GE Measurement & Control

• Moisture Measurement Tutorial
• Instruments
• Application Overview
GE Process Moisture & Gas Instruments Overview

- Paramagnetic Oxygen Transmitters
- Zirconium Oxide Oxygen Analyzers
- Portable Trace Moisture Analyzers
- Thermal Conductivity Gas Sensors (Hydrogen)
- Electrochemical Oxygen Sensors
- Thermal-Paramagnetic O2
- Laser Absorption Moisture Analyzer
- Chilled Mirror Reference Instruments
- Humidity Generators & Calibration

Features & Performance

GE Sensing
Moisture & Gas Overview
Moisture & Humidity Measurement Fundamentals
## Composition of Dry Air

<table>
<thead>
<tr>
<th>Gas</th>
<th>% Volume</th>
<th>Pressure KPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.08</td>
<td>79.09504</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.95</td>
<td>21.22235</td>
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<tr>
<td>Argon</td>
<td>0.93</td>
<td>0.94209</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.031</td>
<td>0.031403</td>
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<tr>
<td>Neon</td>
<td>0.002</td>
<td>0.002026</td>
</tr>
<tr>
<td>Helium</td>
<td>0.0005</td>
<td>0.0005065</td>
</tr>
<tr>
<td>Methane</td>
<td>0.000015</td>
<td>0.000015195</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>0.0001</td>
<td>0.0001013</td>
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<tr>
<td>Hydrogen</td>
<td>0.00005</td>
<td>0.00005065</td>
</tr>
<tr>
<td>Other Noble Gases</td>
<td>0.0002</td>
<td>0.0002026</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.993865</strong></td>
<td><strong>101.2937852</strong></td>
</tr>
</tbody>
</table>

Each component gas exerts a “partial pressure” directly proportional to it’s volume (Dalton’s Law).

When water vapor is added to dry air it also exerts a partial pressure proportional to it’s volume.

At typical summertime ambient conditions the concentration of water in air is about 1-1.5% by volume.
Dalton’s Law

The sum of the partial pressures of all the component gases of a gas mixture is equal to the total pressure.

The concentration of any component gas in a mixture is directly proportional to its partial pressure.

\[ P_1 + P_2 + P_3 + P_4 \ldots = P_T \]

Each component gas obeys the Ideal gas law \( PV = nRT \)
In a closed system at given temperature and pressure, water (liquid or ice) will establish an equilibrium with gaseous water (water vapor) in the “head space”.

At a given temperature, the maximum amount of water that can be held in the gas phase is finite. When a space is holding the maximum amount of water vapor at a given temperature, the water vapor exerts a finite partial pressure called the “saturation vapor pressure”.

Increasing the temperature increases the saturation vapor pressure.

At the boiling point the vapor pressure is equal to the atmospheric pressure (100°C at sea level)
Saturation Water Vapor Pressure

When water vapor is at the saturation point, the space has reached the maximum capacity to hold water in the gas phase.

At the saturation point the water vapor exerts a specific “saturation water vapor pressure”

Any water vapor in excess of the saturation point will be converted to the liquid or solid.

\[ e_s (\text{water}) = K_w \cdot 6.1121 \cdot \exp \left( \frac{17.502t}{240.97 + t} \right) \]

\[ e_s (\text{ice}) = K_i \cdot 6.1115 \cdot \exp \left( \frac{22.452t}{27255 + t} \right) \]

\[ e_s = \text{Saturation Water Vapor Pressure in mBars} \]

\[ P = \text{Pressure in mBar} \]

\[ t = \text{Temperature in °C} \]

Ref: A.L. Buck. *Equations for the Saturation Water Vapor Pressure Over Water & Ice*
Saturation Water Vapor Pressure
Dew/Frost Point Temperature

The dew point or frost point temperature ($T_d$) is defined as the maximum temperature at a given pressure where the gas will be saturated with water vapor.

At the dew point decreasing the temperature, increasing the pressure or the water vapor concentration will cause water vapor to condense as liquid water or ice.

$$T_{dew} = \frac{240.97 \cdot \ln\left(\frac{e}{6.1121}\right)}{17.502 - \ln\left(\frac{e}{6.1121}\right)}$$

$T_{dew} = $ Dew Point Temperature in °C
$T_{frost} = $ Frost Point Temperature in °C
$e = $ Water vapor pressure in mBars
Relative Humidity (%RH)

The ratio of the partial pressure of water vapor to the saturation water vapor pressure at a given temperature multiplied by 100.

\[%RH = \frac{e}{e_s} \cdot 100\%
\]

- \(\%RH\) = Relative Humidity
- \(e\) = Existing partial pressure of water vapor
- \(e_s\) = Saturation water vapor pressure (referenced to the prevailing temperature)

The relative humidity is an indication of how much water vapor is in a space compared to how much the space can hold at the prevailing temperature.
Absolute Humidity (AH)

The ratio of the mass of water vapor to volume of air or gas.

Most commonly expressed as grains (1 grain = 1/7000 of a pound) per cubic foot (gr/Ft\(^3\), grams per cubic meter g/m\(^3\) or pounds per million cubic feet (lbs/MMSCF... used for natural gas).

\[
\frac{g}{m^3} = \frac{216.7e}{T + 273.16}
\]

- \(e\) = Partial pressure of water vapor
- \(T\) = Temperature in °C

Reference to atmospheric pressure
Volume Ratio & Specific Volume

**Volume Ratio:** The ratio of the volume of water vapor to the volume of the carrier gas. Usually expressed as PPMv (Parts per Million by Volume) or %. Also called volume mixing ratio

\[ V_m = \frac{e}{P - e} \]

- \( e \) = Partial pressure of water vapor
- \( P \) = Pressure

**Specific Volume:** The ratio of the volume of water vapor to volume total gas mixture. Usually expressed as PPMv (Parts per Million by Volume) or percent

\[ V_s = \frac{e}{P} \]

\[ \text{PPMv} = V_s \times 10^6 \]
Mass Ratio & Specific Humidity

**Mass Mixing Ratio:** The ratio of the mass of water vapor to the mass of carrier gas. Usually expressed as grains per pound, milligrams per kilogram or PPMw.

\[ W_m = \left( \frac{e}{P - e} \right) \cdot \frac{18}{MW_{cg}} \]

**Specific Mass:** The ratio of the mass of water vapor to mass of the gas mixture. Usually expressed as PPMw (Parts per Million by Volume) or % (Percent)

\[ W_s = \frac{e}{P} \cdot \frac{18}{MW_{cg}} \]

- \( e \) = Partial pressure of water vapor
- \( P \) = Pressure
- 18 = Molecular Weight of Water
- \( MW_{cg} \) = Molecular Weight of the Carrier Gas
If a gas mixture is expanded or compressed, the saturation water vapor pressure will change directly proportional to the ratio of the change in absolute pressure.

\[ \frac{e_2}{e_1} = \frac{P_2}{P_1} \cdot \frac{K_2}{K_1} \]

If a gas containing water vapor is compressed, this is equivalent to concentrating the water vapor in a smaller volume. The partial pressure of water increases directly proportional to the system pressure.

At elevated pressures water vapor deviates from the "ideal gas law".

The "K" enhancement factors are used to compensate for the deviation from the ideal gas law.

\[ K_w = 1.0007 + 3.46 \times 10^{-6} P \]
\[ K_i = 1.0003 + 4.18 \times 10^{-6} P \]
Moisture in Organic Liquids

Henry’s Law:
The amount of a gas that dissolves in a liquid is proportional to the partial pressure of the gas over the liquid.

Direct insertion Aluminum Oxide sensors (trace levels) and polymer %RH sensors (higher levels) may be used to measure the moisture concentration (PPMw) in “non-miscible” liquids.

Water saturation concentration (PPMw) vs. temperature tables are stored in the analyzer.

Water Solubility of Shell Diala Oil

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Instruments

- Chilled Mirror
- Aluminum Oxide
- Polymer
- TDLAS
GE Sensing Humidity Industrial & Process Humidity Sensors

-110°C -80 °C -60 °C -40 °C 0 °C +20°C +40°C +60 °C +85 °C +150 °C

**Trace Moisture**
- Aluminum Oxide Sensors
- Aurora TDLAS
- 4&5 Stage Chilled Mirrors

**Mid-Range**
- Polymer Capacitive Sensors
- 1&2 Stage Chilled Mirrors

**High Humidity**
- Polymer Capacitive Sensor
- Heated Chilled Mirror
Chilled Mirror Principle of Operation

- Infrared Emitters
- Optical Balance
- Photo Detectors
- Gas Flow
- Op Amp
- Heat Pump Control
- Dew Point Temperature Indicator
- Precision PRT
- Power Supply
- Rhodium or Platinum Mirror
- TEC Heat Pump
- IR Emitter Regulation
- Emitter Regulation

-40°C Td
Chilled Mirror Hygrometers

Primary reference standard used for calibrating other humidity sensors
Digital telemetry (Serial & Ethernet) & data logging
Access data via internet
Benchtop Calibration Chamber
Traceable to NIST and other National Standards Labs
Used in R+D & Mission Critical applications
Primary Chilled Mirror Standard

GE Sensing’s Chilled Mirrors are calibrated at National Standards Laboratories such as NIST (USA), NPL (UK), AIST (Japan), CETIAT (France) etc.

They are used as “transfer standards” for the calibration of many types of humidity sensors and instruments.

This technology is noted for it’s precision, long-term stability and repeatability
Automated Chilled Mirror Calibration System

Most of GE Sensing’s chilled mirrors are calibrated in a completely automated process. An automated dew point generator and data acquisition system documents the performance of the units and provides NIST traceability.

Each unit under test (UUT) is referenced to a master chilled mirror which is directly traceable to NIST.

Many of the instruments we service are 20+ years old.
GE’s Boston Center is Accredited to ISO/IEC-17025 By NVLAP

![NVLAP logo]

**National Voluntary Laboratory Accreditation Program**

**Parameter(s) of Accreditation**
Thermodynamic

**Scope of Accreditation to ISO/IEC 17025:2005**
Scope Revised: 2012-08-10

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<th>Measured Parameter or Device Calibrated</th>
<th>Range</th>
<th>Uncertainty (k=2) Note 3</th>
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<td>Humidity Generation</td>
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<tr>
<td>Relative Humidity</td>
<td>24 % to 86 % RH</td>
<td>1.1 % RH</td>
<td>Generated in RH chamber at 25°C</td>
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<tr>
<td>Dew/Frost Point Temperature</td>
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<td>0.15 °C</td>
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<td>Gage Mode</td>
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<td>0.0020 % (not less than 0.07 Pa)</td>
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<tr>
<td></td>
<td>689 kPa to 7 MPa</td>
<td>0.0031 %</td>
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<tr>
<td></td>
<td>7 MPa to 21 MPa</td>
<td>0.0033%</td>
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</tr>
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<td></td>
<td>1.38 kPa to 689 kPa</td>
<td>0.0020 % (not less than 1.35 Pa)</td>
<td>Absolute Mode</td>
</tr>
<tr>
<td></td>
<td>689 kPa to 7 MPa</td>
<td>0.0031%</td>
<td></td>
</tr>
<tr>
<td>Pneumatic Pressure by Comparison to Precision Transducer</td>
<td>-100 kPa to 6 kPa</td>
<td>0.0075 % (not less than 3.45 Pa)</td>
<td>Gauge Mode</td>
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<tr>
<td></td>
<td>0 kPa to 2 MPa</td>
<td>0.0075 % (not less than 3.45 Pa)</td>
<td>Gage or Absolute Mode</td>
</tr>
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</table>

Certification was valid from 2012-04-31 through 2013-03-31.

For the National Institute of Standards and Technology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Uncertainty (95% Confidence)</th>
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</thead>
<tbody>
<tr>
<td>Relative Humidity</td>
<td>24-86% RH</td>
<td>1.1% RH</td>
</tr>
<tr>
<td>Dew/Frost Point</td>
<td>-80 to +20°C Td</td>
<td>0.15°C Td</td>
</tr>
</tbody>
</table>
Aluminum Oxide – Trace Humidity Sensors

Range: -110°C frost point to +20°C Dew Point (parts per billion to parts per thousand)

The oxide layer is porous and under dry conditions the pores are filled with air or gas with a low dielectric (air and N2 are ≈ 1)

Water has a dielectric constant of approximately ≈ 80

When exposed to water, microcondensation occurs in the pores increasing the capacitance between the substrate and upper electrode.

The sensor’s impedance is calibrated against a dew point reference standard

Aluminum Oxide sensors are also be used to measure trace moisture in organic (non-polar) and non-miscible liquids.
Panametrics $\text{Al}_2\text{O}_3$ Sensor

Water vapor rapidly transports through the gold layer and equilibrates to the pore walls of the aluminum oxide layer.

The number of water molecules adsorbed onto the pore walls determines the conductivity of the pore wall.

The sensor is calibrated by measuring the “impedance” (MH or FH Values) against a dew/frost point standard at multiple points.

Each sensor is calibrated a minimum of 2 times.
"MH" is a function of the sensor's "impedance" at a specific excitation voltage & frequency

The calibration process is automated and traceable to NIST or other national standards.
The response of a aluminum oxide trace moisture probe. The probe “wets up” in a very short time but takes considerable time to “dry out”.
By measuring the rate of change (slope) the instrument is effectively able to “predict” moisture content faster than by conventional means.

In the example above the a 90% step change from ambient humidity to <1 ppmv was improved from 50 minutes to <1.5 minutes.

CER is useful when you have a large $\Delta$Td
GE Sensing Trace Moisture Instruments
Dry nitrogen is mixed in precise proportions with nitrogen saturated with water vapor to produce test gas at stable dew/frost points. Mass flow controllers are used to control precise volumetric mixing ratios.

A chilled mirror functions as the reference standard to -80°C Td (500 ppbv)

The system is fully automated and utilizes Labview to control the system, collect data and produce calibration reports.

The system is used at GE’s global moisture calibration centers
Polymer Capacitive Humidity Sensors for Industrial Instruments

**MMR-31 & MDR-3**
Proprietary capacitive polymer %RH sensor. TO type can houses %RH & Temperature Sensor (RTD) sensors. CMOS signal conditioning circuit provides voltage output. Equipped with sintered metal filter.

**MMR-101**
High Temperature proprietary capacitive polymer %RH Sensor. Passive element has separate signal conditioning circuit & temperature sensor.
A Two-Pressure generator is used to produce the target relative humidity.

The chamber is monitored with a chilled mirror hygrometer (standard)

For lower temperature instruments a two point calibration is performed and those instruments use a temperature compensation formula

For high temperature applications the transmitters are calibrated at five humidity values at three exclusive temperatures and the data matrix stored in the instruments memory as a look up table.
Industrial Humidity Transmitters

- Commercial Refrigeration
- Food Processing
- Clean Rooms
- Process Drying
- Paper & Pulp
- Nuclear Plants
- Blast Furnace
- Coal Gasification

- Thin-film polymer capacitive humidity sensor and RTD. Microprocessor based signal conditioner. Stores calibration data for sensor.

- Transmitters and Analyzers with remote probes – Programmable 4-20mA Signals – Local Display

- May be programmed for: Relative Humidity, Dew Point, Mass/Vol, Vol/Vol, Mass/Mass

- Ability to measure up to 150°C

- Stainless steel insertion probes

- Explosion Proof rating
Aurora TDLAS Hygrometer

- Designed for Moisture in Natural Gas
- Tunable Diode Laser Absorption Spectroscopy
- Fast Response  2 second once absorption cell is purged
- NEC/CSA Class 1, Div 1 XP (ATEX Equivalent)
- Magnetic Induction Keypad – may be field programmed w/o “Hot Permit”
- Turnkey sampling system for natural gas
- (3) 4-20mA Signals, (2) RS-485/232 with Modbus protocol
- Supplied with software for remote data acquisition, trend graphing, alarms and spectral scans
GE Aurora TDLAS Moisture Analyzer Schematic

Sample Inlet
Pressure Sensor
Temperature Sensor
Sample Outlet
Optical Window
Photodiode
Driving Circuit
Microprocessor
I/O Interfaces
Key Pad
Display

Collimator
Mirror
Laser Diode
Monochromatic Light
Absorption Cell
Thermoelectric Heater/Cooler
Photodiode
2F Absorption at Various Concentrations of Water
Aurora “dries out” faster than other moisture measurement technologies including impedance, capacitance, electrolytic, vibrating quartz and chilled mirror.

The Optical response time is <2 seconds once the measurement cell is purged.

The dry out response inclusive of the sampling system (sample tubing, coalescing filter, valves & fittings) was less than one minute for a change from 5375 ppm \(_v\) to 12 ppm \(_v\).

System Response Time of Aurora - Dry Down
Water was injected into an 8 ppm$_v$ sample stream. The unit spiked to >3,000 ppm$_v$ and recovered back to within 2 ppmv of the original reading within 3 minutes and to original reading within 7 minutes.
Pressure & Temperature Compensation

At constant water concentration and increase in pressure and temperature reduces the 2F absorption peak.

This is due to more interactions between water as well as other molecules in the carrier gas (collision broadening).

By varying the pressure and temperature calibration data can be stored in the analyzer’s memory and used for compensation.

(US Patent 7,943,915 Method of Calibrating a Wavelength – Modulation Spectroscopy Apparatus)
Aurora-Trace Features

- HDLAS – High Definition Laser Absorption Spectroscopy
- Measurement Range: 0-400 ppm\textsubscript{v} calibrated & 400-1000 ppm\textsubscript{v} trending.
- Accuracy: ±2\% or ±50 ppb\textsubscript{v} includes linearity, hysteresis and repeatability.
- Utilizes many of the same design features of the Aurora-H20
- cFMus Class 1 Div1 certification for the USA & Canada, ATEX & IEC Ex for Europe and other global localities
- Three Programmable 4-20mA signals.
- (2) RS-232/485 digital interface ports with Modbus RTU
- Optional Ethernet TCP/IP or Foundation Fieldbus
- AuroraView – Utility software for remote set up, trend graphing & diagnostics
- Optional calibration system – may be programmed to run on demand
Multi-Pass Absorption Cell

- In order to measure trace levels of moisture (<5 ppmv) a long path length is required. In the Aurora Trace the path-length is 30 meters vs. 1 meter for Aurora H2O resulting in 30X the sensitivity.

- This is achieved in the Aurora Trace by using a “multi pass optical cell”. The cell utilizes specially curved mirrors to bounce the laser light back & forth.
By applying a vacuum, better resolution is achieved than at atmospheric pressure. Absorption peaks are seen that were formerly “masked” by methane & other hydrocarbons.
Spectrum of H2O in Methane at Various Concentrations
The differential method relies on the production of a “zero gas”. The zero gas signal is subtracted from the process gas signal. The small peak in the zero gas is due to co-absorbing background gases. This method relies on the production of zero gas from a finite purifier (an consumable component).
Response Time - Dry Down

Step change from 2500 ppmv to 0.1 ppmv
Optica = Chilled Mirror Reference   AT-01, AT-02 & AT-03 are three test units
$T_{90} < 2$ min
Total Change $\approx 60$ min
These are system response times inclusive of purging the sampling system
Aurora Trace – Step Change Response

![Graph showing step change response over time.](image-url)
A chilled mirror is used as the reference standard for calibrating laser based hygrometers used for continuous moisture measurement in natural gas.

Up to 6 units are calibrated simultaneously. The units are first calibrated using nitrogen as the carrier gas then methane.

The system is automated using Labview to control a two-pressure/two temperature frost point generator and to collect the raw data from each unit.

The data is also archived in an enterprise server.
Applications
• Moisture even in trace amounts is a contaminant in organic chemical feed stocks

• Oil Refineries: Trace moisture measurement in H₂ recycle, cat cracking (CCR), ethylene production, alkylation, isomerization, etc

• Ethylene & Polyethylene production

• Engineered sensors and sampling systems provide turnkey online monitoring
Sampling Systems for Liquids

Aluminum Oxide Sensors may be used for hydrocarbon liquids or gases

Other analyzers such as electrolytic and quartz are for gas only... liquids have to be vaporized

Hazardous Area

Safe Zone

• GE Sensing offers a Complete Solution for moisture monitoring in petrochemical liquid feedstocks
• Sensor + Sampling System + Multi-Channel Analyzer (up to 6 Moisture Probes) + optional pressure, temperature & oxygen
• For determine ppm\textsubscript{w} (parts per million by weight) in liquid feedstock, the solubility data for each liquid is programmed into the analyzer
• Hot liquids are cooled to the operating range of the sensor by a “liquid to liquid” heat exchanger (stainless steel tube in copper tube)
• For gases typically dew point or ppm\textsubscript{v} or is the measurement of choice

Feedstock 1

Feedstock 2

Feedstock 3
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</tr>
<tr>
<td>Sulfur Dioxide</td>
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</tr>
<tr>
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</tr>
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<tr>
<td><strong>Total</strong></td>
<td><strong>99.993865</strong></td>
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</tbody>
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Air separation plants use compression and cooling to liquefy air and “boil off” the various components to separate them. The requirement is often for very pure gases.

Moisture is a contaminant in pure gases.
Semiconductor and Electronic

- PPB levels for Process Carrier Gases
- Clean Rooms
- Product Testing
- Environmental Chambers
- HALT/HASS Testing
- Fiber Optic Splicing
- CRT/Plasma Screen Coating
Natural Gas

- Maximum water for Natural Gas in USA content for USA is 7lbs/MMSCF (approximately -38°C frost point)
- Custody Transfer and Contractual Specifications
- Water in NG = corrosion, costs more to transport in pipelines
- Eliminate ice & methane-hydrates
- Moisture in LNG (Liquefied Natural Gas) processing
- Compressor stations
- Calibration Systems
Power Generation

- Gas Turbines – Power Augmentation, Anti-Icing, Emissions Controls
- Fuel Quality for Gas Turbines
- Hydrogen Cooled Generators
- Weather Telemetry
- Oil Filled Transformers
- SF$_6$ Switchgear
- Nuclear Containment Testing
- Calibration Labs
Pharmaceutical Process Control & Testing

- Tablet Coating
- ETO Sterilization,
- Gel Caps
- Mixing
- Compounding,
- Fluid Bed Processors
- Freeze Drying
- Inerting
- Storage
- Product Testing
- Facility Monitoring
- Validation Chambers
- Medical Compressed Air
Compressed Air

- Instrument Air
- Breathing Air
- Painting & Coating
- Robotics
- Pneumatic Tools
- Packaging
- Airveying
- Inerting
- Testing & Verification of Drying Systems
Metals Processing & Heat Treating

- Blast Furnaces
- Atmosphere Controlled Furnaces
- Annealing
- Sintering
- Carburization
- Welding (Shield Gas)
- Nitriding & Carbonitriding
- Galvanization
- Brazing
Plastics Manufacturing

- Blow Molding
- Injection Molding
- Composites
- Sufficiently drying many plastic resins prevents bubbles, splay and increased scrap rates
Automotive & Engine Power & Emissions Testing

- Inlet Combustion Mass Ratio
- Dynamometers
- Wind Tunnels
- Automotive
- Aerospace
- Marine
- Diesel
- Fuel Cells
- Climatic Chambers
- Gas Turbine Wet Compression
- Deicing & Ice Prevention
Aerospace

- Engine Testing
- Avionics
- Antennas & Waveguides
- Deicing & Ice Prevention
- Rocket Fuel Purge
- Aerospace HVAC
Refrigeration, Heat Exchanger & HVAC Component Testing

The performance of refrigeration and air-conditioning components used for residential, commercial, automotive and industrial systems is validated and tested by GE Sensing’s chilled mirror analyzers.
Environmental Test Chambers

- Electronic components
- Building Materials
- Clothing
- HASS & HALT
- Incubators
- Plant Growth
- Pharmaceutical Validation
- Refrigeration Systems
- Sample Preconditioning for fire & smoke testing
Sampling Systems

Sampling systems are an integral part of the integrity of process and industrial humidity and trace moisture measurements.

Gas samples are temperature conditioned and filtered (without adding or removing water or the desired gas). The flow rate and pressure is also regulated by the sampling system.
GE Sensing is the global leader in automated humidity & moisture instrument calibration

Global service centers – NIST and other NMI traceable calibrations

Web based archive enables customers to access calibration data and plan instrument cal cycles

Onsite training and start up assistance as well as classroom training
Product Training

GE Sensing offers onsite training as well as training in a classroom environment at our global training centers.

The classes cover theory, product operation as well as practical “hands on” training.

GE Sensing Certificate of Training

James T. Kirk
The United Federation of Planets

Successfully Completed GE Measurement & Control Solutions Training Courses
Humidity Measurement Fundamentals
Optica Chilled Mirror Hygrometer
Thirty-Six Hours – Completed January 1, 2011

Instructor
Ken John, Product Manager
Humidity Test of Calibration Instruments