Thank You for Attending Today’s Webinar

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GE Measurement & Control

Aluminum Oxide Sensors for Trace Moisture Measurement
Aluminum Oxide Trace Moisture Sensor

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<th>Dew/Frost Pt</th>
<th>-110°C</th>
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<th>-60°C</th>
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At 1 Bar
The oxide layer is porous and under dry conditions the pores are filled with gas or organic liquids.

Water has a dielectric constant of $\approx 80$

Air & non-polar organic liquids have low dielectric constants. Air $\approx 1$

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

The porous structure of aluminum oxide sensors form parallel capacitors between the aluminum substrate and gold electrode. Capacitors in parallel are added. You can think of the sensor as a “water molecule counter”

$$C_t = C_1 + C_2 + C_3 + \ldots$$
Panametrics Al$_2$O$_3$ Sensor – To 2012

- Temperature Sensor
- Gold Foil Contact on stress relief armature
- Pressure Sensor
- Aluminum Oxide
- ¾ Straight Thread
- Viton “O” Ring
GE Sensor Present

- Used on all Probes & Transmitters (Panametrics & GEI)
- Wafer technology – produces very repeatable sensors
- Improved long-term stability
- Improved bonding and mechanical strength
Aluminum Oxide Probe Styles

**M-Series:** Analog Moisture Sensors
Moisture with thermistor option

**TF:** Analog Three function; moisture, temperature and pressure

**MIS:** Moisture Image Series: Digital
"Smart Probe" TF probe with electronics module (smart probes – stores calibration data)

**Accuracy:**

±2°C Td –65°C to +20°C
±3°C Td –80°C to –66°C

**Temperature:** ±0.5°C

**Pressure:** ±0.5% of scale

**Sensor Shields**

“R” Shield for gases – sintered steel

“W” Shield for liquids
System Wet Up Response Compared to Chilled Mirror

Step Change: -65°C to 0°C Td

- AlOx: $T_{90} \approx 20$ Seconds
- Chilled Mirror $T_{90} \approx 120$ Seconds
- Flow Rate: 1 SCFH (0.5 LPM)
- System inclusive of 6 Ft sample line + valves & fittings
System Dry Down Response Compared to Chilled Mirror

Step Change: -0°C to -65°C Td
AlOX: $T_{90} \approx 9:20$ min
Chilled Mirror $T_{90} \approx 4:30$ min
Flow Rate: 1 SCFH (0.5 LPM)
System inclusive of 6 Ft sample line + valves & fittings

**Chilled Mirror - Optica/1311-DR w/Water Cooling at 10°C**
Response Time of PM880-M2LR

Step Change from +7 to -75°C Td
Flow Rate: 1 SCFH (0.5 LPM)
T90 = 50 minutes inclusive of 6 Ft tubing
Response Time of PM880-M2LR with CER

CER = Computer Enhanced Response
By measuring the rate of change (slope) the instrument is effectively able to “predict” moisture content faster than by conventional means.

CER is useful when you have a large ΔTd

Step Change from +12 to -75°C Td
T90 < 1.5 Minutes
Installing Probes at Pressure - Improves Response

1 ppm\textsubscript{v}

-76°C Td

-49°C Td

0 PSIG

600 PSIG
Aluminum Oxide Sensors & Instruments

Performance/Features vs. Price

- MMY30/31
- dew.IQ
- Hygropor
- MMY245
- PM880
- Moisture.IQ
DewPro MMY Trace Moisture Transmitters

**Common Features**

- Loop Powered 4-20mA Signal (8-32 VDC, 24 VDC Nominal)
- Dew Point Range: -90 to +10°C Td (-130 to +50°F)
- Display & Transmission for: Dew Point (°C or °F) or ppm (based on pressure constant)
- Accuracy: ±2°C Td

Hazardous location use:

- FM IS Cl. I, II, III; Div. 1, Groups A-G
- FM XP Cl. I; Div.1, Groups A-D
- FM Cl. I, Div. 2, Groups A-D; Cl. II, III; Div. 2, Groups E-G
- IP-67 (Type 4X) ingress rating

**MMY31**: Insertion probe (Glove Boxes & thru Ball Valve). 1/2” OD 316 SS tube.

**MMY30**: Integrated 316 stainless steel flow cell with inlet sintered steel filter.

For compressed air and orifice in installed to maintain 1 SCFH (0.5 LPM) at 100 PSIG (8 Bar).
A Cutaway of the MMY30

The MMY30 has a built in sintered steel filter, flow cell and orifice for flow control. It simplifies the sample system design.

The orifice is sized to provide a flow rate of 1.5 SCFH at inlet pressure of 100 PSIG (8 Bar) nominal.
HygroPro

Loop Powered (12-30 VDC) with 4-20 mA signal
User programmable units and scaling
Multiple moisture parameters including dew point temperature, ppm$_v$, ppm$_w$, absolute humidity (m/v) & lbs/MMSCF (natural gas).
Backlit LCD display – up to 3 parameters
Three-Function probe: dew point, temperature and pressure
Programmable “solubility data” for moisture in organic liquids
Operation to 5000 PSIG
IP-67, 4X Type Enclosure
Intrinsically safe – Zener barrier in safe zone
Range: -110 to +20°C Td

The HygroPro is a “mini-moisture analyzer. It has many of the features only found in much larger analyzers.
HygroPro – Field Replaceable Digital Probe

- The HygroPro is designed with a field replaceable probe (RTE)
- Calibration data is stored in the probe (smart probe)
- The probe is “plug & play” and only takes a few minutes to replace
- Eliminates the possibility of entering the wrong calibration data or mixing up probes
dew.IQ

- 1/8 DIN Panel Mounted Analyzer
- Available in bench top and wall mounted configurations
- 100-240 VAC or 24 VDC Power
- Connects to “M” series probes or IQ probe
- IQ.probe is “plug & play” – no need to enter calibration data
- Displays Dew Point, ppm, and mg/m$^3$
- Programmable pressure constant
- Programmable analog output (switch selectable for 0-20mA, 4-20mA & 0-2VDC.
- (2) Alarm Relays (Dry Contact SPDT)
- Fault Relay
- Equipped with 2 GB data logger – enables months of data to be recorded on micro SD card
### dew.IQ Data Logger

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The dew.IQ is equipped with a SD card slot which enables months of data to be saved. The SD micro card pops out and may be directly read on a PC (via a SD card slot) or USB adapter.
MMY245 Portable Trace Moisture Analyzer

- Portable battery operated (4 Standard “D” cells)
- Range: -100 to +20°C Td with ±2°C accuracy
- Al₂O₃ sensor is stored around desiccant when not in use – this keeps the sensor dry (-60°C typ). This results in fast response
- Programmable display: Td, %RH, absolute humidity, volumetric mixing ratio and mass mixing ratio
- Analog output: 0-5 VDC
- IP-66 NEMA-4X case
PM880 Portable Moisture Analyzer

- Use with M, TF or MISP-2 probes
- Graphical Display
- Display up to 4 parameters
- Trend graph display
- Meets IP67 rating
- Internal Data Logger
- IrDATM wireless transfer
- Stores 60 data files (data logger, configuration or probe calibration)
- Stores solubility data for organic liquids
- Rechargeable battery
- Intrinsically safe
- Computerized Fast Response (M or TF probes)

- A great instrument to “walk up” and check trace moisture process – with compact sampling system
- Probes can also be permanently installed in the process
Moisture.IQ Analyzer

- Color Touch Screen Display
- Modular Design - Two Bays
- Each Bay accepts either a 1 channel or 3 Channel Module (1, 2, 3, 4 or 6 channels)
- Each channel supports a moisture probe, Oxygen sensor & (2) 4-20mA inputs
- Up to (6) moisture probes, (6) Delta-F O2 cells & (12) 4-20mA process inputs
- Supports M series & MISP2 Series probes
- Process inputs programmed for display in engineering units & retransmission (4-20mA)
- Numerical or trend graph display
- Programmable 4-20mA outputs & Alarm Relays
- Built in IS Barriers
- USB, RS-232 & Ethernet with Modbus
- Data logging
- VNC Viewer enables emulation of touch screen via ethernet/internet
Moisture.IQ Wall Mounted Versions

NEMA-4X/IP66 Weather Proof  Explosion Proof
The Moisture.IQ is equipped with a USB port. Saved data is easily transferred to a USB memory stick (flash drive) or across a network (LAN or Internet) via Ethernet. The data can be exported to excel for graphing or further analysis.
Panametrics Aluminum Oxide Sensor Calibration System

- Test Chamber
- 64 Ports per Manifold
- Six Manifolds per system
- 5-Stage Chilled Mirror Hygrometer
- Saturator Bath
- T & P Sensors
- Enclosure for Mass Flow Control Valves
- PC based Labview Control & Data Acquisition System
- System equipped with UPS resume on loss of power
Calibration of GE Panametrics Al₂O₃ Sensors

- Dry Nitrogen is saturated with distilled water at a precisely controlled temperature. The saturated N₂ is warmed and diluted with dry N₂ to produce the desired moisture concentration.
- Precise mixing ratios are controlled with mass flow controllers arranged in a cascade system for multiple dilutions.
- Stainless steel manifolds house the sensors under test.
- Impedance data (MH or FH) is recorded for each probe at 10 points.
- The reference dew/frost points is measured with a chilled mirror (redundant standard).
- The calibration data is either programmed into the transmitter or provided on a calibration data sheet for entry into the analyzer.
- The calibration process is automated.
**Analog Probes**
- M
- TF

The calibration data must be entered into the analyzer.

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**Digital Probes**
- MISP-2
- HYGRO-RTE
- DEW.IQ

The calibration data automatically uploads to analyzer.
"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.

$Z^{-1} = Ae^{bT} + C$

- $Z$: Sensor impedance
- $T$: Dew/Frost point temperature
- $A$, $b$, $C$: Constants determined from the fit
- $e$: Exponential function
By plotting the calibration data on successive calibrations we can see how much a probe might have drifted over that period of time.

The average drift is estimated to be <2°C/year.

This example shows an almost 5 year interval.
When air is compressed the moisture and other contaminants are concentrated. The partial pressure of the water vapor will increase and therefore the dew point increases.

The volume ratio ( % by volume or ppm, ) remains the same

The compressed air must be cleaned and the moisture removed
Plant Air Drying System

- Compressed air is the 5th utility. 7% of the total energy consumption in the USA is used to produce compressed air
- Costs: $0.15-0.30/1000 Ft³ (prior to drying)
- Clean dry compressed air is the most expensive utilities

Plant Air: 0 PSIG, 100°F & 50% RH = 78°F T_d

Compressed Air:
100 PSIG, 100-150°F T_d at 180°F & T_a

100 PSIG, 35-50°F T_d at 100°F T_a

T_d = Dew Point
T_a = Temperature

100 PSIG, -40 to -140°F T_d at 78°F T_a

Compressor
Refrigerated Air Dryer
Filter
Desiccant Dryer (PSA) or Heat Regenerated
Receiver
Receiver
ISO-8573 Classifications for Compressed Air

ISO 8573 is the group of international standards relating to compressed air – Part 1 specifies the quality of compressed air & Part 2 defines the testing methodologies.

A maximum level can be specified for each class (Solid Particulate, Water Vapor & Oil).

### ISO 8573: Class 1.2.1
- Not greater than 100 Solid Particles 0.1-0.5 uM
- Not greater than 1 Solid Particles 0.5-1 uM
- No Solid Particles >1 uM
- Dew Point < -40°C
- Oil (including oil mist) < 0.01 mg/m³
Sampling System for Compressed Air

For compressed air systems where oil is present, a coalescing filter should be used upstream of the sensor.
air.IQ simplifies the selection and installation of your moisture analyzer. Install the moisture probe, wire your power and outputs to the terminal strip, and connect your gas to the inlet fitting.

- Turnkey Moisture Analyzer and probe with sample conditioning system assembled in high impact ABS (NEMA-4X) enclosure with dew.IQ meter and IQ.probe.
- Simplified wiring – Terminal for Power, Alarms, & analog output
- Sample cell with built in filter
- Inlet needle valve, rotameter with valve, and pressure gauge to control and indicate flow and back pressure
- Built in data logger
- Special pricing
Regenerative desiccant dryers remove water from compressed air by adsorption onto microscopically porous desiccant. Desiccant materials include, salts, silica gel, activated alumina, or molecular sieve.

These dryers cycle between an “online” column and an “offline” (regeneration) column.

The dryer uses a fraction of expanded dried air to purge the adsorbed water from the desiccant in the “offline” column.

To produce -40°C frost point at 100 PSIG (7.8 Bar) a pressure swing dryer consumes ~15% of the compressed air for regeneration. Lower frost points require more purge air.

Heaters can be employed to reduce the of purge gas usage. A heated dryer uses about ~5% of the compressed air for regeneration to produce -40 °C frost point at 100 PSIG (7.8 Bar).

Typical frost points obtained with these dryers are –40°C to –75°C.

Desiccant column switching can be programmed with a “timer” control or switching could be based on dew point measurement. Dew point switching can often save energy costs.
Desiccant Wheel Process Air Dryers

Desiccant wheel dryers produce large volumes of air at low pressure for environmental control and materials processing.

Desiccant wheels are used to lower the refrigeration or air conditioning loads and used as heat-recovery units in commercial and industrial buildings.

A wheel of desiccant (silica gel) rotates slowly as process air flows through it.

A section of the wheel is back-purged with heated air to regenerate the desiccant.

Desiccant wheels produce air between -40 to -70°C Td.

As desiccants adsorb water heat energy is released. The heat energy can be used to prewarm incoming air to a building.
Membrane Dryers

Water vapor permeates through micro membrane gas separation filters when there is a water vapor pressure gradient. The separated water vapor is then swept away by decompressed “purge” air.

These dryers consume a fraction (~20%) of the dried air and produce -40 to -60°C frost point. There are no moving parts and they are generally used as “point of use dryers”
Ozone Generators

Ozone (O³) is a powerful oxidizer and disinfectant. It is also used as a bleaching agent.

Ozone is produced by exposing dry oxygen to a high voltage corona. It is found that if the dew point is reduced from –40 to -60°C the yield increases by 15%.

Ozone will also oxidize N₂ to NO₂ (nitrous oxide) which will combine with water to produce HNO₃ (Nitric Acid); a very corrosive acid which leads to failure of the corona discharge electrodes.
Desiccant Dryers for Plastics Processing

Desiccant dryers are used for drying plastic resins prior to processing (injection and blow molding).

The dryers also serve to pre-heat the resins prior to molding.

These dryers are heat-regenerative and produce air at low pressure and high volume.

Column switching (heat regenerative) and rotary desiccant wheel technologies are used.

In addition plastics may be dried by refrigerated dryers, batch ovens, vacuum and expansion and heating of compressed air.
Plastics Resin Drying

In this example polycarbonate is dried for injection molding CD Roms.

Polycarbonate resin is dried & preheated prior to being molded under pressure.

If sufficient water is not removed from the resin bubbles & surface imperfections form in the finished CD ROM.

The dew point sensor optimizes the drying process – ensuring the material is dry but not over drying which waste energy.
Case Study: Portable Hygrometer for Submarine Pneumatic Control Systems

Location: Rhode Island – USA

Application: Portable dew point meter for measurement of the moisture content of pneumatic systems used on board submarines. (Example: The periscope is pneumatically operated). The Dew point must be less than -40°C Td

Need for reliable and fast response meter. Subs go out to sea for many months at a time

Also wanted ability to verify & calibrate the units at Navy metrology labs

Product Solution: MMY-245

Amount: 13 units + Optica/1311-XR/MG-101 = $110K

Value Propositions:

• Fast response due to pre pre-drying chamber
• MMY-245 utilizes standard “D” cell batteries
• Unit demonstrated to decision makers
• GE could provide a calibration system + onsite training
Case Study: Bleaching Kaolin with Ozone

Location: Georgia, USA

Application: Kaolin is a mineral which is bleached by exposure to ozone. Ozone (O₃) is produced from oxygen enriched air by passing it through a “corona discharge”. For efficient O₃ production the feed gas must be below -60°C Td. Customer was looking for transmitters to connect to data acquisition system.

Product: MMY-30

Value Propositions:
- Compact transmitter with built in sampling cell & display
- Loop powered 4-20mA for direct connection to DCS (Digital Control System)
- Ordered units with exit orifice however pressure was too low – sales/service call corrected this by replacing the orifice with a needle valve and rotameter.

Kaolin is one of several types of clay, and is commonly referred to as China Clay or Paper Clay. It is a hydrated silica of alumina with a composition of approximately 46% SiO₂; 40% Al₂O₃, and 14% H₂O.

1.5 million tons of kaolin produced annually in the United States, approximately 56% is used in the paper industry. In paper-making, Kaolin is utilized as a pulp filler as well as for coating. Some newspapers have a kaolin content of about 2%, while magazines with a relatively high gloss contain on the average of 30%.

Other uses: Rubber products consume about 16% of the kaolin, with a major portion of the remainder going into such products as linoleum, paints, inks, leather, refractories, pottery, insecticide, fertilizers, and plastics.
Air separation plants use compression and cooling to liquefy air and boil off the various components to separate them. Moisture is a contaminant in pure gases and is monitored.
Trace Moisture in Natural Gas

- Water increases transportation cost
- In colder climates water freezes causing valves and pipes to be damaged or even blocked.
- Under pressure water combines with methane to form hydrates (an ice-like solid)
- Freezing can occur when high pressure gas is expanded (Joule-Thompson cooling – approximately 7 °F/100 PSID
- Water causes corrosion. It also combines with $H_2S$ & $CO_2$ to form corrosive acids
- The maximum moisture content for US interstate commerce is 7 lbs/MMCF; Equal to approximately: -38.7°C/-36.4°F Frost Point at atmospheric pressure, 152 PPMv or 112mg/m³
- Water lowers calorific content (heating value)
- Suppliers can be “locked in” if their moisture content is too high – cost the supplier lots of revenue!

GE Sensing
Trace Moisture Instruments
Natural Gas TEG Drying System

Steam

Glycol Boiler

Hot Dry TEG

Wet Well-Head Gas

Glycol Heat Exchanger

Wet TEG

Absorber Tower

Dry Gas

Moisture Analyzer

Water

Glycol Boiler

Glycol Heat Exchanger

Absorber Tower
Liquid Natural Gas (LNG) and NGL (Natural Gas Liquids)

Moisture Analyzer
Frost Point ≤ -90°C Td at 1 Bar

Pipeline Natural Gas

Pressure Swing Adsorption Dryer

Raw Sweet Natural Gas

Cryogenic Unit

Propane

Ethane

LNG (Liquid Natural Gas)

Methane

Raw Sweet Natural Gas

Cryogenic Unit

Propane

Ethane

LNG (Liquid Natural Gas)

Methane
Liquid Natural Gas (LNG) Processing

Ice Formation in the Cryogenic Unit

At frost points below -80°C ice crystals formed in the cryro are small and pass through the “screens”.

As the frost point increases the formation of ice increases exponentially. Ice formation causes a loss of cooling efficiency (the ice is an insulator). Eventually the ice can block the flow.
Hydrogen Cooled Electric Power Generators

Due to high heat capacity Hydrogen is utilized to remove heat from the high power generators in this application. Hydrogen also has a very low viscosity (or windage), thus allowing higher capacity operation of the generators while maintaining efficient cooling.

The hydrogen must be kept free from moisture, for several reasons.

- Humidity increases the viscosity of the hydrogen (known as windage... windage is the resistance against the turbine blades)
- Humidity decreases the ability to carry away excess heat.
- Moisture deteriorates the seals on the rotating shaft causing leakage of the explosive hydrogen.
- Leaking seals necessitate costly generator rebuilds and operational downtime.
- Humidity increases the danger of arcing the high voltage (up to 12,000 V or more) and high current generators (arching can lead to explosions)
SF₆ Filled Switchgear

Sulfur Hexafluoride a non-polar insulating gas used in switchgear. GE Sensing offers both continuous monitors and portable analyzers to insure that SF₆ is dry. The portable analyzers predry the sensor resulting in minimal waste of expensive SF₆. Typical dew points SF₆ are -60°C/ -76°F or dryer.

SF₆ has unique properties which render it a nearly ideal media for arc interruption and dielectric strength. The dielectric strength is greater than any other known media at the same density. The reason lies in the relatively large physical size and mass of the molecule. The size and mass help reduce the propagation of free electrons.

During arcing the SF₆ breaks down and is reformed. If moisture is present the Fluorine combines with water to make corrosive HF acids.

The PM-880 can be used with permanently installed sensors or the MMY-245 can be used to spot check and minimize wasted SF₆.
GE Sensing – Moisture & Gas Measurement Instruments & Sampling Systems for Metal Heat Treating
Oil Bath Sampling System for Heat Treating Furnaces

In this system oil is used to remove entrained particulate, oils and soot from the furnace.

A vacuum pump pulls a sample from the furnace.

A cooling coil must be used upstream to reduce the sample temperature to the operating range of the sensor.
Custom Mutliparameter Instrument Systems for Furnaces

GE M&C provides instrument cabinets for monitoring furnace atmospheres.

Measurements include:
- Moisture (Dew Point, ppmv...)
- Hydrogen (Purity or % composition)
- Oxygen (Trace levels)
- Combustibles

Saves the customer’s time and money by having one source

- Prewired
- Control Valves for calibration gases
- Vacuum Pump or Eductor
- Pressure Regulation
- Filtration (must not alter moisture, H2 or O2 concentration)
- Control Drawing, Documentation
- Factory Acceptance Testing
- Combustibles Alarms
- Start up and commissioning service
Moisture, Oxygen and Hydrogen Analysis in Steel Production

Location: Burns Harbor, Indiana

Customer: ArcelorMittal Steel

Major Products: Full line of high quality flat rolled steels, including (AHSS) Advanced High Strength Steels and (UHSS) Ultra High Strength Steels

Application

- System upgrades for process control at the hot dip galvanizing line and continuous annealing line.
- In both applications, furnace atmosphere is critical to the quality of the steel strip product.
- Atmosphere is 96% nitrogen, 4% hydrogen, with trace amounts of oxygen.
- Trace (PPM) and percent oxygen measurements in H2/N2 gases
- Trace moisture measurement in H2/N2 gases
- Percent hydrogen in nitrogen measurement
Location: Granite City, IL


Experiencing problems with water side heat exchangers leaking

3 zones per furnace

Sampling system with “oil bath” filter & vacuum pumps

Data sent to PC based control system – provides early warning before catastrophic problem occurs

Amount: $65K (3 furnaces x 3 zones = 9 points + spares)
Carbon Dioxide (CO₂) is the gas that gives soda pop and beer its “fizz”. It is also used in a number of food processing applications including commercial bakeries and fruit distribution. CO₂ retards dough from rising and slows ripening of fruit. Specifications for “food grade” CO₂ have been set by the International Society of Beverage Technologists (ISBT). The specifications are listed at the right.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Purity</td>
<td>99.9 % v/v min</td>
</tr>
<tr>
<td>Moisture</td>
<td>20 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Oxygen</td>
<td>30 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>10 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>2.5 ppmₐₜₐ</td>
</tr>
<tr>
<td>Nitric Oxide (NO)/Nitrogen Dioxide (NO₂)</td>
<td>2.5 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Non-volatile Residue</td>
<td>10 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Non-volatile Organic Residue</td>
<td>5 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Phosphine (PH₃)</td>
<td>0.3 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Total Volatile Hydrocarbons (as Methane and including 20 ppmₐₜₐ max of total non-Methane hydrocarbons )</td>
<td>50 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Acetaldehyde (CH₃CHO)</td>
<td>0.2 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Aromatic Hydrocarbon Content</td>
<td>20 ppbₐₜₐ max</td>
</tr>
<tr>
<td>Total Sulfur Content (excluding Sulfur Dioxide)</td>
<td>0.1 ppmₐₜₐ max</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>1 ppmₐₜₐ max</td>
</tr>
</tbody>
</table>
Carbon Dioxide (CO2) produces the bubbles in beer (carbonation).

For “macro” breweries such as Anheuser- Bush in order to bottle beer at high speed the CO2 is removed. The CO2 is saturated and must be dried.

After the “flat beer” is put into the bottles, dry CO2 is injected back in.

The CO2 is dried by “pressure swing” desiccant dryers.

GE’s MMY30 is specified for their global operations.
Synthetic Fiber Production

Synthetic fibers are produced by extruding polymer resins (Nylon, Polyester, Kelvar etc) with spinnerets. The fibers are drawn from molten resin and twisted. “Quench Air” is used to solidify the fibers.

For certain fibers the quench air must be dry while for other fibers the quench air must contain a specified amount of humidity.
Lithium has become a generic term representing a variety of battery systems in which lithium metal is used as the active anode (negative) material. Variations in the cathode (positive) material and the cell's electrolyte result in hundreds of possible combinations of lithium batteries.

Lithium batteries are processed under dry conditions as Li reacts violently with water to Lithium Oxide or Hydroxide + Heat!

Lithium is transported under dry Argon blanket

Process requirements are <-34°C Td and typically -60°C

Dry air is typically produced by rotary honeycomb heat reactivated desiccant dryers.

Dry is is typically delivered at -40 to -70°C Td
Radio, radar and microwave transmission antennas and waveguides are purged with dry air to prevent, condensation, ice formation and for enhancement of signal transmittance.

As an EMF wave is propagated there is signal loss due the absorption by water

Telephone cables are also pressurized with dry air or Nitrogen
Glove Boxes

- Powder Handling
- Pharmaceutical Compounding
- Chemical Dispensing
- Instrument/Detector Containment
- Lithium Battery Manufacturing
- Hermetic Sealing and Welding
- Thin Film Production
- Electronic Component Manufacturing
- Nuclear Fuel
Moisture in Organic Liquids

<table>
<thead>
<tr>
<th>Propane</th>
<th>C3H8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>44</td>
</tr>
<tr>
<td>T °C</td>
<td>PPMws</td>
</tr>
<tr>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>10</td>
<td>93</td>
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<tr>
<td>20</td>
<td>154</td>
</tr>
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<td>30</td>
<td>240</td>
</tr>
<tr>
<td>40</td>
<td>385</td>
</tr>
<tr>
<td>50</td>
<td>580</td>
</tr>
</tbody>
</table>

\[
ppm_w = K \times P_w
\]

\[
K = \frac{ppm_{ws}}{P_{ws}}
\]

\[
ppm_w = \frac{ppm_{ws} \times P_w}{P_{ws}}
\]

K = Henry’s Law constant

ppm_w = parts per million by weight

ppm_{ws} = parts per million by weight at saturation

P_w = Partial Pressure of water in the liquid

P_{ws} = Partial Pressure of water in the liquid at saturation

Another way of measuring moisture in liquids is the “Karl Fisher”. This requires a “grab sample” to be taken back to the lab.

Other methods include vaporizing the liquid but Joule Thompson Cooling and moisture ingress pose additional issues.
Our Website is the best place to get up to date additional information on our moisture and gas sensors and instruments
• Data sheets
• Application notes
• Product Manuals

www.ge-mcs.com

Thank you for your attendance.

Questions?

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