VIASPACE VIASENSOR HS-1000
REAL-TIME FUEL CELL HUMIDITY SENSOR

USER MANUAL

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INTRODUCTION

Critical to the proper design and performance characterization of polymer electrolyte membrane fuel cells (PEMFCs) is the accurate measurement of its operating conditions, including temperature, pressure and moisture content of the hydrogen and air inlet gases. Proper reactant gas humidification ensures good fuel cell membrane hydration which is instrumental in maintaining high ionic conductivity. Low ionic conductivity leads to decreased fuel cell performance and potentially physical damage as well.

The VIASPACE VIASENSOR HS-1000 (Real-Time Humidity Sensor) uses patent pending miniature laser technology to enable real-time, accurate, and reliable measurement of the humidity of the inlet gases in PEMFC testing and operation. The VIASENSOR provides researchers and fuel cell developers with a solution for in-situ real-time humidity measurements.

The VIASENSOR solves the key challenges of accurately measuring the fuel cell humidity levels in high temperature and high humidity environments. Specifically, the VIASENSOR solution has the following features:

- Continuous, fast response real-time operation -- data taken as quickly as every 1.6 seconds
- Able to detect transients in humidification
- Non-invasive humidity measurement of the inlet gas stream
- Designed for high humidity and high temperature environments
- Does not condense the water vapor, no long cycle times between measurements
- Sensor does not get flooded and have to dry out
- Low cost of operation
- Modest package size and weight
- Output interfaces to any PC

How does the VIASENSOR HS-1000 work?

The VIASENSOR uses patent pending tunable diode laser absorption spectroscopy technology to provide direct, real-time, fast-response measurements of the water vapor content in fuel cell gas streams. The laser beam, tuned to a specific absorption wavelength of water vapor, is aimed across the inlet gas stream, and the sensor essentially counts the number of water vapor molecules passing the laser.

The tunable diode laser absorption technology is a proven technique as it has been widely used for over 40 years in many other applications. The current approach was originally developed at the NASA/Caltech Jet Propulsion Laboratory. As the humidified gas passes in front of the laser, located in a small heated chamber to prevent condensation, some of the laser light is absorbed by the water vapor in the gas stream. A detector then measures how much laser light was absorbed by the water vapor, which corresponds directly to how many water vapor molecules are in the laser's path. For a given temperature, the area under the spectral line of H_2O provides a direct and quantitative measure of the amount of water vapor in the gas stream. This water vapor number density (molecules per cm^3) value can be converted to any other desired unit such as dew point, absolute humidity, and relative humidity, with knowledge of pressure and temperature at the measurement point.

Since the laser wavelength is tuned rapidly and continuously, this measurement approach is both simple to implement and robust. There is virtually zero drift over time and no calibration needed.

The VIASENSOR is an excellent and unmatched, long term humidity measurement solution for fuel cell testing.

PACKING LIST

The VIASENSOR HS-1000 includes:

- Sensor head
- Control box
- Sensor Control Cable
- Power cord
- Serial cable
- User manual
- CD-ROM with monitoring software for a PC

Please check that all items are present before discarding or storing any packaging or shipping boxes.

WHAT THE VIASENSOR MEASURES

The VIASENSOR HS-1000 will measure and display humidity as Dew Point in degrees Celsius or as Partial Pressure in millibar for all typical gasses used with PEM fuel cells. These include:

- Hydrogen
- Air
- Oxygen/Nitrogen mixes

The range of Dew Point that is measurable is between 30ºC and 100ºC.

Pressure range for the VIASENSOR is from zero gauge pressure up to 2 atmospheres of back pressure.

The sensor reading is not flow rate dependent. The flow can be in either direction. At low flow rates (less than 0.3 L/min) there will be some increase in the response time of the sensor because of the time required to move the gas mixture through the sample chamber. At high flow rates (above 5 L/min) the pressure drop across the sensor may become significant. For very high flow rates it is best to divert only a portion of the gas stream through the sensor.

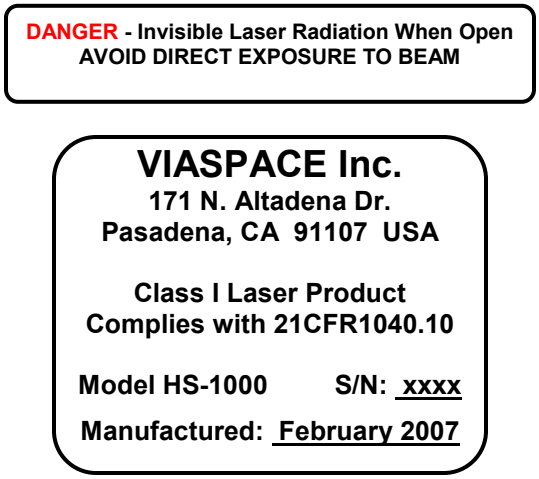
SENSOR HARDWARE SETUP

The VIASENSOR Sensor Head has ¼" compression fittings on ¼" tubing at the two gas ports. Either port may used for the inlet. Typically, the humidified gas stream from the user's fuel cell test station connects directly to an inlet of the Sensor Head. Subsequently, the outlet of the Sensor Head connects to the user's fuel cell stack.

Note: the VIASENSOR has a heated sample chamber within the main sensor box that is heated to 105ºC (to prevent condensation). All lines from the user's humidification source to the fuel cell stack should be heated above the dew point temperature to avoid condensation in the line.

Connect the Sensor Control Cable (supplied with the VIASENSOR) to the Control Box, port 1. Connect the cable ends labeled 2, 3 and 4 to the Sensor Head at the connectors labeled the same. NEVER connect or disconnect this cable at either end when power is on.

Connect the power cord to the Control Box. The ON/OFF switch is right above the power cord inlet on the Control Box. The red LED will light up on the front of the Control Box when power is on.



Connect the serial cable to the Control Box and to your computer.

Note: there are no user serviceable parts inside the sensor head. Should the VIASENSOR appear to malfunction (i.e. give no measurement readings on the computer), contact the factory for a Return Material Authorization number and return the unit to the factory for service.

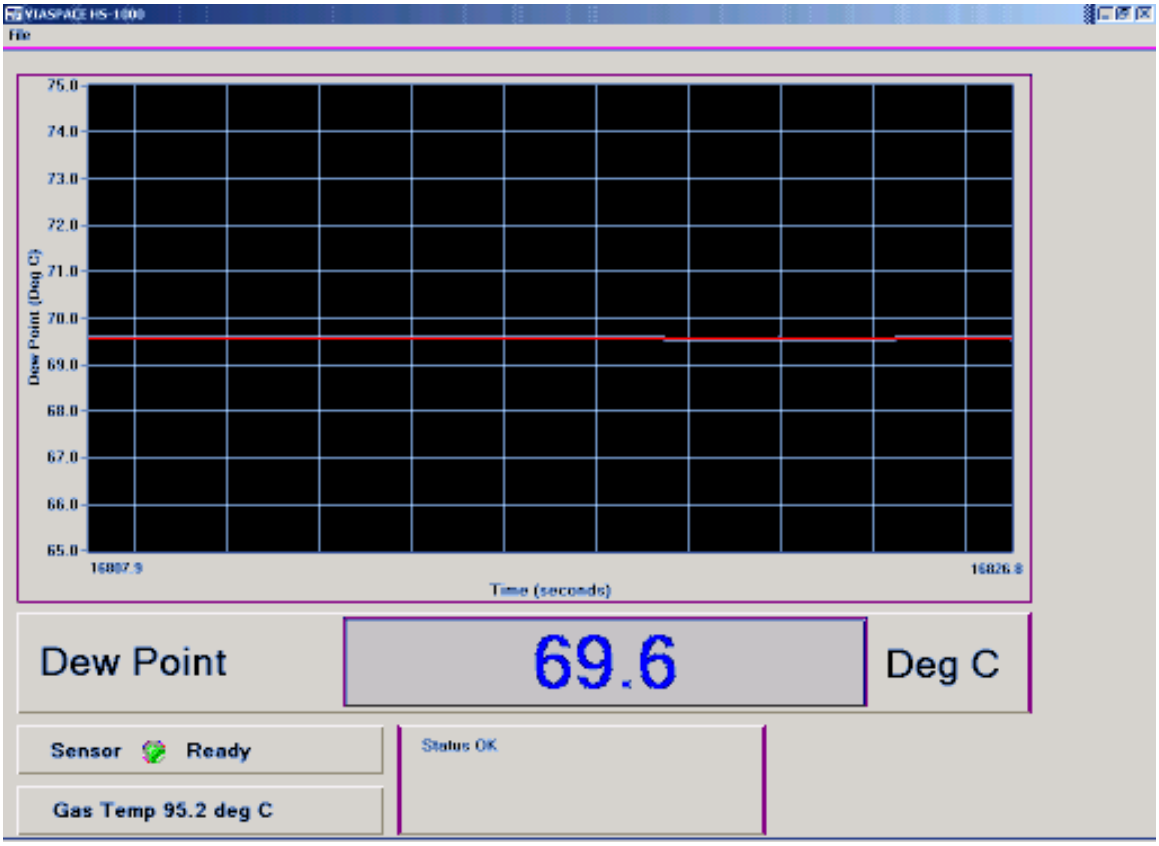
SOFTWARE SETUP

To install the VIASENSOR monitoring software onto a computer, insert the CDROM in the computer's CDROM drive. The installation utility should run automatically. Follow the prompts until completion.

SOFTWARE DESCRIPTION

The VIASENSOR control box has a serial port for communication with a computer. Connect the serial cable between this serial port and a serial port on your computer. In case your computer has no available serial port, a serial to USB adapter will work.

To run the VIASENSOR monitoring software, double click on the program icon on your computer's desktop. The following screen shot is the main screen of the program.



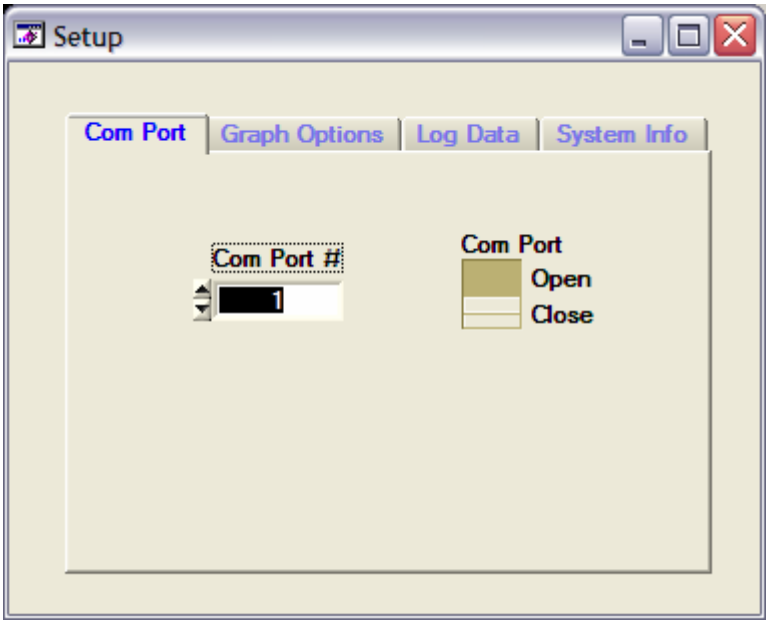
The horizontal axis is time in seconds and the vertical axis is user-selectable for dew point in degrees Celsius, partial pressure (of water vapor) in millibars (mB), or partial pressure in kilopascals (kPa). The data progresses across the screen much like a strip chart. The latest dew point or partial pressure data point is displayed at the bottom of the screen in blue numerals.

“Sensor Ready” indicator is green when the gas temperature in the VIASENSOR sample chamber is at least 5ºC greater than the measured dew point of the gas in the chamber. At initial power up of the unit and while it warms up, the Sensor light typically is red and states “Not Ready”. This is to reduce the risk of condensation in a cold sample chamber if high humidity is run through prior to sufficient warm-up.

“Gas Temp” is the measured gas temperature within the heated sample chamber in the VIASENSOR.

“Status” will display any system error. Typically, errors will display during the initial 15 seconds after power up while the internal self-test is under way, and then clear. Descriptions of the error codes are in Appendix E.

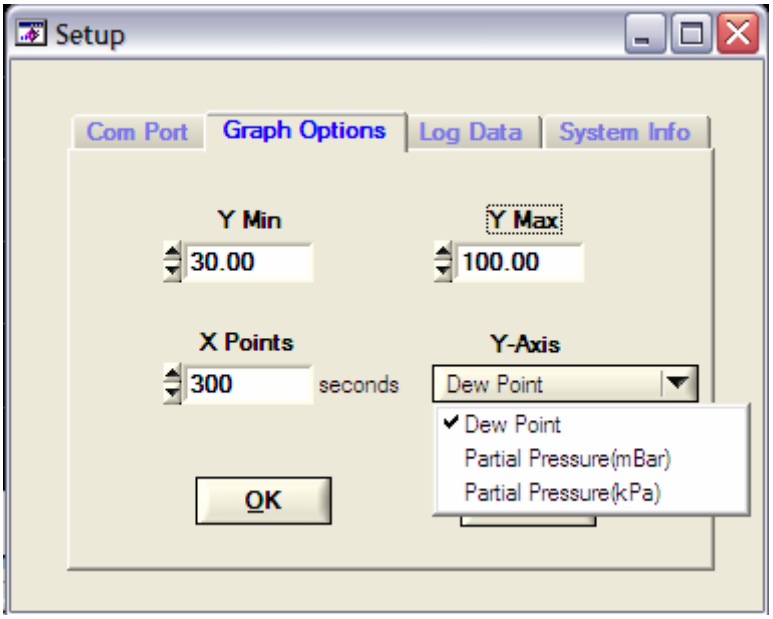
Several options may be set by going to the pull down menu under “File” at the top left of the main screen.



The “Com Port” tab allows selection of the com port in use by your computer to communicate with the VIASENSOR. (The default value is 1.) Make your selection and click the Com Port “switch” to “Open”.

If an incorrect com port is selected, an error message will appear alerting you to that fact. Check which com ports are available on your computer by viewing the Hardware Device Manager under System Properties.

Click on the white/red “X” in the upper right corner of this screen to save and close this screen.

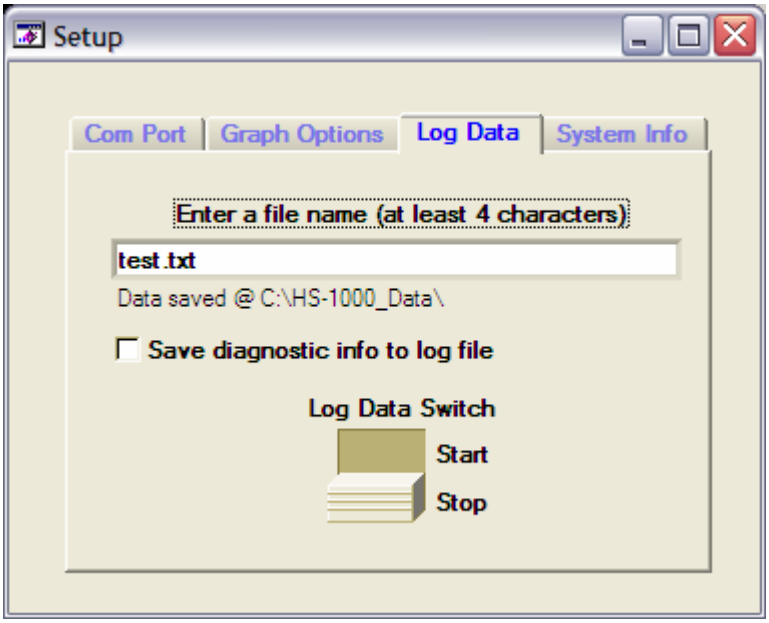


The “Graph Options” tab allows selection of the minimum and maximum values on the Y-axis (vertical axis) of the display.

“X Points” selects the scale of the horizontal axis. It selects the quantity of data points that will be shown across the full width of the display in seconds. Additional data will cause the existing data to scroll to the left, off of the screen, with the visual effect of a strip chart.

The “Y-Axis” pull-down menu allows the data to be displayed on the main screen as dew point, partial pressure in millibars, or partial pressure in kPa. Note that this selection does not affect the data that is saved in any log file – it only changes the display on the PC.

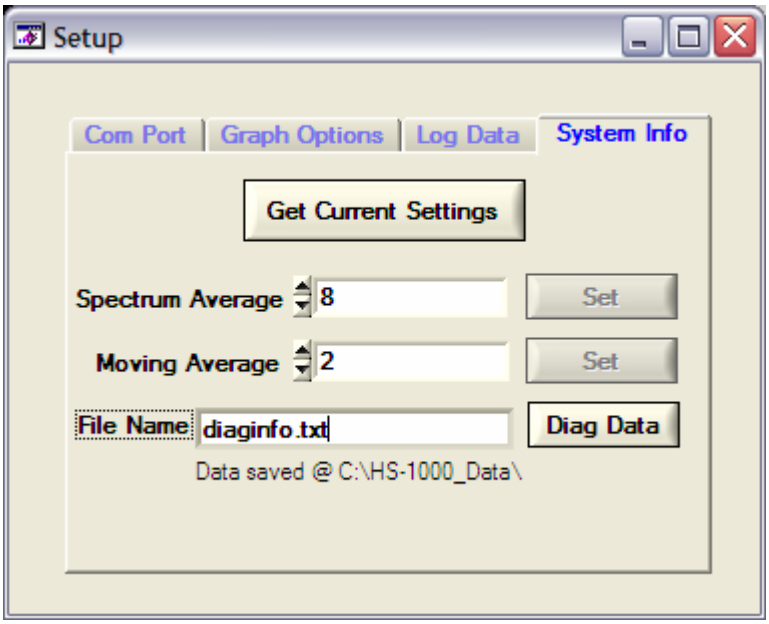
Click on the white/red “X” in the upper right corner of this screen to save and close this screen.



The “Log Data” tab allows the data to be logged. Enter a file name in the text box, and include the “.txt” extension with the file name. Click on the “Log Data Switch” to start, or stop, logging of the data. The saved file is in text format, and may be imported readily into any analysis program (such as Microsoft Excel). Sample data is shown in Appendix A.

Check the box next to “Save diagnostic info to log file” to save columns of diagnostic data along with the standard data being saved. Sample data with diagnostic info is shown in Appendix B.

Click on the white/red “X” in the upper right corner of this screen to save and close this screen.



The “System Info” tab allows selection of VIASENSOR internal parameters “Spectrum Average” and “Moving Average”. The factory default is Spectrum Average 8, Moving Average 2 – these are typically the largest values used per each. The minimum value for each is 1, and they must be integers.

The response time of the VIASENSOR depends on two factors, the measurement rate, and the gas flow rate. The slowest of those rates will determine the response time. The measurement rate is calculated from the spectrum average and moving average values as follows:

t_{resp} = (1.05+.53 * (spectrum averages)) * (moving averages)

The internal volume of the sample chamber is 4 cm^3. The response time due to purging the chamber volume is: t_{resp} = 4 cm^3 / flow rate.

The time between each data point is calculated as follows:

t_{data} = 1.05+.53 * (spectrum averages)

For Spectrum Average of 8, the time between data points is approximately 5.3 seconds; for Spectrum Average of 1, the time is 1.6 seconds. The trade off is that a smaller Spectrum Average will provide less smoothing and slightly more noise in the signal than a larger Spectrum Average will.

The “Get Current Settings” button retrieves and displays the current values of the Spectrum Average and Moving Average parameters. The “Set” buttons are used

to save any changes of these values. These parameters are saved in the VIASENSOR unit and do not need to be reset each time the PC software is run.

Diagnostic Data may be saved. Enter a file name in the text box, and include the ".txt" extension with the file name. Click on the "Diag Data" button to save. Note that it may take up to 10 seconds to download and save this data. See Appendix C for a sample file and descriptions. The saved file is in text format, and may be imported readily into any analysis program (such as Microsoft Excel).

SERIAL COMMUNICATION WITH THE VIASENSOR

See Appendix D for communication parameters and sample data.

ANALOG OUTPUT OPTION

An optional feature that may be included with the VIASENSOR in addition to the serial output is an analog output. Two standard banana jacks, spaced for a dual connector, would be located on the front panel of the Control Box. The red jack has the positive leg of the signal. The analog signal is floating and should not be tied to ground.

The analog output signal is 0 to 5VDC. It is linear between 0.5 and 4.5VDC.

0.5VDC = 0 millibars, partial pressure of water vapor
4.5VDC = 1000 millibars, partial pressure of water vapor
4.6VDC or greater indicates an error condition in the VIASENSOR

FREQUENTLY ASKED QUESTIONS (FAQs)

What is the expected lifetime of the laser diode?
The laser used in the sensor is a telecommunications type laser diode that has an expected lifetime of greater than 20 years.

Does the sensor drift over time?
The sensor is designed to be insensitive to variations in most of its components. The laser wavelength is scanned continuously across the water absorption line. Drift in the laser, detectors, or sample chamber are balanced out during each scan. In addition, since none of the sensitive components are in contact with the gas stream, they will not become damaged by contaminants in the gas. Therefore, the sensor calibration should be stable for at least several years.

How often does the sensor need to be calibrated?
Even though the sensor calibration should be stable for several years, we recommend for critical applications that the calibration be verified each year.

What is the accuracy of the sensor?
The uncertainty of the sensor reading is +/- (2% of the reading + 1 mB of partial pressure).

What range of gas flow rate can be measured with the sensor?
The sensor reading is not flow rate dependent. The flow can be in either direction. At low flow rates (less than 0.3 L/min) there will be some increase in the response time of the sensor because of the time required to move the gas mixture through the sample chamber. At high flow rates (above 5 L/min) the pressure drop across the sensor may become significant.

How do you measure very high flow rate gas streams?
For very high flow rates it is best to divert only a portion of the gas stream through the sensor. Very little pressure drop is required to flow gas through the sensor. Therefore, a Pitot tube or slight restriction in the main gas flow tube is all that is required. Contact your sales representative for advice in specific applications.

How is data output from the sensor?
The sensor outputs a line of RS-232 serial, tab delimited text after each measurement. The measurement interval can be chosen by the customer from 1.5 seconds per point with no averaging, to over 10 seconds per point when averaging 15 scans for each measurement. Any software that can read this serial data can interface with the sensor.

Can I get an analog (4-20mA current loop) output from the analyzer?
An analog output option is now available. Consult your sales rep.

What is the maximum dew point range for the sensor?
The standard measurement range is dew point between 30ºC and 100ºC. Dew point ranges up to 120ºC and beyond are also available. Contact your sales representative for specific applications.

Can this sensor be used for applications other than fuel cells?
Yes, almost any application that requires a humidity measurement with dew point in the range of 30ºC to 100ºC can use this sensor.

What is the response time of the sensor?
The response time depends on two factors, the measurement rate, and the gas flow rate. The slowest of those rates will determine the response time. The measurement rate is calculated from the spectrum average and moving average values as follows:

T_{resp} = (1.05+.53 * (spectrum averages)) * (moving averages)

The internal volume of the sample chamber is 4 cm^3. The response time due to purging the chamber volume is: T_{resp} = 4 cm^3 / flow rate.

How is operating status indicated with analog output?
The analog output can be configured to go to full scale or zero in the event of a status not OK condition. Or, as another option, a status relay contact can be provided.

Can the instrument measure below 20C dew point?
A special range instrument would have to be configured. Please consult your sales rep with a complete set of requirements.

How is the gas temperature measured?
An epoxy coated thermistor bead measures the temperature.

Is there a specific orientation for the sensor?
No. The sensor can be placed in any orientation without affecting the accuracy of the reading.

Why is the sample chamber heated?
The sample chamber must be hotter than the dew point of the incoming gas or the moisture will condense into water in the sample chamber. An indicator on the software display will show when the chamber is less than five degrees above the dew point temperature.

In what units does the sensor read?
The serial output data from the sensor is in partial pressure of water in millibars. However, the display software will also convert the partial pressure reading into kPa or into dew point in ºC.

Is the sensor reading dependent on gas pressure?
No. The partial pressure reading for water vapor is not dependent on gas pressure. However, if the partial pressure of water is higher than the gas pressure, then condensation will take place.

Will the sensor respond to entrained water droplets?
No, the sensor can only measure the absorption of individual water molecules, not liquid droplets.

In what background gases can the sensor measure water vapor?
The sensor reading will be accurate in backgrounds of mono or di-atomic molecules (H2, N2, O2, He, Ar, …) It will also work in typical products of combustion backgrounds (CO, CO2, NOx, SOx, …) Please consult your sales representative for specific backgrounds.

What are the advantages of the TDLAS sensor over a chilled mirror?

- Fast response
- No need for regular cleaning or maintenance
- Any sensor problem is detected by the software and indicated in the output.

Can the sensor measure lower levels of moisture?
Not at this time. However, the technology can be applied to measure very low levels of moisture. Please consult your sales representative with your requirements.

PRODUCT SPECIFICATIONS

- Measurement Range: 40 mB to 1000 mB water vapor partial pressure (30ºC to 100ºC dew point)
- Response time: As quickly as 1.6 seconds for gas flows greater than 0.4 L/min
- Max pressure: 30 psig (200 kPa)
- Flow rate range: flow rate independent (Note: response time increases below 400 mL/min)
    - (High flow rates (above 5 L/min) may be accommodated using a slipstream/bypass flow line.)
- Ambient temperature range: 10ºC to 30ºC
- Max sample cell temperature: 105ºC
- Wetted materials: Nickel plated aluminum, sapphire, epoxy
- AC power: 90 to 240 VAC, 1 A, 50 to 60 Hz
- Dimensions and weight:
    - Sample cell: 6” x 6” x 2” (15 cm x 15 cm x 5 cm), 1.7 lb (0.8 kg)
    - Electronics: 8.75” x 10” x 3.5” (22.2 cm x 25.4 cm x 8.9 cm), 3.75 lb (1.7 kg)
- Cable length: 40” (1 m)
- Data logging software requirements:
    - Minimum display resolution: 1024 x 768
    - Serial input or Serial/USB adapter
    - Optional analog input (0-5VDC)

APPENDIX A: Sample Log File

A sample log file from the VIASENSOR Monitoring Software on the PC:

DewPoint(C)	Vapor Pressure(mbar)	Temperature(C)	ErrorCode
67.4	279.1	107.9	0
67.2	277.1	107.8	0
66.9	273.4	108.0	0
66.8	272.6	108.2	0
67.5	281.1	105.1	0

DewPoint(C) is the dew point in ºC of the gas passing through the sample chamber in the VIASENSOR. It has been calculated from the Vapor Pressure.

Vapor Pressure(mbar) is the vapor pressure (partial pressure) in millibar of the water vapor in the gas stream passing through the sample chamber in the VIASENSOR.

Temperature(C) is the temperature in ºC of the gas as it passes through the sample chamber in the VIASENSOR.

ErrorCode is defined in Appendix E. A value of "0" is the normal output when there is no error condition.

Note: This data is saved as a text file and is readily imported into most programs that you may use for data analysis, such as Microsoft Excel.

APPENDIX B: Sample Log File with Diagnostic Info

A sample log file from the VIASENSOR Monitoring Software on the PC:

DewPoint(C)	Vapor Pressure(mbar)	Temperature(C)	ErrorCode	Index	Transmission	Area	HalfWidth	L Interp	R Interp
66.4	267.7	102.1	0	262	0.911	17.90	61.44	-0.48	0.37
66.4	267.7	103.9	0	265	0.912	17.79	61.82	-0.01	-0.35
66.2	264.9	105.1	0	262	0.913	17.53	60.95	0.21	-0.31
66.1	264.0	105.9	0	263	0.912	17.67	61.04	-0.02	0.11
66.1	264.1	106.6	0	261	0.913	17.54	61.26	0.37	0.16
65.9	261.9	106.7	0	262	0.914	17.37	61.41	0.45	0.37
65.9	262.2	106.7	0	261	0.913	17.58	61.79	0.45	0.13

The information in the columns "Index", "Transmission", "Area", "HalfWidth", "L Interp", and "R Interp" are characteristics of the laser absorption peak. This information may assist in troubleshooting the VIASENSOR with VIASPACE technical support personnel.

Note: This data is saved as a text file and is readily imported into most programs that you may use for data analysis, such as Microsoft Excel.

APPENDIX C: Sample Diagnostic Data download file

A sample diagnostic data download file from the VIASENSOR Monitoring Software:

Hygrometer Diagnostics - 070430 A

Idx	DC1	DC2	lnT
0	36821	32495	0.000000
1	21014	17931	0.000000
2	11445	9770	0.000000
3	6237	5345	0.000000
4	3404	2944	0.000000
…	…	…	…
270	26632	29195	0.087473
271	26685	29244	0.087162
272	26743	29293	0.086665
273	26803	29342	0.086095
…	…	…	…
509	38407	38758	0.000000
510	38437	38779	0.000000
511	38476	38805	0.000000

Computational Statistics

dc counts

Line center found at: 263
Minimum Transmission: 0.915
Maximum of -ln(T): 0.089
Sample cell zero level: 53
Reference leg zero level: 137

Calculated values

H20 vapor pressure: 260.59 mbar
Temperature: 107.4 C
Temperature: 107.4 C

EEPROM Settings

Phase: 315
Midpoint: 60
Ramp amplitude: 30
Imod: 0
Null Point: 6
Spectrum Average: 8
Rcalb: 1500
Xleftvmr: 180
Xrightvmr: 385
SpanFct(x 1000): 1000
PA 1: 0.000E+00
PA 2: 1.000E+00
PA 3: 0.000E+00
PA 4: 0.000E+00
TA 1: 1.000E+00

TA 2: 0.000E+00
TA 3: 0.000E+00
TA 4: 0.000E+00
pr1: 0.000
pr2: 1.000
Thermistor A: 9.4630E-04
Thermistor B: 2.6650E-04
Thermistor C: -5.0700E-08
Span (x 100): 2000
Zero Offset: 0 ppmv
Moving Average: 2

The laser scan is divided among 512 channels. Plotting DC1 and DC2 as functions of Idx (Index) will display the sample spectrum and reference spectrum. lnT is the negative natural logarithm of the laser transmission at each channel.

Only "# Spectrum Average" and "Moving Average" may be user set within the software program running on the PC. The balance of these parameters is settable only at the factory or by an authorized service representative. This information may assist in troubleshooting the VIASENSOR with VIASPACE technical support personnel.

Note: This data is saved as a text file and is readily imported into most programs that you may use for data analysis, such as Microsoft Excel.

APPENDIX D: Sample Serial Output Data

Sample serial output data direct from the RS-232 Serial Port on the VIASENSOR Control Box:

Vapor Pressure (millibar)	Chamber Gas Temp (ºC)	Error Code	Peak Index	Trans-mission	Peak Area	Peak Half Width	L Interp	R Interp
688.24	89.1	0	252	0.721	89.07	86.64	-0.03	0.32
677.25	89.0	0	251	0.721	88.77	86.26	-0.26	-0.23
676.76	88.8	0	252	0.721	88.42	86.03	0.11	-0.05
598.92	88.5	0	251	0.735	74.04	76.64	-0.39	-0.32
271.19	88.3	0	252	0.914	10.99	38.76	0.49	0.03
56.57	88.3	0	252	0.954	4.74	31.77	-0.10	-0.37

Your communications software should be set for 9600 baud, 8-N-1.

Note: The column headings are added for clarification in this appendix and do not appear in the serial output of the VIASENSOR.

The Error Codes are defined in Appendix E. A value of "0" is the normal output when there is no error condition.

The information in the columns “Index”, “Transmission”, “Area”, “HalfWidth”, “L Interp”, and “R Interp” are characteristics of the laser absorption peak. This information may assist in troubleshooting the VIASENSOR with VIASPACE technical support personnel.

APPENDIX E: Error Codes

Error Code	Description
00	Status Okay
01	Sample power fail
02	Reference power fail
04	Spectrum fail
08	Null fail

These errors may appear on the computer display during the first 15 seconds after the VIASENSOR is powered up. Once the VIASENSOR completes its internal self-test, the errors should clear.

Should any of these errors appear during normal use of the VIASENSOR, power the unit off, wait 5 seconds, and power the unit back on. If this does not clear the error condition, please contact the factory or your authorized service representative.

APPENDIX F: Sample Main Screen Displaying Partial Pressure