INSTRUCTION MANUAL

KH20 Krypton Hygrometer

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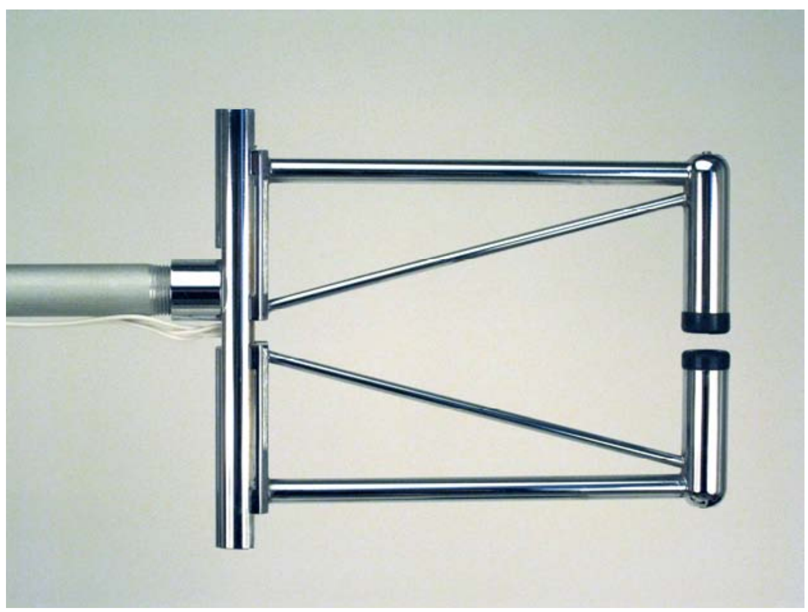

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KH20 Krypton Hygrometer

1. General Description

The KH20 is a krypton hygrometer for measuring water vapor fluctuations in the air. The name KH20 (KH-twenty) was derived from KH2O (K-H_2O), and the sensor has been known with this name since 1985. It is typically used with the CSAT3 3-D sonic anemometer for measuring latent heat flux (LE), using Eddy Covariance technique. Please refer to the Open Path Eddy Covariance System operator's manual for details on flux measurements using the KH20 sensor.

The KH20 sensor uses a krypton lamp that emits two absorption lines: major line at 123.58 nm and minor line at 116.49 nm. Both of these lines are absorbed by water vapor, and a small amount of the minor line is absorbed by oxygen. The KH20 is not suitable for absolute water vapor concentration measurements due to its signal offset drift.

The KH20 heads are sealed and will not suffer damage should they get wet. In addition, the electronics box and the connectors are housed inside a rain shield (CSI p/n 14113) that protects them from moisture. The KH20 is suitable for long-term continuous outdoor applications.

The KH20 sensor is comprised of two main parts: the sensor head and the electronics box. The sensor head comes with cables with 6 ft of lead length that connect the sensor to the electronics box. It is shipped with a rain shield (CSI p/n 14113) to protect the electronics box and the connectors from moisture, a 20 inch 3/4 IPS threaded aluminium pipe (CSI p/s 3874), a 3/4" x 3/4" Nu-Rail (CSI p/n 1017), and a 5/32 inch Allen wrench (CSI p/n 4697) for mounting. The sensor comes with a signal/power cable which has 25 ft lead length. If a longer cable is desired, the customer can order a replacement cable (p/n KH20CBL-L) and specify the desired lead length after -L.

NOTE Discussion on the principles and theory of measurement is included in Appendix A.

2. Specifications

2.1 Measurements

Calibration Range:	1.7 to 19.5 g/m^3 (nominal)
Frequency Response:	100 Hz
Operating Temperature Range:	-30 to +50°C

2.2 Electrical

Supply Voltage:	10 V to 16 Vdc
Current Consumption:	20 mA max at 12 Vdc
Power Consumption:	0.24 Watts
Output Signal Range:	0 to 5Vdc

2.3 Physical

Dimensions

Sensor Head:	11.5” x 9” x 1.25” (29 cm x 23 cm x 3 cm)
Electronics Box:	7.5” x 5” x 2” (19 cm x 13 cm x 5 cm)
Rain Shield with Mount:	11.5” x 7” x 2.5” (29 cm x 18 cm x 6.5 cm)
Mounting Pipe:	20” (50 cm)
Carrying Case:	25” x 15” x 7” (64 cm x 38 cm x 18 cm)

Weight

Sensor Head:	3.55 lbs (1.61 kg)
Electronics Box:	1.4 lbs (6.4 kg)
Rain Shield with Mount:	4.75 lbs (2.2 kg)
Mounting Pipe with Nu-rail:	1.0 lbs (0.45 kg)
Carrying Case:	9.45 lbs (4.3 kg)
Shipping:	20.15 lbs (9.2 kg)

Package Includes:

KH20 sensor head with 5’ of cables
Power/Signal cable with 25’ lead length (CSI p/n KH20CBL-L)
Electronics Box
Rain Shield (CSI p/n 14113)
Horizontal Mounting Boom (20 inch 3/4” IPS threaded aluminium pipe) (CSI p/n 3874)
Nu-rail (3/4” x 3/4”) (CSI p/n 1017)
Allen Wrench (5/32”) (CSI p/n 4697)

3. Installation

3.1 Siting

When installing the KH20 sensor for latent heat flux measurement in an eddy covariance application, proper siting, sensor height, sensor orientation and fetch are important. Please refer to Section 2 Installation and Mounting of the Open Path Eddy Covariance System manual for more discussion on siting.

3.2 Mounting

3.2.1 Parts and Tools Needed for Mounting

You will need the following hardware to mount the KH20 sensor:

1. Tripod (CSI model CM115 standard) or tower
2. CM20x series crossarm (CSI model CM204 standard)
3. 3/4 inch IPS Aluminum Pipe, 12 inches long (CSI p/n 18048)
4. 3/4” x 1” Nu-rail (CSI p/n 1049)
5. Small Phillips and flat-head screw-drivers
6. 1/2 inch wrench

3.2.2 Mounting the KH20 Sensor

Mount the KH20 sensor head as follows:

1. Attach the 20 inch long mounting boom to the KH20.

2. Mount a crossarm onto a tripod or tower.

3. Mount the 12 inch long pipe (CSI p/n 18048) to a crossarm via 1” x 3/4” Nu-rail (CSI p/n 1049).

4. Mount the KH20 onto the 12” long pipe using a 3/4” x 3/4” Nu-rail (CSI p/n 1017). Mount the KH20 such that the source tube, the longer of the two tubes, is positioned on top, as shown in Figure 1. Gather any loose cables and tie them up, using cable ties, onto the tripod or tower mast.

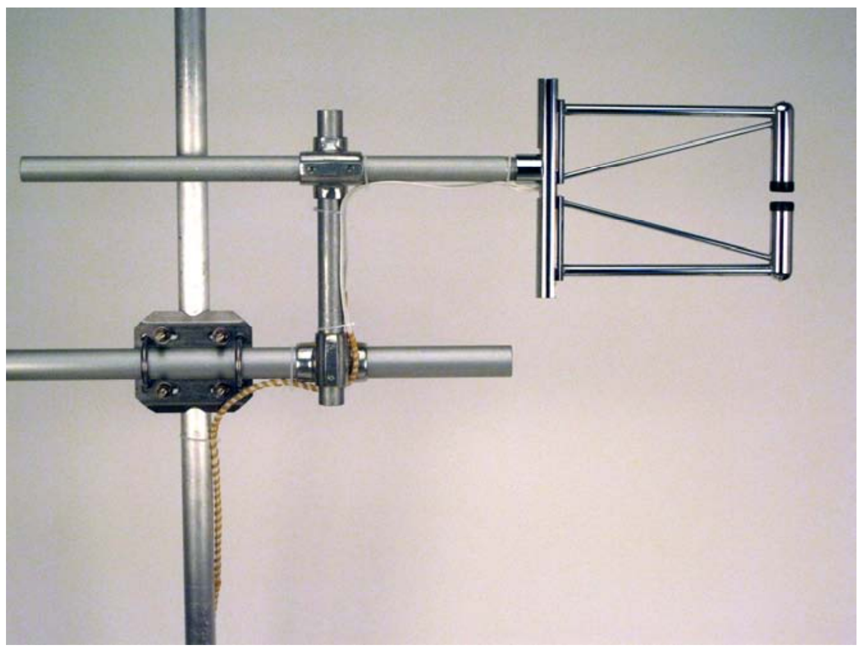

FIGURE 1. Mounting KH20 onto a tripod.

3.2.3 Mounting the Electronics Box

Mount the electronics box as follows:

1. First, remove the front cover of the rain shield by loosening the two pan-head screws on the bottom front of the rain shield, and then pushing the cover all the way up, and sliding it out.

NOTE It will be difficult to mount the rain shield to a mast with the front cover on, since the 1/2 inch nut holding the bottom U-bolt is located inside the rain shield.

2. Before mounting the rain shield onto a tripod, first mount the electronics box inside the rain shield. Remove the four pan-head screws from the back panel of the rain shield. Align the electronics box, and use the four pan-head screws to secure the electronics box onto the back panel. Make sure the electronics box is pushed all the way up, and the screws are positioned at the bottom of the mounting slot on the electronics box (see Figure 2). This will provide enough room to attach the connectors to the bottom of the electronics box later on.

FIGURE 2. Proper mounting position of the electronics box.

NOTE If the electronics box is not pushed all the way up during mounting, you will not have enough room to attach the connectors to the bottom of the electronics box, as the U-bolt for the rain shield will block the position of the connectors.

3. Mount the rain shield onto the tripod or tower mast using the U-bolt provided. Make sure that the distance between the KH20 sensor head and the rain shield is within 5 feet so that the cables from the sensor head will be within reach of the electronics box. Also make sure that the rain shield is mounted vertically with an opening pointing downward so that the rain will effectively run down the rain shield and not penetrate inside.

4. Connect the three cables to the bottom of the electronics box around the U-bolt on the rain shield (see Figure 3). If there is not enough room for the connectors around the U-bolt, make sure the electronics box is mounted at a highest possible position (see step 2).

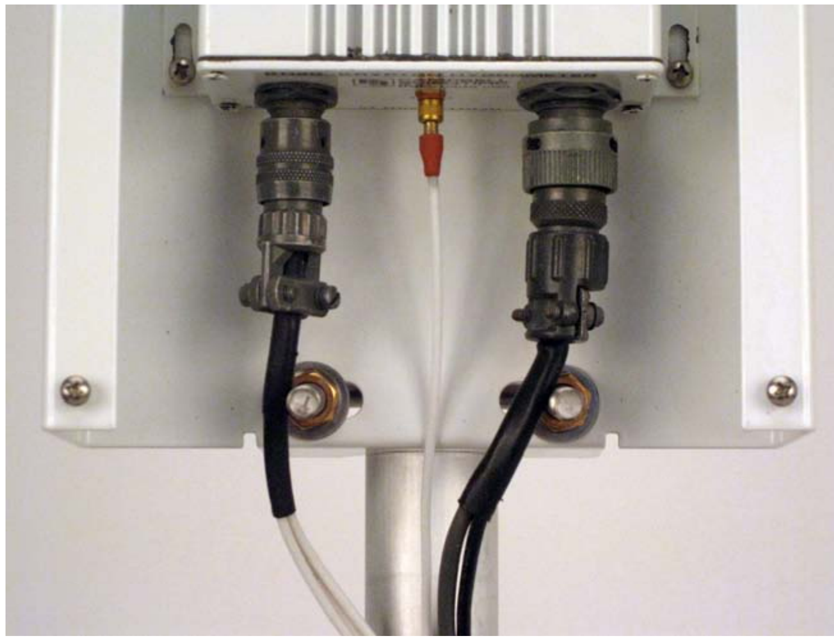

FIGURE 3. Attaching cables to the electronics box.

5. Place the front cover back on the rain shield and tighten the two pan-head screws to secure it in place.

6. Gather any loose cables and tie them up, using cable ties, onto the tripod or tower mast.

4. Wiring

The KH20 sensor is shipped with a power/signal cable with a 25 ft standard lead length. Table 1 shows the connections for the KH20 to the CR1000, CR3000, and CR5000.

TABLE 1. Datalogger Connections for Differential Measurement

Function	Wire Color	CR1000/CR3000/CR5000
KH20 Signal +	White	Differential Input (H)
KH20 Signal -	*Black	Differential Input (L)
KH20 Power +	Red	12V
KH20 Power -	Black (from Red/Black set)	G
Shield	Clear	⏚

*Jumper to ⏚ with user supplied wire

5. Datalogger Programming

The KH20 sensor outputs 0 to 5 Vdc analog signal. These signals can be measured using the VoltDiff instruction on the CRBasic dataloggers or the Volt (Diff) (P2) instruction on the traditional Edlog dataloggers.

5.1 KH20 Calibration

Each KH20 is calibrated over a vapor range of approximately 2 to 19 g/m^3. The calibration is performed twice under the following two conditions: window clean, and scaled. The water vapor absorption coefficient for three different vapor ranges are calculated from the collected calibration data: full range, dry range, and wet range. Table 2 shows a sample of the KH20 vapor ranges over which three different water vapor absorption coefficients are calculated. See Appendix A for more information on KH20 calibration.

TABLE 2. KH20 Calibration Ranges

Ranges	Vapor Density (g/m^3)
Full Vapor Range	2 – 19
Dry Vapor Range	2 – 9.5
Wet Vapor Range	8.25 – 19

Before the water vapor absorption coefficient, k_w, is entered into the datalogger program for the KH20, the following decisions must be made:

- Will the windows be allowed to scale?
- What vapor range is appropriate for the site?

Once the decision is made, the appropriate k_w can be chosen from the calibrations sheet. The calibration sheet also contains the path length, x, for a specific KH20. Using the water vapor absorption coefficient for either the dry or the wet vapor range will produce more accurate measurements than using that for the full range. If the vapor range of the site is unknown, or if the vapor range is on the border line between the dry and the wet vapor ranges, the full range should be used.

5.2 Example 1, CR3000 Program to Measure Water Vapor Fluctuations

The following example program measures the KH20 at 10Hz, and stores the average values into a data table called ‘stats’, as well as the raw data into a data table called ‘ts_data’.

NOTE The KH20 cannot be used for measuring absolute water vapor concentration.

```
'CR3000 Series Datalogger

'This datalogger program measures KH20 Krypton Hygrometer.

'The station operator must enter the constant and the calibration value for the KH20.
'Search for the text string "unique" to find the locations of these constants
'and enter the appropriate values found from the calibration sheet of the KH20.


'*** Unit Definitions ***

'Units    Units
'ln_mV    ln(mV)   (natural log of the KH20 millivolts)
'mV       millivolts
'rho_w    g/m^3


'*** Wiring ***

'ANALOG INPUT
'1H       KH20 signal+ (white)
'1L       KH20 signal- (black)
'gnd      KH20 shield (clear)

'EXTERNAL POWER SUPPLY
'POS      KH20 power+ (red)
'         datalogger POWER IN 12 (red)
'NEG      KH20 power- (black)
'         KH20 power shield (clear)
'         datalogger POWER IN G (black)

PipeLineMode

'*** Constants ***

'Measurement Rate                  '10 Hz
Const SCAN_INTERVAL = 100          '100 mSec

'Output period
Const OUTPUT_INTERVAL = 30         'Online flux data output interval in minutes.
Const x = 1                        'Unique path length of the KH20 [cm].
Const kw = -0.150                  'Unique water vapor absorption coefficient [m^3 / (g cm)].
Const xkw = x*kw                   'Path length times water vapor absorption coefficient [m^3 / g].
```

```
'*** Variables ***
Public panel_temp
Public batt_volt
Public kh(2)
Public rho_w
Alias kh(1) = kh_mV
Alias kh (2) = ln_kh
Units panel_temp = deg_C
Units batt_volt = volts
Units kh_mV = mV
Units ln_kh = ln_mV
Units rho_w = g/m^3

'***  Data Output Tables ***
'Processed data
DataTable (stats,True,-1)
    DataInterval (0,OUTPUT_INTERVAL,Min,10)
        Minimum (1,batt_volt,FP2,False,False)
        Average (1,panel_temp,FP2,False)
        Average (2,kh(1),IEEE4,False)
EndTable

'Raw time-series data.
DataTable (ts_data,True,-1)
    DataInterval (0,SCAN_INTERVAL,mSec,100)
        Sample (1,kh_mV,IEEE4)
EndTable

'*** Program ***

BeginProg

    Scan (SCAN_INTERVAL,mSec,3,0)

        'datalogger panel temperature.
        PanelTemp (panel_temp,250)

        'Measure battery voltage.
        Battery (batt_volt)

        'Measure KH20.
        VoltDiff (kh_mV,1,mV5000,1,TRUE,200,250,1,0)
         ln_kh = LOG(kh_mV)
         rho_w = ln_kh/xkw

      CallTable stats
      CallTable ts_data

    NextScan
EndProg
```

6. Maintenance and Calibration

The KH20 sensor is designed for continuous field application and requires little maintenance. The tube ends for the KH20 have been sealed with silicone elastomer using an injection-mold method. Therefore, the tubes are protected from water damage, and the KH20 continues to make measurements under rainy or wet conditions. If the water tends to pool up on the tube window and blocks the signal, you can turn the sensor head at an angle so as to shed the water off the tube window. The rain shield protects the electronics box and the connectors from moisture.

6.1 Visual Inspection

- Make sure the optical windows are clean.
- Inspect the cables and connectors for any damage or corrosion. If you see a discoloration on the white co-axial cable, you may suspect that the cable has water damage.

6.2 Testing the Source Tube

The source tube is the longer of the two tubes. You can check to see if the source tube is working properly by performing the test explained below.

First, make sure the UV light is emitted from the source tube. To do this, you may look into the source tube (the longer of the two tubes), and you should see a bright blue light emitted from it.

NOTE Avoid looking into the source tube for an extended period of time when the KH20 is powered on to minimize the prolonged exposure to the UV light.

If you see a faint or flickering blue light, perform the following test.

Check the current drain on the KH20

> Typical current drain for the KH20 during normal operation should be 15 ~ 20 mA. The current drain of around 5 mA or less indicates the problem on the source tube. Obtain an RMA from Campbell Scientific, Inc. and send the unit in for repair.

Check the voltage signal output from the KH20

> If the voltage output reading is below 50 mV, you may have problems with either the source tube or the detector tube. For the detector tube testing, see Section 6.3 below.

6.3 Testing the Detector Tube

If the source tube tests fine but the output from KH20 is still in question, perform the following test. Prepare a piece of paper and insert it between the source tube and the detector tube to completely block the optical path. You should see an immediate decrease in the voltage reading, and it should go close to zero. No noticeable change in the voltage output, when the optical path is completely blocked, indicates a problem in the detector tube. If the decrease in the voltage reading takes place but the reading remains below 50 mV, when the paper is removed from the optical path, the source tube may be at fault. Obtain an RMA from Campbell Scientific, Inc. and send the unit in for repair.

6.4 Managing the Scaling of KH20

The KH20 cannot be used to measure an absolute concentration of water vapor, because of scaling on the source tube windows caused by disassociation of atmospheric continuants by the ultra violet photons (Campbell and Tanner, 1985 and Buck, 1976). The rate of scaling is a function of the atmospheric humidity. In a high humidity environment, scaling can occur within a few hours. That scaling attenuates the signal and can cause shifts in the calibration curve. However, the scaling over a typical flux averaging period is small. Thus, water vapor fluctuation measurements can still be made with the hygrometer.

To see if the source tube window has been scaled, get a clean, dry cotton swab and slide it across the source tube window. The scale is not visible to the naked eye, but if the window is scaled, you will feel a slight but noticeable resistance while you slide the swab across the window. There will be little resistance if the window is not scaled. If you determine the window is scaled, you can clean it with a wet cotton swab.

Use distilled water and a clean cotton swab to clean the scaled window. After cleaning the window, slide a clean, dry swab across the window to confirm the scale has been removed.

NOTE You can use the water vapor absorption coefficient for scaled window from the calibration sheet if the window will be allowed to scale during measurements.

6.5 Older KH20

The older version of the KH20 used to suffer permanent damage when exposed to water, due to corrosion and loss of vacuum within the tubes. The new version of the KH20 has employed a new sealing around the window to prevent this type of damage.

6.6 Calibration

For quality assurance of the measured data, Campbell Scientific, Inc. recommends the KH20 be recalibrated every two years. Please contact Campbell Scientific, Inc. to obtain an RMA number for recalibration.

For more information on the calibration process, refer to Appendix A of this manual.

Appendix A. Calibrating KH20

A.1 Basic Measurement Theory

The KH20 uses an empirical relationship between the absorption of the light and the material through which the light travels. This relationship is known as the Beer's law, the Beer-Lambert law, or the Lambert-Beer law. According to the Beer's law, the log of the transmissivity is anti-proportional to the product of the absorption coefficient of the material, *k*, the distance the light travels, *x*, and the density of the absorbing material, ρ. The KH20 sensor uses the UV light emitted by the krypton lamp: major line at 123.58 nm and the minor line at 116.49. As the light travels through the air, both the major line and the minor line are absorbed by the water vapor present in the light path. This relationship can be rewritten as follows, where k_w is the absorption coefficient for water vapor, *x* is the path length for the KH20 sensor, and ρ_w is the water vapor density.

$$T = e^{-k_w x \rho_w} \qquad \text{A-1}$$

If we express the transmissivity, *T*, in terms of the light intensity before and after passing through the material as measured by the KH20 sensor, *V* and V_0, respectively, we obtain the following equation.

$$\frac{V}{V_0} = e^{-k_w x \rho_w} \qquad \text{A-2}$$

Taking the natural log of both sides, and solving for the density, ρ_w, yields the following equation.

$$\rho_w = \frac{1}{-k_w x}(\ln V - \ln V_0) \qquad \text{A-3}$$

If the path length, *x*, and the absorption coefficient for water, k_w are known, it becomes possible to measure the water vapor density ρ_w, by measuring the signal output, *V*, from KH20.

A.2 Calibration of KH20

The KH20 calibration process is to find the absorption coefficient of water vapor, k_w. To do this, we rewrite the equation A-3, and solve for ln(V).

$$\ln V = -k_w x \rho_w + \ln V_0 \qquad \text{A-4}$$

It now becomes obvious from the equation A-4 that there is a linear relationship between the natural log of the KH20 measurement output, ln*V*, and the water vapor density, ρ_w. Figure A-1 shows the plot of the equation A-4 after we ran a KH20 over a full calibration vapor range.

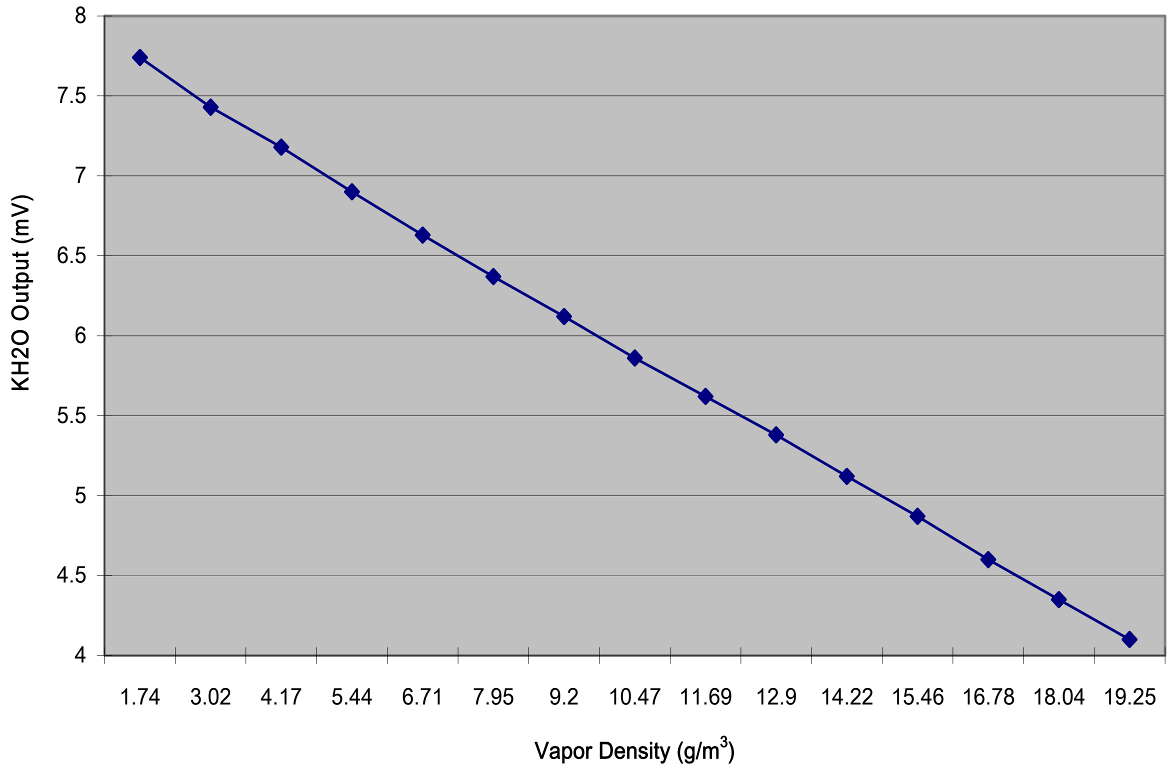

FIGURE A-1. KH20 ln(mV) vs. Vapor Density

We can perform the linear regression on the plot above to obtain the slope for the relationship between the ln(mV) and the vapor density. The slope for the graph above will be the coefficient, $k_w x$ which we are after. Table A-1 below shows the result of linear regression analysis. Again the slope is the product of the absorption coefficient of water vapor, k_w, and the KH20 path length, x.

TABLE A-1. Linear Regression Results for KH20 ln(mV) vs. Vapor Density

Description	Values
Slope (xk_w)	-0.205
Y Intercept ($\ln(V_0)$)	8.033

If we substitute these values, along with the measured lnV into equation A-3, we can obtain the water vapor density, ρ_w. Campbell Scientific, Inc. performs the calibration twice for each KH20: once with the window cleaned, and again with the window scaled. We then break up the vapor density range into dry and wet ranges, and compute the k_w values for each sub range, as well as for the full range. If you know the vapor density range for your site, it is recommended that you select the coefficient, k_w, that is appropriate for your site, the dry range or the wet range. If the vapor range for the site is unknown, or if the vapor range is on the border line between the dry and the wet ranges, use the value for the full range. Table A-2 shows the final calibration values the KH20 calibration certificate contains. The data shown in Table A-2 is from an actual KH20.

TABLE A-2. Final Calibration Values for KH20

	Vapor Range (g/m^3)	Slope (xk_w)	Y Intercept ln (V_0)	Coefficient (k_w)
Full Range	1.74 ~ 19.25	-0.205	3087	-0.144
Dry Range	1.74 ~ 9.20	-0.216	3259	-0.151
Wet Range	7.95 ~ 19.25	-0.201	2899	-0.141

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