GAS PORTFOLIO 2016
Product Portfolio

**Electrochemical**
- oxy.IQ
  - Galvanic Fuel Cell oxygen sensor for ppm or %O₂ in gases

**ThermoParamagnetic**
- XMO2
  - %O₂ in gases Transmitter w/optional displays with relatively constant background gas

**Zirconium Oxide**
- CGA351
  - Clean Gas Oxygen Analyzer for analytical applications

**Thermal Conductivity**
- XMTC
  - %Gas Analyzer in other gases based on measuring differences in thermal conductivity (Typically H₂ analysis)
Fuel Cell O2
The Biggest Small Thing in Oxygen Analysis
Measuring Oxygen: Fuel Cell O2 Sensor

Cathode:
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Anode:
$2Pb \rightarrow 2 Pb^{+2} + 4e^-$

Overall:
$2Pb + O_2 \rightarrow 2PbO$

Current output is proportional to O2 concentration
Simple Installation

oxy.IQ has same process and electrical connections
- 1/8 NPT
- 2 wire loop powered 4 to 20 mA
Key Features

✓ Display & Keypad
✓ Small size, half size of O2X1
✓ User Interface
  ✓ Multiple user selectable output ranges
    ✓ 0 to 10, 20, 50, 100, 200, 500, 1000, 2000, 5000 ppm
    ✓ 0 to 1, 2, 5, 10, 25, 50, 100% O2
✓ Sensor diagnostics
  ✓ Sensor lifetime feature
  ✓ Sensor raw signal
✓ Error indication choice
  ✓ High low, specific mA output value, NAMUR format
  ✓ Low reading / possible sensor failure alarm
✓ Temperature compensation algorithm
✓ Sensor noise reduction
✓ Tropicalized
✓ Intrinsically Safe (IS) option for hazardous area locations
Specifications

Accuracy
±2% of range at the calibration point for the 0 to 10 ppm range (OX-1 or OX-2 only)
±1% of range at calibration point all other ranges

Repeatability
±2% of Range for the 0 to 10 ppm range (OX-1, 2 only)
±1% of range

Resolution
±0.1% of range

Linearity
±2% of range (OX-1, 2, 3, 5)
±5% of range (OX-4)

O2 Sensor Operating Temperature
32°F to 113°F (0°C to 45°C)
Specifications

Atmospheric Pressure Effect
±0.13% of reading per mmHg (directly proportional to absolute pressure). During calibration, pressure and flow must be kept constant.

Recommended Sample Pressure
Vent to atmosphere

Sample Flow Rate
1.0 SCFH (500 cc/min) recommended

Dimensions
4.10 in x 2.75 in x 2.05 in

Weight
1.35 lb (612 grams)
Specifications

Electrical Classification/Certification

Certifications received in March 2015

Intrinsically Safe

USA/Canada

IS for Class I, Div 1, Groups ABCD, T4 AEx ia IIC T4

ATEX and IECEx

Ex ia IIC Ga T4 Tamb -20 to 60°C

European Compliance

Complies with EMC Directive 2004/108/EC
oxy.IQ Ex Flameproof Option – ATEX & IECEx Certified
## oxy.IQ Sensor Selection Guide – Acid Gas Compatibility

<table>
<thead>
<tr>
<th>Gas</th>
<th>OX-1 and OX-5, ppm Cont.</th>
<th>OX-2, ppm Cont.</th>
<th>OX-3, % Cont.</th>
<th>OX-3, % Int. (1)</th>
<th>OX-4% Cont.</th>
<th>OX-4% Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S</td>
<td>&lt;5 ppm</td>
<td>&lt;10 ppm</td>
<td>0.0005%</td>
<td>0.01%</td>
<td>0.001%</td>
<td>0.1%</td>
</tr>
<tr>
<td>SO₃</td>
<td>&lt;10 ppm</td>
<td>&lt;10 ppm</td>
<td>0.01%</td>
<td>0.1%</td>
<td>0.01%</td>
<td>0.1%</td>
</tr>
<tr>
<td>SO₂</td>
<td>&lt;10 ppm</td>
<td>(3)</td>
<td>0.01%</td>
<td>0.1%</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>HCl</td>
<td>&lt;1000 ppm</td>
<td>(3)</td>
<td>0.1%</td>
<td>1.0%</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>HCN</td>
<td>&lt;1000 ppm</td>
<td>(3)</td>
<td>0.1%</td>
<td>1.0%</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>CO₂</td>
<td>&lt;1000 ppm</td>
<td>(3)</td>
<td>0.1%</td>
<td>20%</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>NO₂</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>Cl₂</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
</tbody>
</table>

Cont. = Continuous, Int. = Intermittent  
(1) Recommended maximum exposure 30 minutes followed by flushing with ambient air for equal period  
(2) Minimal effect on sensor performance, but produces signal interference of 1:2 ratio, ppm levels only. For example, 100 ppm NO₂ looks like 200 ppm O₂  
(3) Minimal effect on sensor performance
Glove boxes are used to create a protective atmosphere for the materials under process. Typically Oxygen and Moisture are controlled at trace levels.

- Oxygen measurement is usually at trace ppm levels, therefore electrochemical O2 sensor is required.

oxy.IQ is the low cost solution – ideal for OEM Glove box manufacturer

Low initial costs in line with range ability, accuracy, response time and maintenance expectations.

Fig 1: Glove box with purification for product protection. Work under positive pressure with controlled atmosphere 1 ppm [O2] and [H2O]. Manipulation of products sensitive to moisture and/or oxygen.

Fig 2: Remote purification system used in combination with glove box systems for product protection. Controls e.g. Oxygen and Moisture concentrations.
HygroPro and oxy.IQ
oxy.IQ replaces O2X1
oxy.IQ Applications - Natural Gas in Europe

- EASEE-gas: European Association for the Streamlining of Energy Exchange
- Organization has defined Common Business Practices (CBP) and recommends specifications for Minimum Gas Quality at cross border points in Europe, and describes parameters, ranges, and implementation plan. The spec for Oxygen in NG is (0.01 %)
- EASEE has specified oxy.IQ as the preferred sensor for the measurement of Oxygen at cross border stations and other locations.
- Eff Oct 2010, the CBP is applicable for all organization in the NG supply chain: producer, distributor and network operators.

![Diagram of typical sample system for NG quality measurement](image)

Components required:
1: oxy.IQ Oxygen Transmitter
2: Cable
3: Zener Barrier (located in safe area) MTL7706
4: Sample System

Fig 1: typical sample system for the application of NG quality measurement. oxy.IQ replaces O2X1

Fig 2: selection of member organization of the EASEE:
**N₂ Generation**

- Oxygen measurement is trace so paramagnetic analyzer is not suitable.
- Usually want least expensive oxygen measurement device which is typically depleting electrochemical

oxy.IQ low cost solution – ideal for OEM Nitrogen generator manufacturer

Low initial costs in line with range ability, accuracy, response time and maintenance expectations

*Fig 1: Compressed Air feed Oil-free Membrane allows other gases to permeate out of supply air Result is purified N₂ stream*

*Fig2: N₂ membrane generator at GE Sensing China Service Center in Shanghai Nov. 2006*
H₂ Generation

- Several processes used for H₂ production including catalytic reforming of methanol, Natural Gas, LPG or NH₃ in combination with PSA purifying
- Oxygen measurement is trace so paramagnetic analyzer is not suitable
- Usually want least expensive oxygen measurement device which is typically depleting electrochemical

Fig 1: methanol and demineralized H₂O, through heater into reactor, reforming in catalytic reactor forming CO₂ and H₂

Fig 2: Steam reactor unit used for H₂ production
Petrochemical/Refinery

Hydrocarbon Gases

- Flare Gas
- Process Gases
  - Ethane
  - Propane
  - Butane
- Vapor Recovery
Paramagnetic O2
XMO2 Thermomagnetic O2 Sensor Overview

XMO2

TMO2D

XDP

Sample Systems
XMO2 Thermomagnetic O2 Sensor

Upper measurement chamber

Induced gas flow

Wind-generating thermistor

Lower flow-through chamber

Wind-receiving thermistor

Magnetic field

Diagram:

W1, W2 = WIND GENERATING THERMISTORS
R1, R2 = WIND RECEIVING THERMISTORS

Vcomp
Inerting Gas Application

Why monitor oxygen?

Safety:

Process Control:
Inerting Gas Application

Tank with HC Liquid

N2 Blanket Gas

Vapor Recovery / Vent

XMO2, XDP, & Sample System

XDP Display / Power Supply can be mounted locally or remotely

N2 Blanket
Inerting Gas Application

Sample System for Inerting Application with Auto-calibration
More than 400 XMO2 sailing the seven seas
Oxidation Reactor Application

- **Purge N₂**
- **Vent Gas**
- **Hydrocarbon Liquid**
- **Air or Pure O₂ Feed**

Typical XMO2 Sample Point; Nitrogen saturated with hydrocarbon vapors and residual oxygen.
Section 3: XMO2 Thermomagnetic O2 Sensor Applications

Centrifuge Application

- Reciprocating Piston Rod
- Spinning Basket
- Filter Cake
- Slurry Feed Pipe
- Solids Discharge
- Liquid Drain
- Housing
- Nitrogen Purge Feed
- Typical XMO2 Sample Point
- Vent Gas

Oxygen Analysis
10/30/2017
Furnace Application

Bell Furnace

Sample system – Filtration and Pump required
Furnace Application – 3 Measurands

XMO2 Thermomagnetic O2 Sensor Applications

XMTC

XMO2
Biogas Applications

Landfill Gas

Ken Pugh calibrating an XMO2 and XMTC at the Frederick County Landfill in Maryland, USA
Waste Water Treatment Plant – Aerobic Digesters
Our Valued Customers

### Chemical
- 3M
- Momentive Performance Materials
- Monsanto
- IFF (International Flavors & Fragrances Inc.)
- L'Oréal
- Ciba
- Sasol
- DSM
- Rhodia
- Nestlé
- BASF
- Marathon
- BP

### Pharmaceutical
- Merck
- Bayer
- Novartis
- AVEVA
- GlaxoSmithKline
XMO2 Thermomagnetic O2 Sensor  Case Studies

Our Valued Customers

Heat Treating
XMO2 Thermomagnetic O2 Sensor

The XMO2 Advantage

**XMO2 Oxygen Transmitter**
- Thermoparamagnetic sensor
- No moving parts
- Ultra stable thermistors
- Dual chamber design
- Stainless steel or Hastelloy wetted materials

- **No Moving Parts**
- **Dual chamber design**
- **Hazardous Area Rating**
- Longer time in-between calibrations / Less touch time by the customer
- Less transmitter down time
- Smaller package, no external barriers – lower cost

![Diagram of XMO2 Oxygen Transmitter](image)
Delta F O2 cell
DF Electrochemical sensors & analyzers
DF Electrochemical sensors & analyzers

Specifications

• Range: PPM & % range cells available (up to max 25%)
• Output: moisture.IQ outputs (Digital & analog 0/4-20mA)
• Accuracy: +/- 1% of full scale (+/-5% of full scale for ranges <2.5ppm)
• Response Time: Instantaneously to O2 change
• Stability: 0.4% of span per month
• Intrinsically safe for hazardous area use

Technical Benefits

• Ultra stable, drift free
• Long lifetime
• Fast response and fast recovery after transient oxygen shock.

Applications

• Gas purity monitoring
• Petrochemical feed gases
• When oxygen is present in the sample, a current is produced in the measurement circuit which is proportional to the oxygen concentration. Unlike the galvanic cell, the measurement reaction is driven by an applied voltage across the measurement electrodes supplied from the instrument electronics.
Zirconia O2 Analyzer
CGA351 Zirconium Oxide O₂ Analyzer

Specifications

• Range: Field Programmable between 0.1 ppm to 100% O₂, typical range 0 to 10 ppm O₂
• Output: 0/4 to 20 mA
• Dual Alarm contacts, fail safe
• Accuracy: +/- 0.2 ppm from 0 to 10 ppm or +/- 2% of reading
• Response Time: less than 2 sec for 90% step change
• Stability: less than 3% of reading per year
CGA351 Zirconium Oxide O$_2$ Analyzer

Technical Strengths

- Fastest Responding Oxygen Sensor
- Provides Oxygen Measurement over the widest range
- Maintenance free

Applications

- Air Separation Plants – Gas Purity Measurement
- Cylinder Filling
Thermal Conductivity Gas Analyzer
XMTC Thermal Conductivity Gas Analysis

- XMTC
  - Thermal Conductivity Principle of Operation
  - RS232 & IDM
  - Improved linearity
  - Fast response
  - Temperature Compensation for reduced temperature effect based on heater duty cycle
Binary gas analyzer: measures one gas in another gas or gas mixture based on difference in TC or thermal conductivity of the two gases

- Hydrogen, Hydrogen, Hydrogen
  - furnace gases, steel galvanizing
  - petrochemical gases
  - electricity generators, hydrogen purity
  - chlorine gas

- Used by itself as stand alone transmitter or with optional displays TMO2D or XDP
Definitions

Thermal Conductivity

- The quantity of heat that will flow through a material in a certain amount of time, over a specific distance, per degree of temperature gradient

Typical Units

- \( W / (m \times K) \)
- \( \text{Cal} / (cm \times \text{sec} \times K) \)
XMTC Thermal Conductivity Gas Analysis

Relative Thermal Conductivity of Common Gases

-240mv SO₂ CO₂ -120mv CH₄ 160mv Ne

Air/N₂

1000mv He

1200mv H₂

0 C₄-C₆ 1.0 2.0 3.0 4.0 5.0 6.0 7.0

Lowest Measurable Ranges with N₂ Background

- 0 to 2% H₂ in N₂
- 0 to 2% He in N₂
- 0 to 20% CO₂ in Air
- 0 to 20% CH₄ in N₂
- 0 to 10% CH₄ in CO₂
- 0 to 5% SO₂ in Air
**TC Sensor**

- Sample and Reference Gases Come in Contact With Constant Current Thermistors (~150°C)
- Heat Is Transferred From 150°C Thermistor to 55°C Cell Wall at a Rate Proportional to the Thermal Conductivity of the Gas Mixture
- RT1 and RT2 Reach Different Equilibrium Temperatures; Therefore, They Have Different Resistances
- RT1 and RT2 Are Two Legs of a Wheatstone Bridge Circuit
- Linear Relationship Between Bridge Voltage and Gas Composition
Wheatstone Bridge

- The resistance difference between RT1 and RT2 yields a mV signal across the inside of the Wheatstone Bridge.
XMTT Thermal Conductivity Gas Analysis

- **Wetted Parts:** 316SS (Optional Hastelloy), FEP Coated Aluminum (CPVC), glass
- **Dimensions**
  - NEMA 4X: 242 mm (H) x 145 mm (D)
  - NEMA 7: 266 mm (H) x 145 mm (D)
- **Weight:** 9.5 lb (4.3 kg)
- **Connections**
  - Electrical: 3/4 inch NPTF
  - Process: 1/4 inch NPTF
- **Certifications**
  - Explosion-proof: Class I, Division 1, Groups A,B,C&D
  - FM File No. J.I.2Z4A8.AE (3615) CSA LR44204-15
  - Flameproof: ATEX II 2 GD EEx d IIC T6 or T5
  - ISSeP02ATEX022
Furnace Gases

Metal and Steel Manufacturers use heat treating furnaces to achieve certain characteristics in different materials:

- Hardness
- Strength
- Ductility
- Surface Finish

XMTC Thermal Conductivity Gas Analysis - Applications

Continuous Annealing Line

O2, H2 and Moisture Control System (Five Steins / GE)
Furnace Gases

- Why is Hydrogen used in furnace gases?
  - To assist in heat transfer to the metals so that they can heat and cool at different rates
  - Hydrogen will react with any oxygen to form water to reduce the possibilities of corrosion caused by oxidation
Typical continuous feed furnace:
Typical Bell Type Furnace:
Hydrogen Cooled Generators

Generators use hydrogen for two reasons:

1. Hydrogen, because of its extremely high thermal conductivity, is used to draw the heat away from the generator and keep it cool.

2. Hydrogen has a very low viscosity and, therefore, reduces the amount of wind resistance on the spinning main shaft.
Hydrogen Cooled Generators

- Electricity
- Generator
- Coils
- Brushes
- Low-Press. Steam
- High-Press. Steam
- Turbine
- H₂ Make Up
- Pump
- Dryer
Three Range Application

- Shut-Down and Start-Up Mixtures

<table>
<thead>
<tr>
<th>Curve 1:</th>
<th>Hydrogen in Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve 2:</td>
<td>Carbon Dioxide in Hydrogen</td>
</tr>
<tr>
<td>Curve 3:</td>
<td>Air in Carbon Dioxide</td>
</tr>
</tbody>
</table>
Hydrogen Cooled Generators

- 0 to 100% Air in CO₂
- 0 to 100% CO₂ in H₂
- 0 to 100% H₂ in Air

4 mA 5.5 mA 20 mA

CO₂ Air H₂
How does the XDP fit into this application?

- Each of the previous mixtures is a binary gas
- Each of the gases in the binary mixture has a different thermal conductivity
- Program XDP with Three Different Calibration Curves Depending upon Operating Situation
- Certified for
  - FM/CSA Cl. 1, Div. 1, Gr. B, C, D
  - Flameproof: KEMA 01ATEX2128, Atex E II 2 GD Eex d IIC T6
Hydrogen Recycle Gas

- Petrochemical Plant Application

  - Measurement of Hydrogen in a pseudo-binary gas mixture. Other gases present besides Hydrogen are light to heavy end hydrocarbons (C1 to C6 typically).
Hydrogen Recycle Gas

Even if background gases vary somewhat, there is little error in the 60-90% H₂ range!
Hydrogen Recycle Gas

Liquid Feed → Heater

Make Up Hydrogen → Vaporized Liquid Mixed with Recycled Hydrogen

Analyzer Point

Gas-Liquid Separator → Gas Liquid

Reformer

Cooler

Product
Biogas

- Landfill Application
  - Measurement of either methane or carbon dioxide that is reclaimed from a covered landfill
Biogas

Thermal Conductivity Gas Analyzer Applications

Covered Landfill

Blower

To Utility Company or Flare

Pipes