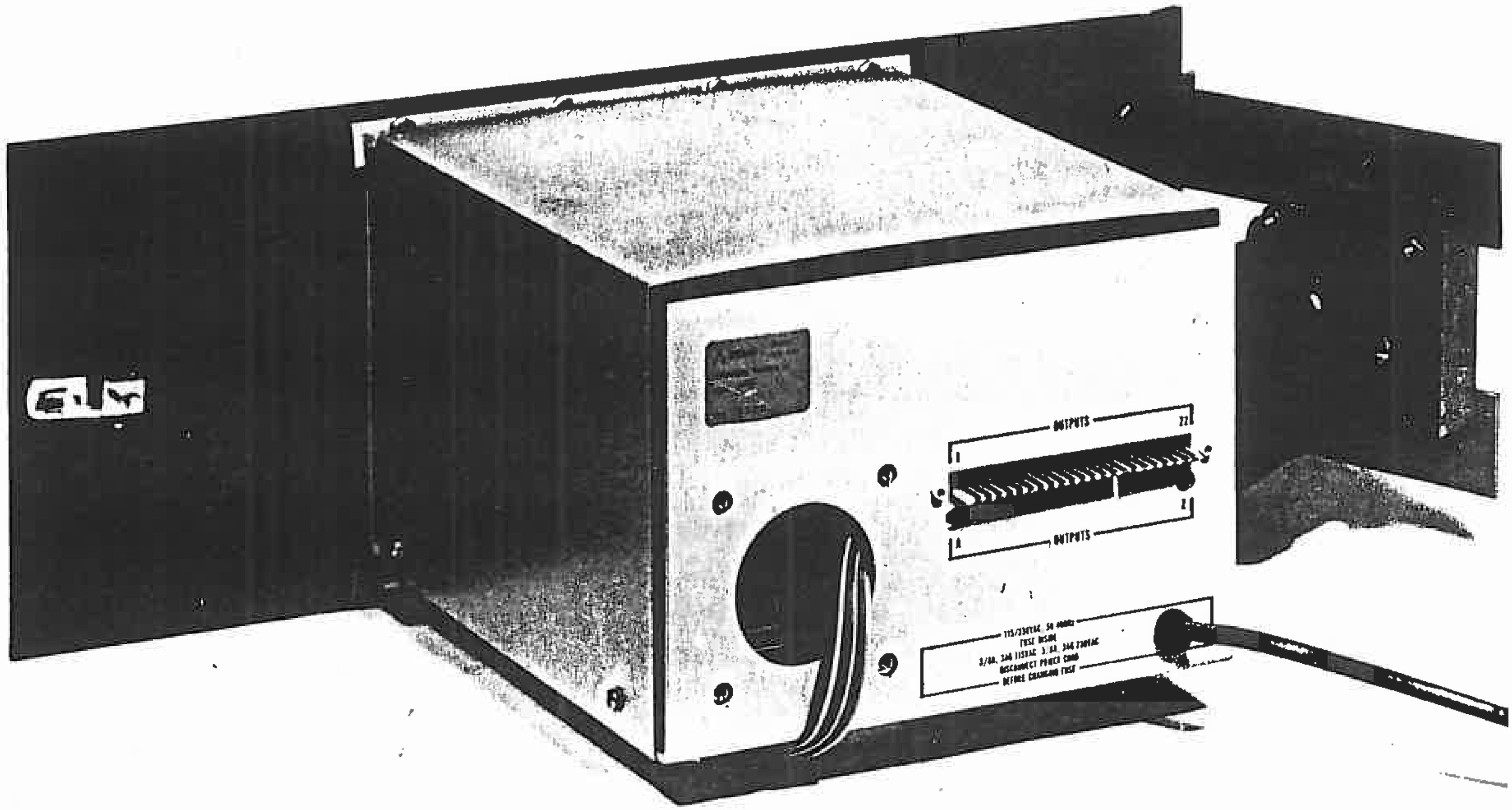


Figure O8 — Panel Mounted 660 Control Unit Rear View Showing Panel Latch and Cable Exit

Section P — *DEW POINT DATA SHEETS AND INFORMATION*

EG&G Dew Point Hygrometer Sampling Systems

Basic Humidity Definitions

Model 660 Simplified Schematic

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 5×10^{-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.

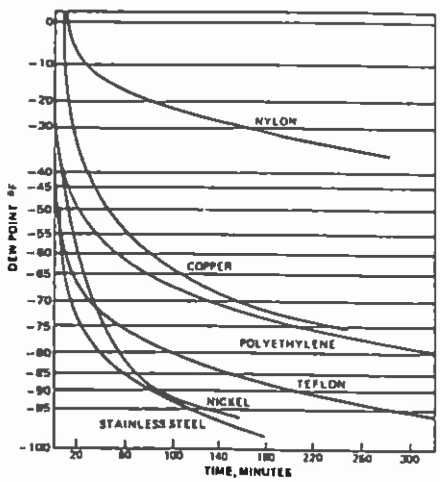
There are three types of pumps generally suitable for hygrometric work. For installations where the sample is not to be returned to the process, the Gast Manufacturing Co. vane pump is acceptable. This pump offers a reasonably high degree of reliability, and can handle large volumes of air. The vane 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 lines 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.

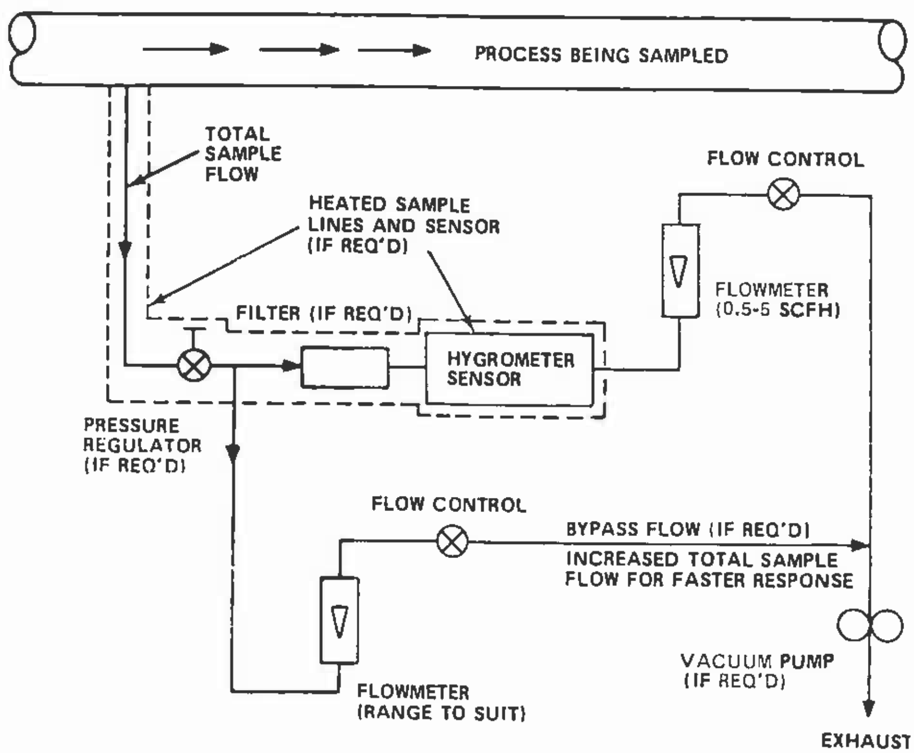
Noncondensibles

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.



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)

$$PPM_v = \frac{\text{Parts}}{\text{Million}}$$

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

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

$$= 10.7 \text{PPM (by volume)}$$

Example 2. (English Units)

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

$$PPM_v = \frac{\text{Parts}}{\text{Million}}$$

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

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

$$= 17 \text{PPM (by volume)}$$

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.

xample 1. (Metric Units)

f frost point = − 60°C, system total essure 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°C and system total pressure is 1013 mb (1.033 kg/cm^2), what is the dew point at 21 kg/cm^2?

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

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

From the Vapor Pressure Tables (over ice), the Frost Point = − 35.2°C

Example 2. (English Units)

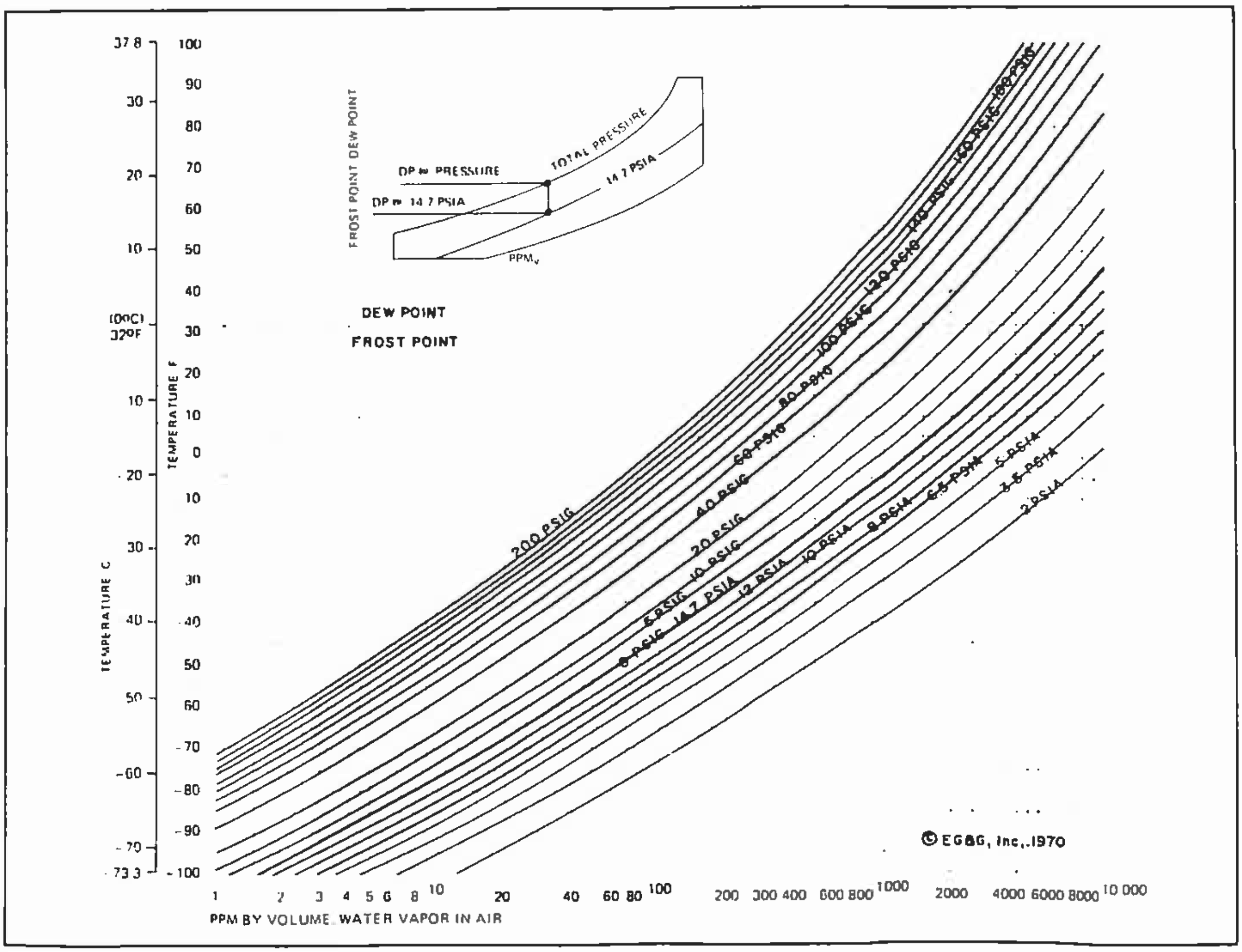
If frost point = − 70°F and system total pressure is 14.7 PSIA, what is the dew point at 70 PSIG (84.7 PSIA)?

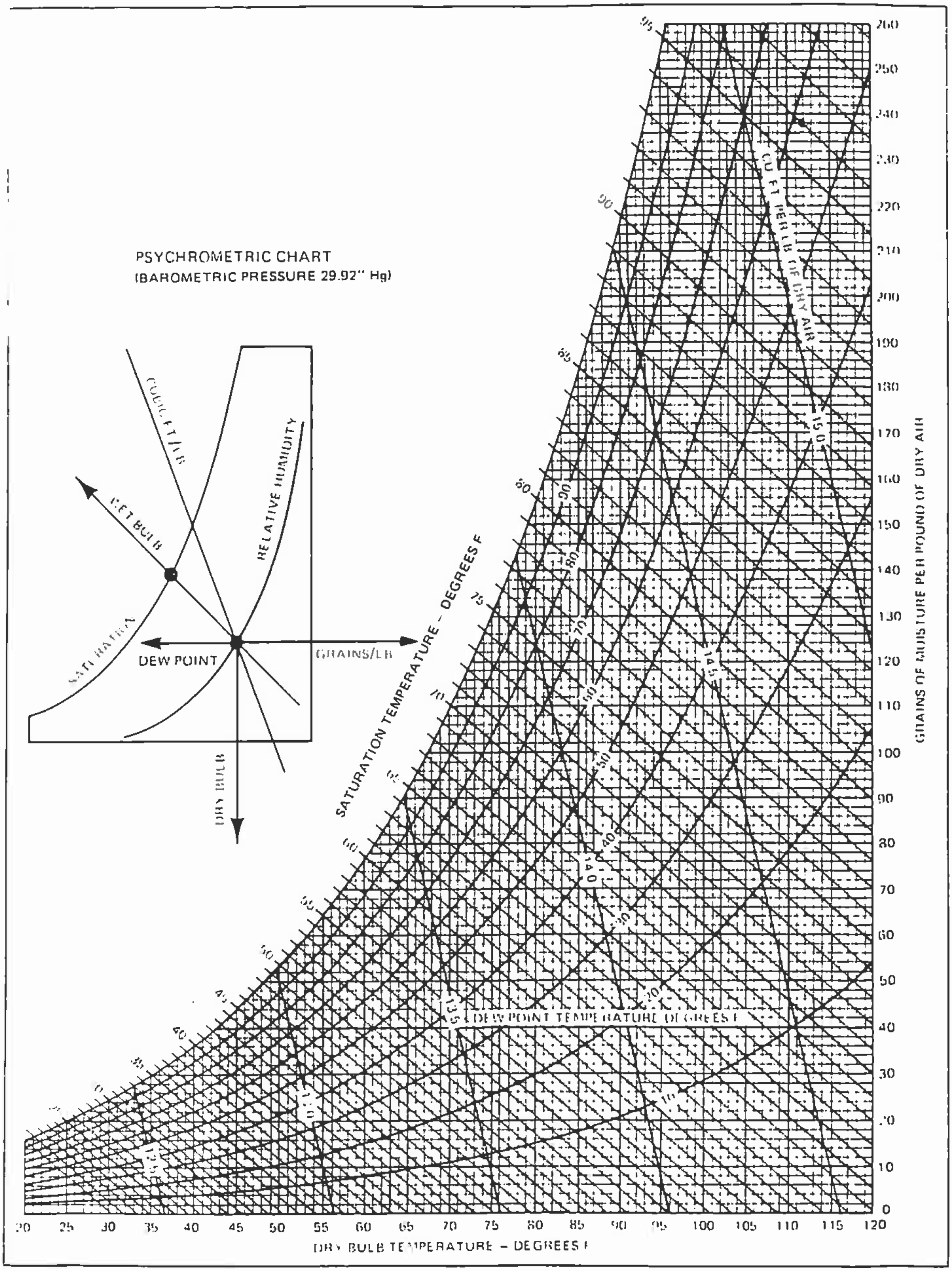
$$\frac{\text{Vapor Pressure at } -70^\circ\text{F}}{14.7 \text{ PSIA}} = \frac{\text{Vapor Pressure at New Dew Point}}{84.7 \text{ PSIA}}$$

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

From the Vapor Pressure Tables (over ice), the Frost Point = - 44.5°F

DEW POINT/PRESSURE CONVERSION CHART




PSYCHROMETRIC CHART
(BAROMETRIC PRESSURE 29.92" Hg)
CUBIC FT/LB
WET BULB
RELATIVE HUMIDITY
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