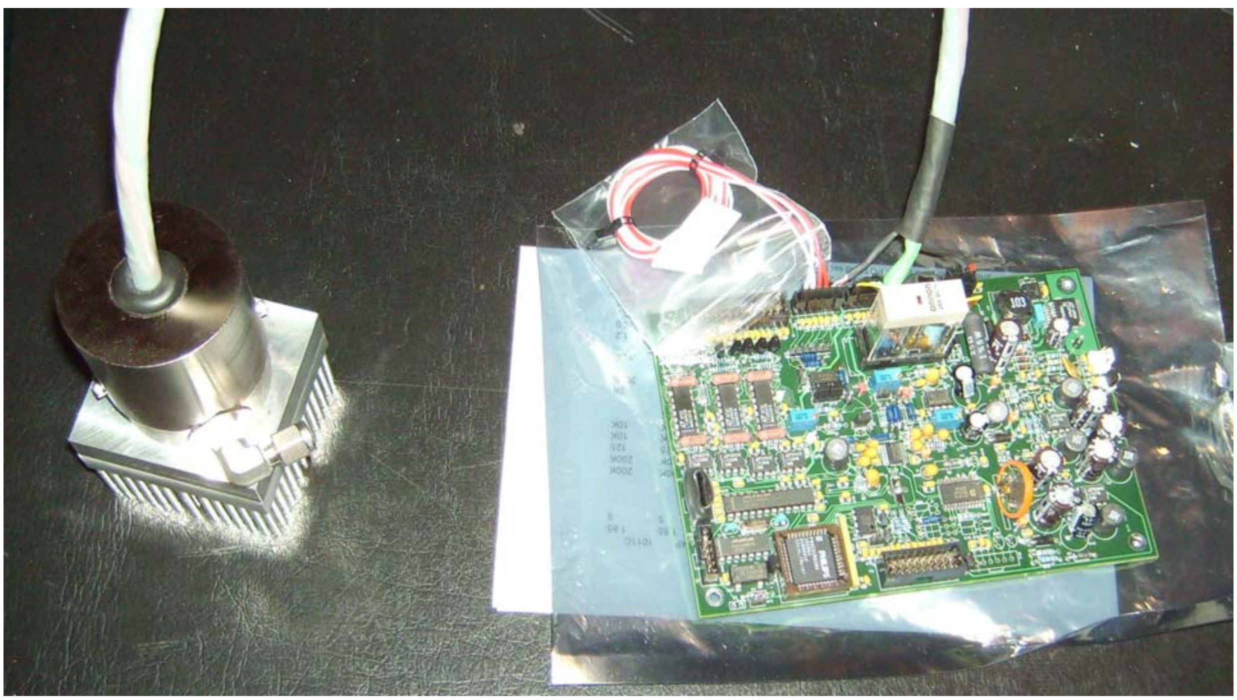
BUCK RESEARCH INSTRUMENTS L.L.C.

MODEL CR-5 HYGROMETER

OPERATING MANUAL



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MODEL CR-5 HYGROMETER OPERATING MANUAL

1. INTRODUCTION

The CR-5 is a chilled mirror hygrometer that uses a 3-stage thermoelectric cooler (TEC) to enable frost point measurements of as low as –60^{o}C under favorable ambient conditions. Depending upon configuration, it can measure dew points as high as +60^{o}C. The CR-5 is designed to measure in air, natural gas and most non-corrosive gases at pressures ranging from near vacuum to as high as 150 psia.

1.1 General Description

The CR-5 is a chilled mirror, condensation type hygrometer. It achieves its high performance by heating and cooling a mirror, using a thermoelectric cooler (TEC), and holding the mirror at the dew or frost point by means of a servo control system. An IR LED and optical detectors are used for sensing condensate on a mirror, and an ultra-stable temperature sensor imbedded in the mirror is used to determine mirror temperature--the dew or frost point. Since operation of the CR-5 is based on a fundamental property of water vapor (dew/frost point), it is intrinsically capable of long-term accuracy and stability, without the need for periodic recalibration.

The CR-5 features an autobalancing function that automatically adjusts for mirror contamination. To keep a constant layer of dew or frost on the mirror, the reflectivity of the mirror must be measured when the mirror is completely cleared of condensation and when it is completely obscured by condensation. Once this is done, 20% of this span is calculated and set to be the control point. This is achieved by heating the mirror to a high enough temperature to remove condensation, then turning on and off the LED that shines on the mirror. If contamination ever gets to be enough that the control point cannot be achieved, another balance function will be initiated and the control point reset. Once the contamination becomes too great, an output flag is enabled in the RS-232 data stream.

The CR-5 is microcontroller-based. The microcontroller uses flash memory that is field-programmable and updateable. If this is required, please contact Buck Research Instruments, LLC for instructions.

The components of the CR-5 are:

- Main board
- Board connectors with pins
- Operating manual
- Cleaning Kit with spares
- Sensor with 2 foot cable
- RTD with 3 foot cable (optional)
- ¼” and 1/8” Teflon tubing

1.2 Specifications, Model CR-5 Chilled Mirror Hygrometer

Measurement range:	
Dew/frost point temperature:	-60°C to ambient[1]
Dew point reading accuracy:	± 0.1°C, NIST-traceable calibration
Response time (10 degree step):	Less than 20 sec typical[2]
Nominal operating range:	
Ambient Temperature:	-40 to +60°C
Relative Humidity:	0 to 100% RH, non-condensing
Flow rate of sample:	0.2 - 2 liters/minute
Max pressure rating:	150 psia
Thermoelectric cooler type:	3-stage cascade
Output signals:	Mirror temp. %RH., Ambient temp, Balance in 0-10 V, 4-20 mA and RS-232 signals
Construction	FR4 – main board Nickel-plated aluminum (sensor assembly)
Input voltage	24 VDC, 2A max
Power consumption (typical)	< 50 watts
Dimensions, inches and (cm):	
Main board:	4.5" (11) w x 6.5" (26) d x 2" (5) h
Sensor:	2.5" (6) w x 2.5" (6) d x 5" (12.5) h
Approximate Weight:	2.2 lbs (1 kg)

[1]Do not attempt to read dew points above ambient without heating sample lines and sample chamber. Please contact Buck Research Instruments, LLC if you plan to do this.

[2]Response time once initial frost layer acquired. See section 7 for ways to dramatically improve the speed of initial frost formation, which can otherwise take 15 to 30 minutes.

Note: These are approximate specifications. Exact performance will vary depending on installation and operating environment.

2. LOCATION OF PRINCIPAL COMPONENTS

2.1 Main Unit (Figure 1)

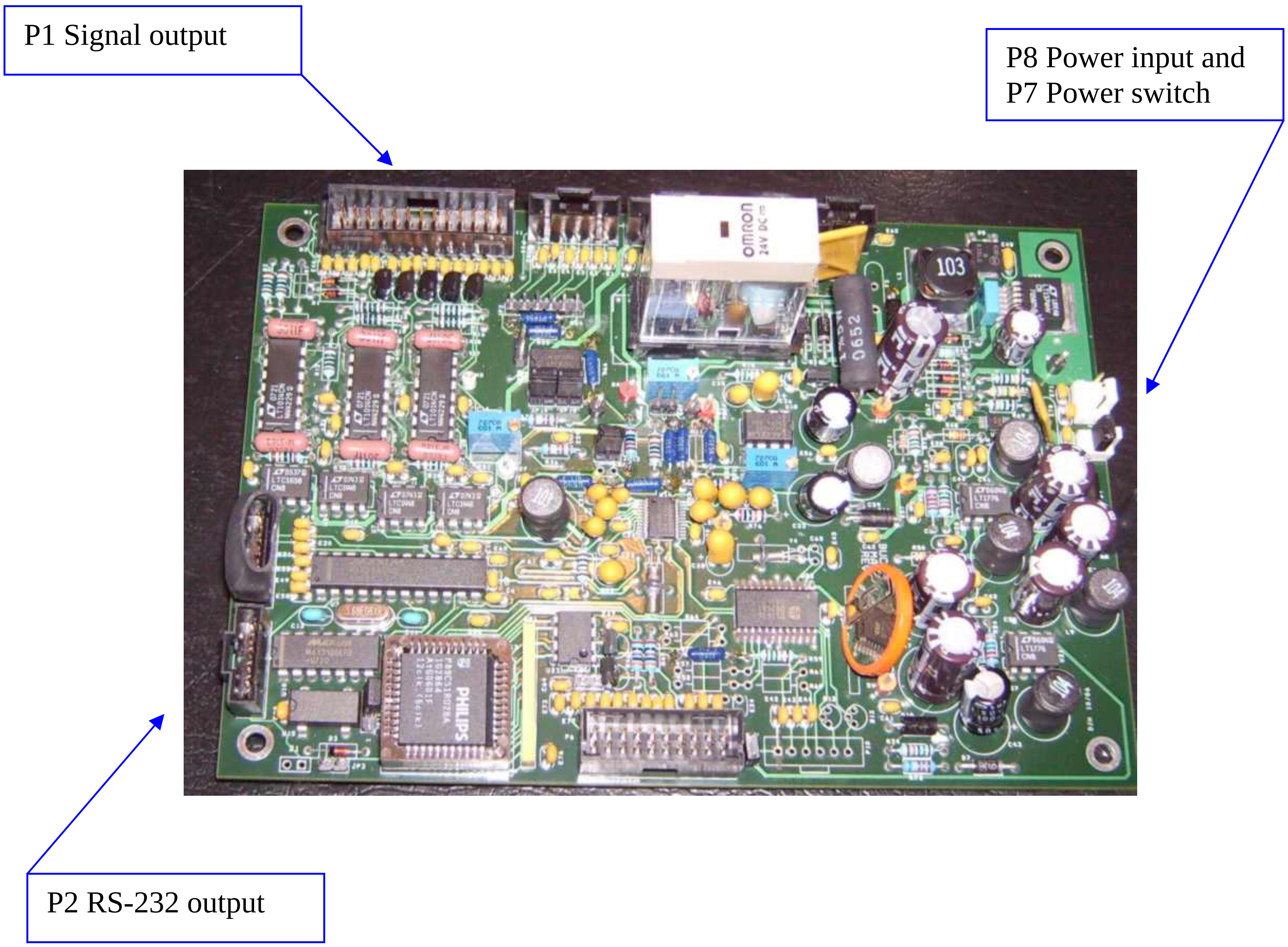


Fig. 1. Main board

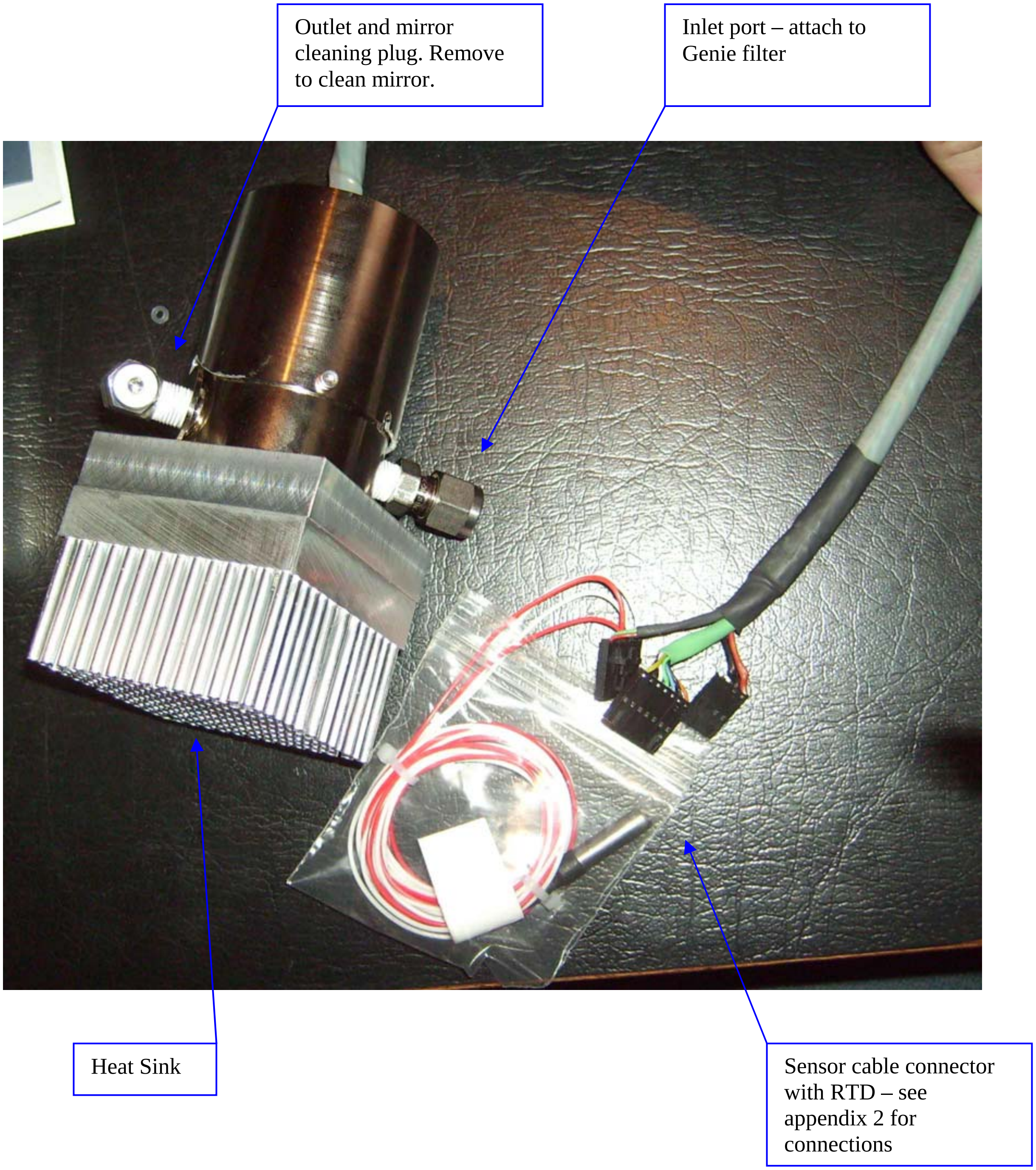


Fig. 2. Sensor unit

3. INSTALLATION AND OPERATION

3.1 Installation

1. Inspect the instrument for mechanical or other damage.

2. See Appendix 4 for installing tubing and filter and pump.

3. Initially and as often thereafter as necessary, check that all electrical and mechanical connections are secure. It may be advisable to test for leaks using one of the methods in Section 7. This is especially important when operating the instrument in a humidity environment that is very different from that of the sampled air.

3.2 Power-up Procedure

1. Connect the sensor cables to the main board. Connect P2 to a computer running hyperterminal. Attach P8 to 24 VDC and either jumper P7 or attach a SPDT switch to P7 as an ON-OFF switch.

2. After initialization of the electronics and a brief output of first 4, then 12.5 then 20 mA from the mirror temperature output, a balance cycle will be initiated. The RS-232 will show an increasing mirror temperature until the mirror is 10°C above ambient temperature..

3. Then, wait for the instrument to stabilize at the operating point. The mirror temperature will decrease until the Balance value gets close to 0. This can be verified initially using the RS-232 cable and a PC running Hyperterminal.

4. The instrument is now ready for use.

   NOTE: Below 0°C, the CR-5 will measure a dew point initially, as supercooled dew will form more easily than frost until -40°C is reached.

3.3 Operation

During operation, no special attention is required except for an occasional check of operating voltages to assure proper function. If possible, keep flow in the range 0.5 - 2 liters/minute (0.25 – 4 scf/h). At very high dew/frost point temperatures, higher flow may be allowed.

Keep the sample line inlet protected from contamination. This is best achieved by keeping the sample line closed when not connected to the desired sample gas. WHEN MEASURING WATER CONCENTRATION IN NATURAL GAS, A GLYCOL-ABSORBING FILTER,

SUCH AS AN A+ GLYSORB FILTER, MUST BE INSTALLED BEFORE THE INLET TO THE CR-5 OR ERRONEOUS READINGS WILL RESULT.

When making a large downward change in humidity, it is better to make several intermediate steps rather than one large step, to avoid losing the condensation layer on the mirror. At low frost point values, always allow time for the moisture levels in the lines and sensing chamber to equilibrate, and for the D/F point temperature to completely stabilize before taking a reading.

To avoid internal line condensation and resultant erroneous readings, do not allow the inlet lines to cool below the expected frost point temperature.

3.4 Power-down Procedure

1. If contamination is a likely hazard, turn off the sampling pump to protect the mirror.

2. Flip the Power Switch to OFF or remove the jumper from P7 or turn off the power to P8.

The mirror will remain very cold for several minutes. To avoid excessive condensation in the sensing chamber, allow the instrument to reach room temperature before opening inlet or outlet lines.

4. SIGNAL PROCESSING

4.1 Data Signals

The following analog signals are available at signal connector J2, and vary over the following ranges:

VDF	Mirror temperature (Dew/frost point), 0-10v and 4-20 mA
%RH	Relative Humidity, 0-10v and 4-20 mA (optional)
BAL	Balance voltage, 0-10v and 4-20 mA
VAMB	Ambient temperature, 0-10v and 4-20 mA (optional)

The 4-20 mA outputs sink current. Connect up +24 VDC to the 4-20 mA returns, either using the pins on the connector or from your data acquisition system. The current flowing into the 4-20 mA returns corresponds with the equations below.

4.2 Data Reduction Equations

VDF: Dew/frost point temperature is determined from VDF by:

T_{df} (°C) = [-100 + 20 x VDF(v)]. (0-10V) (1)

T_{df} (°C) = [-100 + 8 x IDF(ma)]. (4-20 mA) (2)

VAMB: Chamber temperature is determined from VAMB by:

T_{amb} (°C) = [-100 + 20 x VAMB(v)]. (0-10V) (3)

T_{amb} (°C) = [-100 + 8 x IAMB(ma)]. (4-20 mA) (4)

%RH: Relative humidity is calculated from the V%RH signal voltage by:

%RH = (VRH – 1.6) * 10 (5)

%RH = ((IRH – 4) / 1.6) * 10 (6)

BALANCE: When balanced, BAL = 5V or 12.5 mA.

Conversion to Other Humidity Units To convert dew/frost point readings to other humidity units, refer to Appendix 1.

5. PRINCIPLES OF OPERATION

5.1 General

The CR-5 is a chilled-mirror, condensation-type hygrometer, consisting of the following principle components: a stainless steel mirror with an attached stem, an associated temperature sensor, a 3-stage thermoelectric cooler (TEC), an optical system to sense condensing frost or dew (mirror reflectance) and control circuitry for controlling mirror temperature via the TEC.

Operation is based on maintaining equilibrium vapor pressure over a water or ice surface on the mirror. Above the equilibrium temperature, mass transport is away from the surface, and below the equilibrium temperature it is onto the surface. When the surface is just at the dew/frost point temperature, the mass of condensate on the surface remains constant.

As is the case with conventional cooled dew-point devices, the mirror, optics and electrical circuit make up a thermo-optical servo system that operates to maintain a constant layer of condensate. When condensate is thus equilibrated, mirror temperature is then at the dew/frost point, which is sensed by the imbedded temperature sensor. Since the dew/frost point temperature is a fundamental measure of humidity, the CR-5 is intrinsically capable of long-term accuracy and stability.

The development of this hygrometer follows the original work of H.J. Mastenbrook at NRL. His work was adapted by the NOAA Geophysical Monitoring for Climatic Change (GMCC) program for balloon-borne stratospheric water vapor measurements. Buck Research Instruments has extensively redesigned and reconfigured the instrument for a broader range of measurements and applications, incorporating proprietary new technical innovations in the process.

5.2 Technical details

A block diagram of the chilled mirror hygrometer is given in Figure 2 and the sensor assembly is diagrammed in Figure 3.

5.2.1 Sampling system

The gas to be measured (sample gas) is brought to the sensing chamber through an inlet system and allowed to flow across the mirror surface in the sensor chamber. At the exit of the sensor chamber, the sample is then returned to the original gas stream.

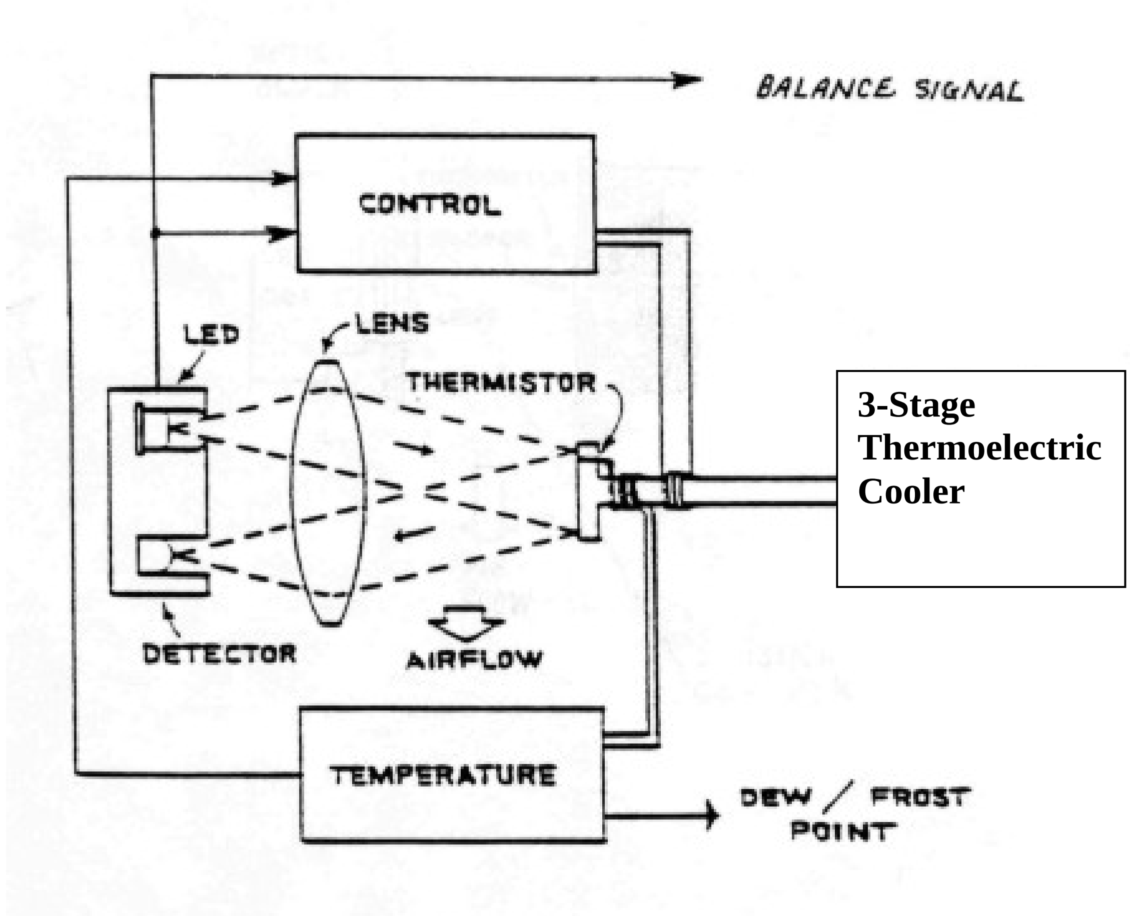


Fig. 3. Block diagram, CR-5 chilled mirror hygrometer

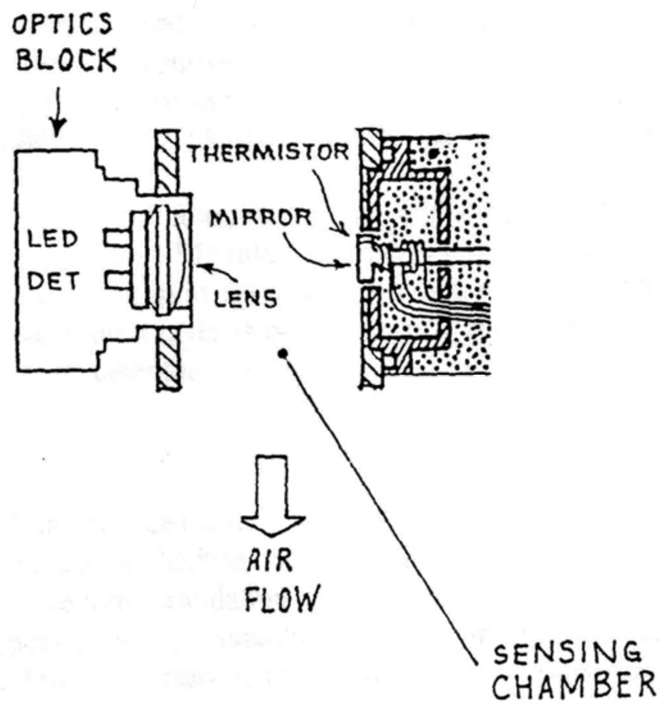


Fig. 4. Sensor assembly block diagram

The sampling system must be carefully sealed to prevent room air from contaminating the measurements.

5.2.2 Mirror Module

The mirror assembly consists of a mirror, a mirror support, a temperature sensor, a 3-stage TEC, a heat sink. A small, ultra-stable temperature sensor is installed in the mirror face to measure the dew/frost point temperature. Heating and cooling is provided by the 3-stage TEC and heat sink.

5.2.3 Optics Module

The mirror surface is maintained continuously and automatically at the frost-point temperature by an electro-optical control system. This system measures the quantity of light specularly reflected from the mirror condensate and maintains a constant reflectance at the mirror surface, thus providing the condensate equilibrium for the frost-point temperature.

The optics module consists of a photodiode pair and a light emitting diode (LED). One photodiode maintains constant LED intensity; the other photodiode provides a current output that is proportional to the light reflected from the mirror. The bias circuit is set so that when the proper condensation layer is on the mirror, about 80% of the light emitted by the LED is received at the detector.

5.2.4 Cooling System

The mirror stem is thermally coupled to the 3-stage TEC by a thermally conductive coupling. In operation, heat is pumped away from the TEC by the heat sink. Since the TEC has limited heat-pumping capability, the coupling must be very efficient and well insulated from external heat.

5.2.5 Temperature Readout

For obtaining the dew or frost point temperature from the temperature senor, three outputs are provided – an RS-232 output, a 0-10 V and a 4-20 mA output. All are accurate within 0.1 ^{o}C throughout the measurement range.

6. MEASUREMENT LIMITATIONS

Under field operations, measurement errors can arise from a number of causes. Any deviation of the mirror temperature from the frost-point temperature will of course cause error.

Perhaps the most common error source is from outside air leaking into the hygrometer sampling system. Therefore, it is important that the instrument be leak tested periodically, and with each relocation of the instrument, especially if components of the instrument have been exchanged or serviced.

Long exposure of the sampling system to high humidities, or condensation of water (which occurs if cold surfaces are exposed to ambient air which has a higher dew point than the temperature of the surfaces) causes temporarily high readings until the walls have completely outgassed. The lines may take a very long time to dry enough to allow accurate readings when measuring frost points below -50°C. Any hygroscopic material in the lines or chamber, such as dust, further lengthens this time. It is therefore advised to keep the lines clean and dry.

Calibration of the mirror temperature sensor and associated electronics is required to accurately determine dew/frost point temperature. Buck Research Instruments has done this. Once calibrated, the temperature sensor has been found to exhibit no measurable drift, even after years of use. Low drift components are used throughout the temperature sensing circuit to ensure long-term accuracy. However, recertification and recalibration is recommended yearly to ensure proper operation.

Errors can arise from failure to correct for differences between chamber pressure and ambient values. This is only important if you are measuring ambient dew/frost point and not H2O concentration.

The system must be allowed to fully equilibrate before accurate readings can be obtained. When measuring very low dew points, equilibration can take much longer.

Contamination of the mirror by salt or other electrolytes can vary the relationship between vapor pressure and dew/frost point (Raoult error). Other chemical contamination may cause similar error. This is particularly relevant when measuring in natural gas, as glycols contained within it can condense out on the mirror. This is why a glycol-absorbing filter must be used when measuring natural gas.

7. MAINTENANCE AND TROUBLESHOOTING

The following maintenance items should receive attention as required:

1. Cleaning of sample lines, depending on use (Sect. 7.1).
2. Mirror check and cleaning (Sect. 7.2).
3. Leak checking (Sect. 7.3)

7.1 Inlet Port Cleaning

To keep inlet port clean, thus improving response at very low humidities, remove port from sample chamber and wash with water or acetone and blow dry with a mild pressure from a dry air or nitrogen source.

7.2 Mirror Cleaning

The mirror should be cleaned when the mirror flag on the RS-232 output goes from 0 to 1.

1. Make certain mirror is at or near the room temperature and power has been shut off. Remove mirror cleaning plug, which contains the 1/8" Swagelok connector.

2. Moisten a soft cotton swab with mirror cleaning fluid (acetone) and gently wipe the swab over the mirror surface. Immediately dry the surface with fresh cotton swab. Inspection with flashlight may be helpful.

3. If necessary, repeat process. If contamination persists, clean again with acetone, followed by water, using a small amount. Never use alcohol in the sensing chamber, as this affects the hygroscopic properties of the mirror surface for some period of time. (In the absence of acetone, distilled water alone or used after acetone or MEK can be effective.)

   CAUTION: The mirror surface has a coating that scratches easily. However, moderate scratching does not prevent normal operation. Use only soft flexible cotton swabs to clean the mirror. Apply minimal pressure

4. Turn instrument power on and wait and see if the mirror flag on the RS-232 output goes from 1 to 0.

5. If the mirror flag will not go to 0 by cleaning the mirror, clean the lens and the entire sample chamber.

7.3 Leak Testing

The introduction of even small amounts of room air into the sampling system will cause errors in low frost point readings. Therefore, it is desirable that leak testing be performed on the instrument package and sampling system after initial assembly, and after any maintenance activity that involves disassembly of the instrument or interconnecting tubing.

Method 1. Connect a vacuum pump and vacuum gauge to the sampling system inlet port, and close or cap the outlet port (or vice versa). Evacuate down to the minimum attainable pressure. A reading of 100 microns Hg or less indicates the system is adequately sealed.

To locate a leak, place a few drops of alcohol on each tubing connection and watch the vacuum gauge pressure reading. If the reading abruptly increases, there is a leak. Allow some time for the vacuum readings to recover after each upscale deflection before proceeding to the next connection.

Method 2. If the vacuum pumping system is unable to evacuate the inlet plumbing to a level that will produce an on-scale reading on the vacuum gauge, disconnect the vacuum pump from the gas inlet port and replace it with a low-pressure air supply with a needle valve for regulation. Slowly pressurize the gas inlet tubing, being careful to limit the pressure applied to no more than two atmospheres. Dampen the inlet tubing connections with soap solution or other leak detection solution, and watch for air bubbles forming at each connection. The presence of any air bubbles indicates a leak at the connection. Repair any connections found leaking and recheck for leaks. When no more bubbles can be found, disconnect the low-pressure air supply and reconnect the vacuum pumping system. Repeat the preceding vacuum leak testing procedure.

> CAUTION: Overpressure within the above limits will not damage the pressure sensor. However, slight calibration adjustments may be necessary after any overpressure. Overpressure limit: 100% of span.

Method 3. Plug one end of the sensing chamber. Attach an ordinary pump with a shutoff valve to the other end. Lower the pressure as much as possible. Close the shutoff valve and monitor pressure inside the sensing chamber to determine leak rate. With proper sealing, the pressure change rate should be less than 0.2 % of pressure differential per minute. Leaks can then be located by overpressuring the instrument as in Method 2.

7.4 Troubleshooting Guide

Mirror flag = 1:

1. Mirror needs cleaning. Clean mirror
2. Sensor cable is disconnected. Reconnect sensor cable.

Oscillation of output:

1. Reduce sample flow until oscillation stops, then gradually increase flow again.
2. Turn instrument off, allow to warm up, and clean mirror.

APPENDIX 1: HUMIDITY CONVERSION EQUATIONS

(Revised 7/96)

Computer-efficient algorithms for converting among several humidity units, as used in HCON, are given here. They utilize vapor pressure formulations developed by A. Buck (1981).

DP	= dew or frost point in deg C
e	= vapor pressure in millibars
es	= saturation vapor pressure in millibars
P	= pressure in millibars
r	= mixing ratio by weight in ppm
RH	= relative humidity in percent
rho	= absolute humidity in g/m3
rhos	= absolute humidity at saturation
T	= temperature in deg C
Tk	= absolute temperature in K

Saturation vapor pressure (es) = f1(T) = e/RH

Dew/frost point (DP)	= f2(e)	(e)
	= f2[r x P/(622 x 10^3 + r]	(r)
	= f2(RH x f1(T)/100)	(RH)
	= f2(rho x Tk/216.7)	(rho)

Vapor pressure (e)	= f1(DP)	(DP)
	= r x P/(622 x 10^3 + r)	(r)
	= RH x f1(T)/100	(RH)
	= rho x Tk/216.7	(rho)

Mixing ratio (r), ppmw	= (18.02/ M.W. of gas) x 10^6 x e/(P-e)	(e)
	= (18.02/ M.W. of gas) x 10^6 x f1(DP)/[P - f1(DP)]	(DP)
	= (18.02/ M.W. of gas) x 10^6x RH x es/(100 x P - RH x es)	(RH)
	= (18.02/ M.W. of gas) x 10^6 x rho x Tk/(216.7 x P - rho x Tk)	(rho)

Relative humidity (RH)	= 100 x f1(DP)/f1(T)	(DP)
	= 100 x e/es	(e)
	= 100 x r x P/[(622x10^3 + r) x es]	(r)
	= 100 x rho x Tk/(216.7 x es)	(rho)

Absolute humidity (rho)	= 216.7 x f1(DP)/Tk	(DP)
	= 216.7 x e/Tk	(e)
	= 0.2167 x r x P/[(622 + .001 x r) x Tk]	(r)
	= 216.7 x RH x es/(100 x Tk)	(RH)

mixing ratio by volume (ppmv) = mixing ratio by weight (ppmw) x (M.W. of gas)/ 18.02

grains/lb = r x 0.007

Precipitable cm per km = rho/10

NOTE 1: f1(DP) and f2(e) are variations on vapor pressure formulations found in Buck, A: J Appl Met 20, pp 1527-1532 (1981). They are given by:

e vs. DP or es vs. T:

$$f1(DP) = EF \times aw \times \exp [(bw - DP/dw) \times DP/(DP + cw)] \text{ (over water)}$$

$$= EF \times ai \times \exp [(bi - DP/di) \times DP/(DP + ci)] \text{ (over ice)}$$

DP vs. e or T vs. es:

$$f2(e) = dw/2 \times [bw - s - ((bw - s)^2 - 4\, cw \times s/dw)^{1/2}] \quad \text{(over water)}$$

$$= di/2 \times [bi - s - ((bi - s)^2 - 4\, ci \times s/di)^{1/2}] \quad \text{(over ice)}$$

where:

aw = 6.1121	ai = 6.1115
bw = 18.678	bi = 23.036
cw = 257.14	ci = 279.82
dw = 234.5	di = 333.7

$s = \ln (e/EF) - \ln (aw \text{ or } ai)$

$EF_w = 1 + 10^{-4} [7.2 + P (0.0320 + 5.9 \times 10^{-6} T^2)],$

$EF_i = 1 + 10^{-4} [2.2 + P (0.0383 + 6.4 \times 10^{-6} T^2)],$

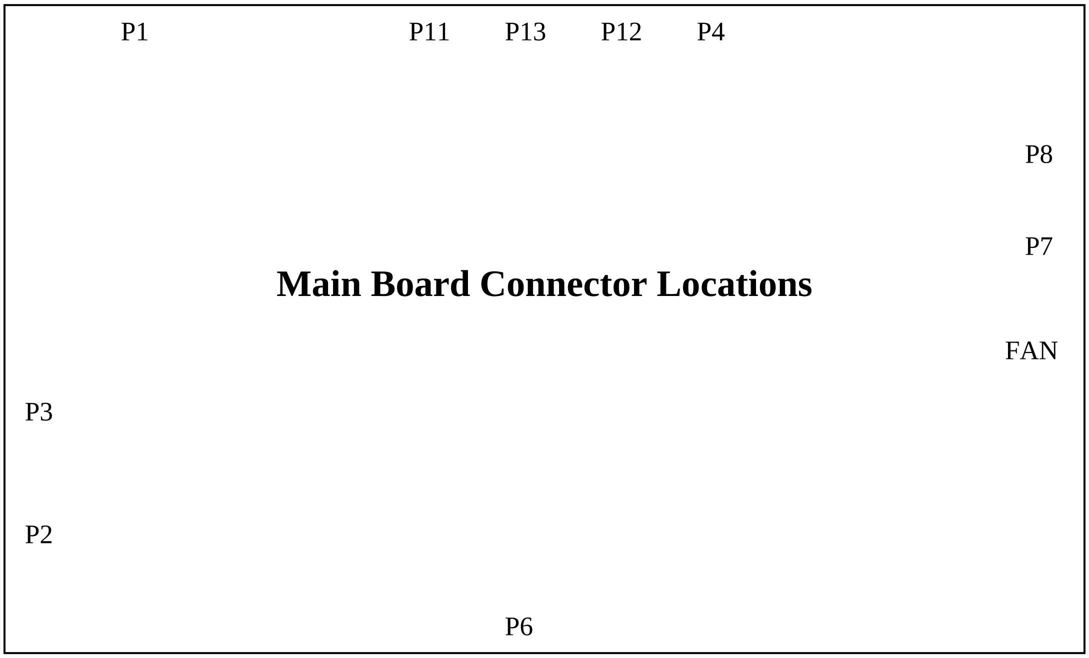
where P is in millibars and T is in ^oC.

NOTE 2: RH is defined here using es with respect to ice below freezing. However, RH is also frequently defined using es with respect to water, even below freezing.

NOTE 3: These conversions are intended for use with moist air rather than pure water vapor. They therefore include EF, the enhancement factor, which corrects for the slight departure of the behavior of water in air from that of a pure gas.

NOTE 4: The definitions f1 and f2 for ice agree with an extrapolation of NBS values down to -120 deg C, within 0.5%.

APPENDIX 2: CONNECTOR PIN ASSIGNMENTS



P1 26-pin Signal connector

25 23 21 19 17 15 13 11 9 7 5 3 1
26 24 22 20 18 16 14 12 10 8 6 4 2

Pin	
1	%RH. (0-10V)
2	%RH Return
3	%RH (4-20 mA) Return
4	+24 VDC
5	Balance (0-10 V)
6	Balance Return
7	Balance (4-20 mA) Return
8	+24 VDC
9	VAMB (0-10 V)
10	VAMB Return
11	VAMB (4-20 mA) Return
12	+24 VDC
13	VDF (0-10V)
14	VDF Return
15	VDF (4-20 mA) Return
16	+24 VDC

P2 RS-232 connector

1
2
3
4
5
6

Pin	
2	Rx (Data In)
3	Tx (Data Out)
5	Gnd

Use Hyperterminal with settings: 9600 Baud, 8-N-1. Flow control set to NONE. Use null modem cable with Female/Female ends.

P3 LCD connector – not used

P4 TEC connector

4 3 2 1

Pin	
1	Red
2	Black

P6 Front panel connector – not used

P7 Power switch connector

2
1

Pin	
1	24 VDC in
2	24 VDC out (connect pin 1 to pin 2 to power board)

P8 Power connector

3
2
1

Pin	
1	24 VDC
2	24 VDC Returm
3	Chassis ground

P11 RTD and thermistor connector

6 5 4 3 2 1

Pin	
1	Thermistor
2	Thermistor
3	RTD power
4	RTD sense +
5	RTD sense -
6	RTD ground

P12 Pressure connector – not used

P13 Optics connector

Pin	
1	2.5 VR
2	Balance -
3	Balance +
4	5 V
5	Ground
6	LEDON
7	Chassis ground

7 6 5 4 3 2 1

FAN Fan connector – not used

APPENDIX 3:WARRANTY

Manufacturer warrants that the items delivered shall be free from defects (latent and patent) in material and workmanship for a period of one year after acceptance of the specific goods by Buyer. The Buyer's sole and exclusive remedy under this warranty shall be limited to repair or replacement. Defective goods must be returned to the Manufacturer promptly after the discovery of any defect within the above referenced one-year period. Transportation expenses to return unit to Manufacturer shall be borne by the Buyer. Return shipping to Buyer shall be borne by Manufacturer for valid warranty claims. This warranty shall become inapplicable in instances where the items have been misused or otherwise subjected to negligence by the Buyer

NOTWITHSTANDING ANY OTHER PROVISION OF THIS CONTRACT, NO OTHER WARRANTIES WHETHER STATUTORY OR ARISING BY OPERATION OF LAW, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THOSE OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE, SHALL APPLY TO THE GOODS OR SERVICES PROVIDED HEREUNDER, OTHER THAN THE REPAIR AND REPLACEMENT WARRANTY ABOVE . SELLER SHALL IN NO EVENT BE LIABLE TO BUYER OR ANY THIRD PARTY FOR ANY DAMAGE, INJURY OR LOSS, INCLUDING LOSS OF USE OR ANY DIRECT OR INDIRECT INCEDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND.

APPENDIX 4: INSTRUCTIONS FOR USING CR-5 WITH A SAMPLING PUMP.

1. You will need 2 pieces of tubing.
2. Connect one end of the 1/8” Teflon tubing to the outlet of the CR-5 and the other end to the sampling pump using the 1/8” Swagelok union.
3. Connect one end of the ¼” Teflon tubing to the inlet of the CR-5 and the other end to the Genie 150 filter. Tighten all fittings.
4. Turn on the pump. Make sure there is flow by feeling the outlet of the pump. Place your finger in front of the outlet and see if you can feel air flowing on it. If you have a flowmeter, you can connect up the outlet to the flowmeter using any available tubing. The flowmeter should read between 1-2 lpm.
5. Connect up the RS-232 and/or signal connector to the CR-5. Plug in power to the CR-5. Turn on CR-5 The CR-5 will output 4,12 and 20 mA in steps for about 1 minute total. Then there will be a balance cycle.
6. Allow CR-5 to settle. At normal ambient temperatures, this should take no more than 1-2 minutes. At –30 to 40 C this can take about 10 minutes. This is dependent upon how long it takes to acquire a layer of frost on the mirror. One way to speed this up is to put your finger over the outlet of the sample pump for a second or two and then remove your finger from the outlet. Watch the balance signal. It will start to go positive. At the same time, the heater will start heating the mirror.

RS-232 output stream

Connect RS-232 output using null modem cable to computer that has HyperTerminal. Set HyperTerminal for 9600-8-N-1 with flow control set to none. You will see the following:

-1000,XXX.XX,22.12,8.13,0,-255,0, 27.50,2008.03.13,16:43:30
-100,XXX.XX,22.12,29.13,0,-10,0, 27.50,2008.03.13,16:43:50
15,43.48,22.12,9.13,1,-12,0, 27.50,2008.03.13,16:43:55

Balance, relative humidity, ambient temp, mirror temp, status, PWM, mirror flag, board_temp, date, time

Where:
Balance: within + or – 300 counts of zero indicates dew or frost point
Relative Humidity: %RH. XXX.XX = not on a dew point, otherwise %RH to 2 decimal places
Ambient temp: RTD temperature in degrees C
Mirror temp: mirror temperature in degrees C
Status: 0 = mirror temperature, 1 = dew/frost point, 2 = balance routine
PWM: -255 to 255, indicates how much power is applied to TEC. – is cooling and + is heating.
Mirror flag: 0 = clean mirror, 1 = mirror contaminated, should be cleaned soon
Board_temp: temperature of main PCB
Date: date in years.months.days
Time: time in 24 hours: minutes : seconds

Key stroke input to RS-232

p decrease the proportional gain coefficient by 2/3rds
P increase the proportional gain coefficient by 50%
d decrease the derivative gain coefficient by 2/3rds
D increase the derivative gain coefficient by 50%
i decrease the integrator time constant coefficient by 2/3rds
I increase the integrator time constant coefficient by 50%

Each repeated key press is progressive. For example, 5 C presses will increase the contrast by 10%. 5 p presses will decrease the gain by about 87%

R resets all coefficients and contrast to original values
B initiates a balance routine
G polled output of RS-232 data