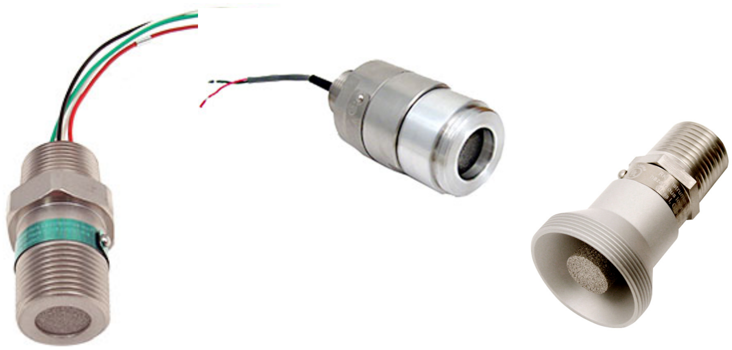
Gas Detection Basics



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Safety vs Process Control

- RKI's products mostly address safety applications
- A few of RKI's products may also address some process control applications
- **SAFETY**
  - Protecting life and property/assets
  - Gases normally not present
  - Detect occasional leaks if they occur
- **PROCESS CONTROL**
  - Adjusting processes based on the gas present
  - Gases normally present

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Types of Gases/Compounds

- Combustibles ------------------------------
  - Flammable gases and vapors
    - Most are also toxic
    - Organic compounds (HC's)
- "Toxics" --------------------------------------
  - Usually refers to non-hydrocarbons
    - Inorganic compounds (Non-HC's)
    - Several inorganic compounds are also combustible
- Inerts --
  - Non-reactive gases
    - Usually are N2, He, Ar

Propane
Hexane

H_2S
CO
Inorgani
c HC

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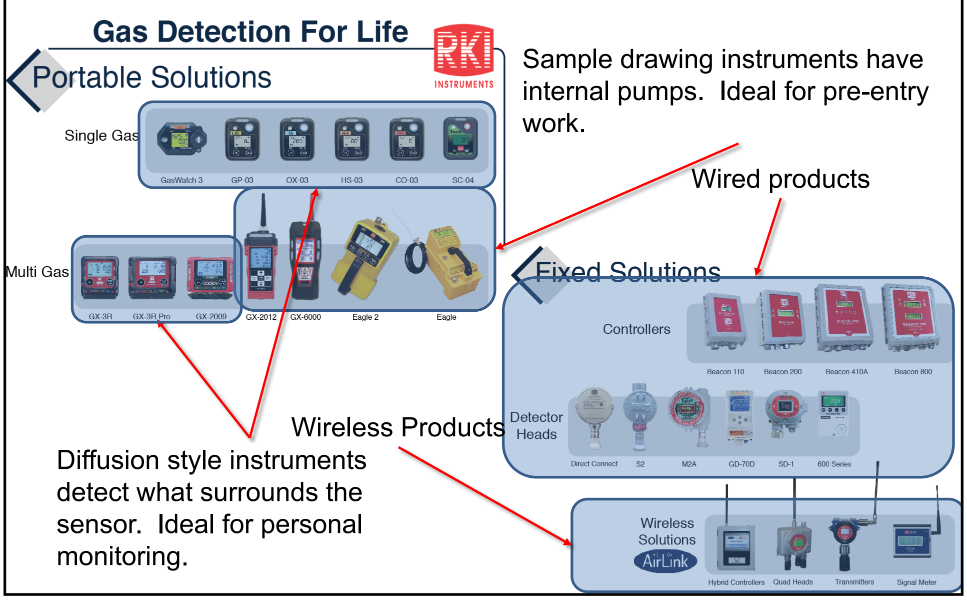
Product Family

Sample drawing instruments have internal pumps. Ideal for pre-entry work.

Wired products



Wireless Products

Diffusion style instruments detect what surrounds the sensor. Ideal for personal monitoring.

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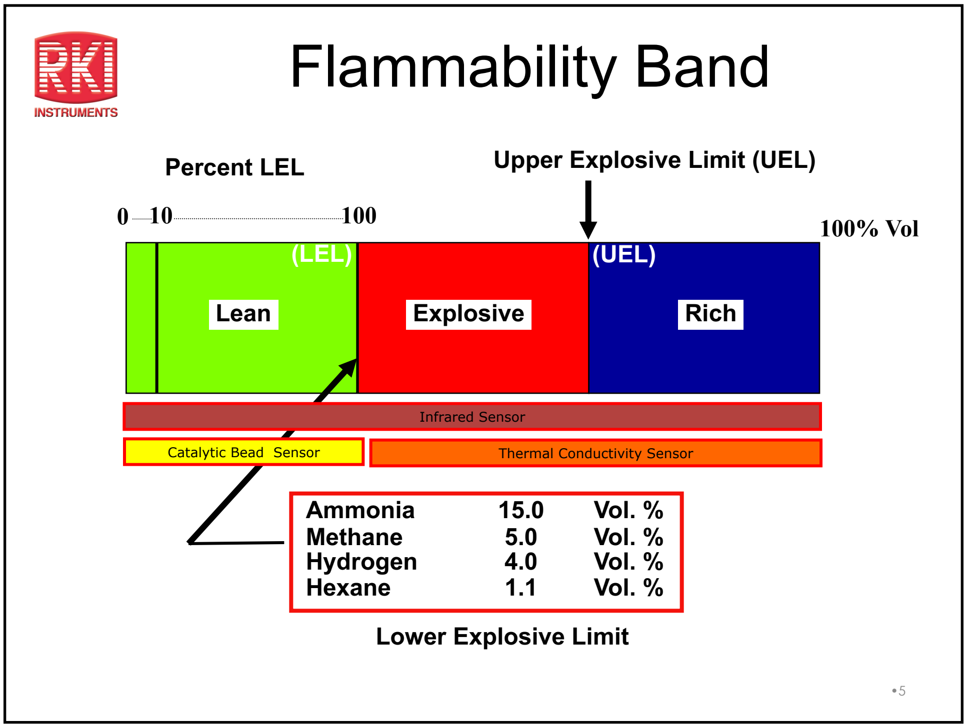
RKI INSTRUMENTS
Flammability Band
Percent LEL
Upper Explosive Limit (UEL)
0
10
100
100% Vol
(LEL)
(UEL)
Lean
Explosive
Rich
Infrared Sensor
Catalytic Bead Sensor
Thermal Conductivity Sensor
Ammonia 15.0 Vol. %
Methane 5.0 Vol. %
Hydrogen 4.0 Vol. %
Hexane 1.1 Vol. %
Lower Explosive Limit
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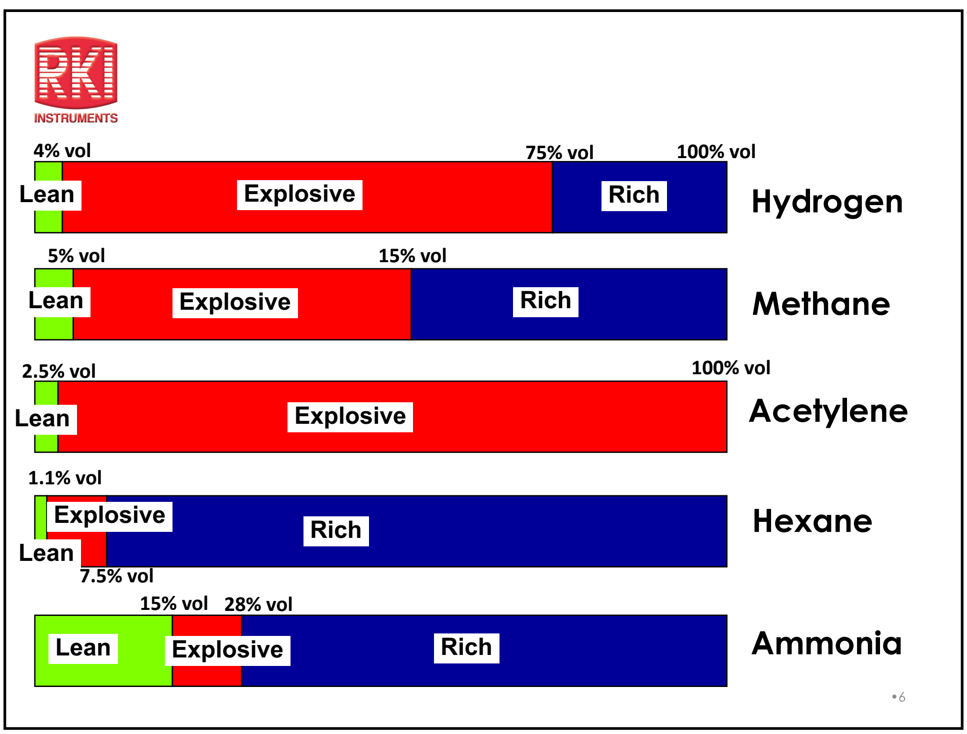
RKI INSTRUMENTS
4% vol
75% vol
100% vol
Lean
Explosive
Rich
Hydrogen
5% vol
15% vol
Lean
Explosive
Rich
Methane
2.5% vol
100% vol
Lean
Explosive
Acetylene
1.1% vol
Explosive
Rich
Lean
7.5% vol
Hexane
15% vol
28% vol
Lean
Explosive
Rich
Ammonia
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Area Classifications

NEC Division System Gas Groups		
Area	**Group**	**Representative Materials**
Class I, Division 1 & 2 Div 1: ARE present Div 2: COULD be present	A	Acetylene
	B	Hydrogen
	C	Ethylene
	D	Propane
Class II, Division I & 2 No approvals for this Class	E (Division 1 only)	Metal dusts, such as magnesium
	F	Carbonaceous dusts, such as carbon & Charcoal
	G	Non-conductive dusts, such as flour, grain
	None	Ignitable fibers/flyings, such as cotton lint, flax & rayon

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Toxicity

TLV's & PEL's: Threshold Limit Values & Permissible Exposure Levels

TWA

- Time Weighted Average:
  -Average Exposure over 8 hours

STEL

- Short Term Exposure Limit:
  -Average Exposure over 15 minutes

C

- Ceiling:
  -Not to be exceeded for any length of time

IDLH

- Immediately Dangerous to Life and Health:
  -30 minutes of exposure may result in permanent physiological damage

Agencies

- **ACGIH**: **A**merican **C**onference of **G**overnmental **I**ndustrial **H**ygienists
- **NIOSH**: **N**ational **I**nstitute of **O**ccupational **S**afety and **H**ealth
- **OSHA**: **O**ccupational **S**afety and **H**ealth **A**dministration

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Inerts

- Oxygen deficiency
  - Permissible Low Levels Exposure
    - ✓ Oxygen sensor used to measure the displacement of oxygen by an inert compound
    - ✓ Typical first alarm points at 19.5% Vol. or 18.0% Vol. (Decreasing Alarm Logic)

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Sensor Technologies

- Catalytic - requires 10%vol oxygen present
  - ✓Combustibles- %LEL
- Metal Oxide Semiconductor (MOS)
  - requires 10%vol oxygen present
  - ✓Combustibles- PPM, % LEL
- Infrared – does not require oxygen be present
  - ✓Combustibles- %LEL, % Vol.
  - ✓Carbon Dioxide- PPM, % Vol.

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Sensor Technologies

- Thermal Conductivity –
  - ✓Combustibles- % Vol.
- Electrochemical – *Fixed: requires 2-5%vol oxygen present*
  - ✓Inorganic gases/Compounds PPB, PPM
- Galvanic (Partial Pressure) –
  - ✓Oxygen - %Vol.
- Capillary
  - ✓Oxygen - %Vol

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Sensor Technologies

- Zirconia
  - ✓PPB, PPM, %Vol O2
- Paper Tape –
  - ✓Formaldehyde, Inorganic gases – PPM

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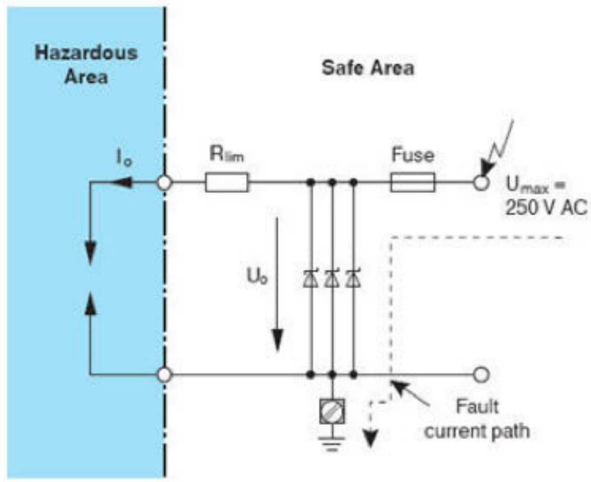
Intrinsic Safety



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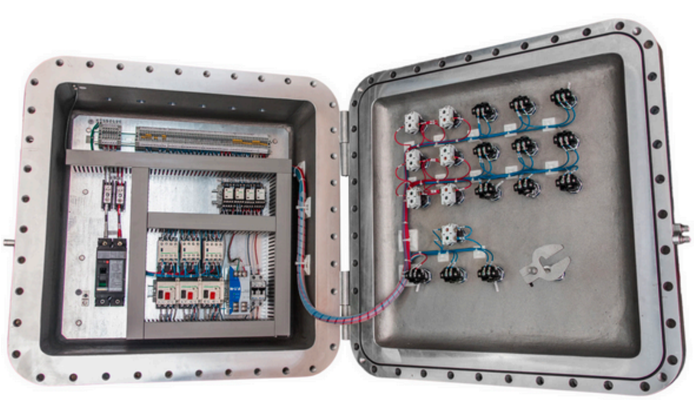
Explosion Proof



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INSTRUMENTS

Catalytic Bead Combustible Gas Sensor

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INSTRUMENTS

Principle of Operation

- The catalytic bead sensor consists of two coils of fine platinum wire each embedded in a bead of alumina, connected electrically in a Wheatstone bridge circuit. One of the pellistors is impregnated with a special catalyst which promotes oxidation while the other is treated to inhibit oxidation. Current is passed through the coils so that they reach a temperature at which oxidation of a gas readily occurs at the bead treated with the platinum cataylist (500-550° C). Passing combustible gas raises the temperature further which increases the resistance of the platinum coil in the catalysed bead, leading to an imbalance of the bridge. This output change is linear, for most gases, up to and beyond 100% LEL, response time is a few seconds to detect alarm levels (around 20% LEL), at least 10% oxygen by volume is needed for the oxidation.

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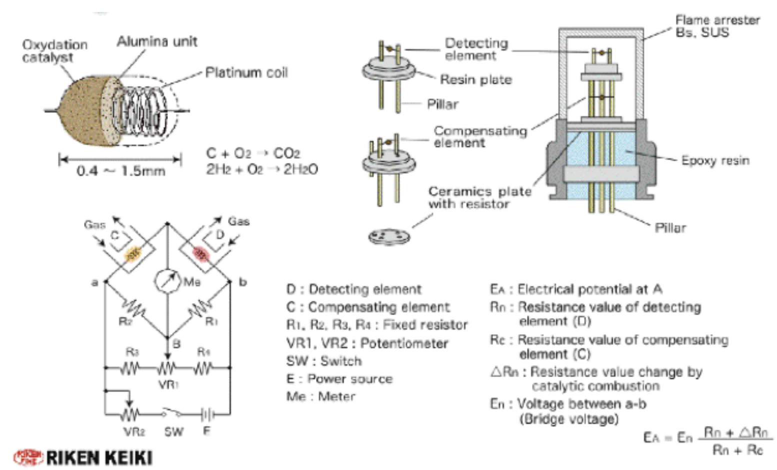
Catalytic Bead Sensor



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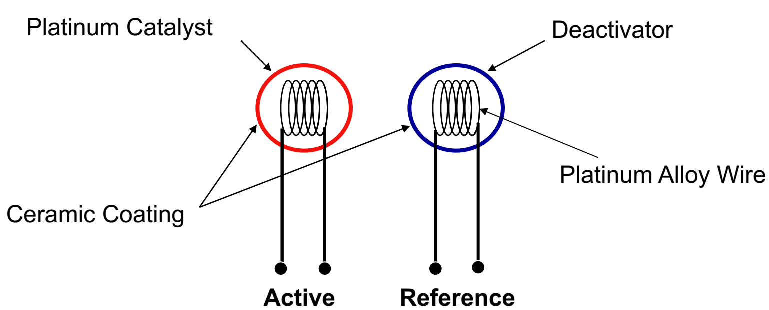
Catalytic Bead Sensor



Four Wire Catalytic Bead Combustible Gas Sensor
Constant Current

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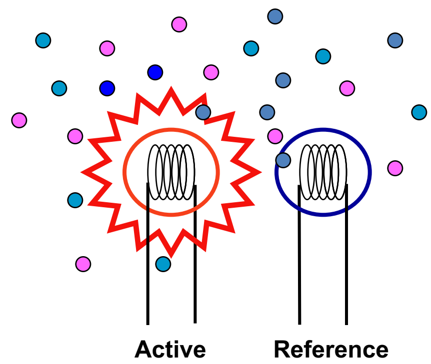
Catalytic Oxidation



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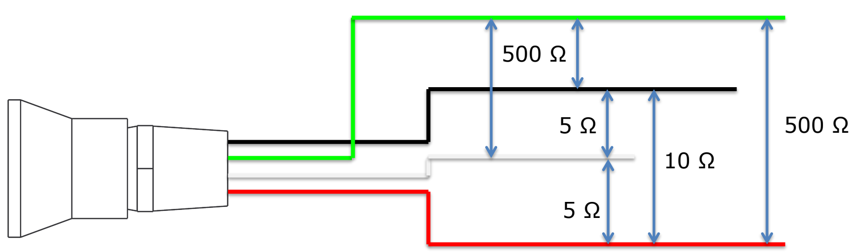
Catalytic Bead Sensor



Resistance values are approximate and will vary slightly
Between sensors. H2 specific sensors will be approximately 3 Ohms per leg.

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Catalytic Bead Sensor

- Sensor current for fixed systems can be adjusted to "tune" the gas sensor for specific gas to be detected
- Methane, Propane, Iso Butane, Pentane & Hexane Detection (NC-6241)
  - Set at 148 mA
- Hydrogen (NC-6241)
  - Set at 130 mA
- Hydrogen Specific (NC-6205)
  - Set at 115 mA

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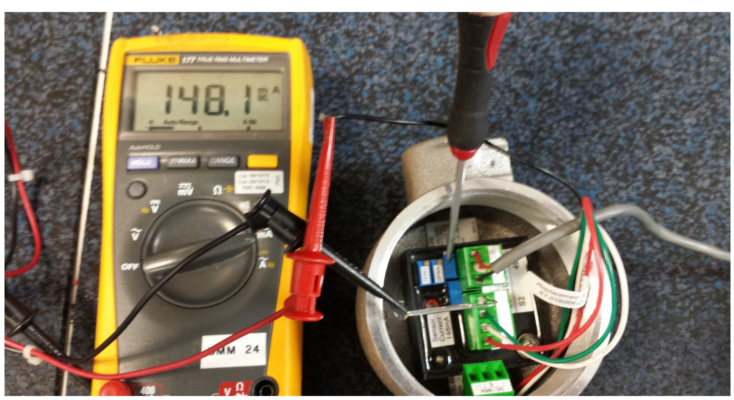
Adjusting Sensor Current

(S2-Series)



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Catalytic Bead Sensor

Sensor Type	Pros	Cons
Catalytic Bead	Linear output, responds to most hydrocarbons, low cost, long life, can be used for ppm HC detection	Affected by catalyst poisons, not suitable for wet or high vibration areas, requires oxygen to operate, not suitable for measuring gas above 100% LEL
Infrared	Not affected by catalyst poisons, long life, requires less frequent calibration,	Non linear output, not suitable for high vibration or humid areas, will not respond to certain compounds such as hydrogen and acetylene. Not suitable for low ppm detection.

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Catalytic Bead Sensor

Sensor Type	Pros	Cons
Thermal conductivity	Long life, does not require oxygen to operate, sensors available for methane and hydrogen,	Not suitable for ppm combustible detection,

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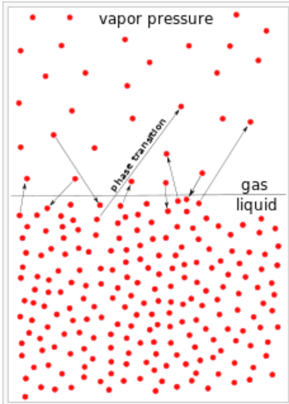
Vapor Pressure



The picture shows the particle transition, as a result of their vapor pressure, from the liquid phase to the gas phase and converse.

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Hydrocarbon Comparison

Standard Temp and Pressure

gas / liquid

Formula	Name	Ign Temp Deg. F	Flash Point Deg. F	100% LEL	Vapor Density
CH4	Methane	999	Gas	5.0	0.60
C2H6	Ethane	882	Gas	3.0	1.00
C3H8	Propane	842	Gas	2.1	1.60
C4H10	Butane	550	Gas	1.9	2.00
C5H12	Pentane	500	<-40	1.5	2.50
C6H14	Hexane	437	-7	1.1	3.00
C7H16	Heptane	399	25	1.05	3.50
C8H18	Octane	403	56	1.00	3.90
C9H20	Nonane	401	88	0.80	4.40
C10H22	Decane	410	115	0.80	4.90

* %volume equivalent

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Common Failures

- Reading pegs either upscale or downscale
  - Open Active or Reference detector element
  - Excessive vibration can damage the filaments
  - Liquids or corrosion can cause output failure
- Unstable or Erratic Operation
  - Reading can be slow to respond or slow to recover due to contamination of the sensor elements and or contamination of the flame arrestor

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Common failures

- Low span on test gas
  - Deterioration of the catalyst caused by continuous exposure to flammable gas, repeated exposure to high concentrations of gas, contamination or age of the sensor.
- Exposure to catalyst poisons such as:
  - Silicone compounds
  - Chlorinated hydrocarbons
  - Corrosive gases or vapors
  - Leaded gasoline

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RKI INSTRUMENTS

Thermal Conductivity Gas Sensor

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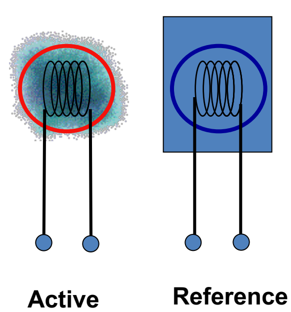
RKI INSTRUMENTS

Thermal Conductivity

Reference element contained out of gas stream

Temperature coefficient of air is different than gas causing temperature of coil to cool increasing resistance. No catalytic activity on sensor.



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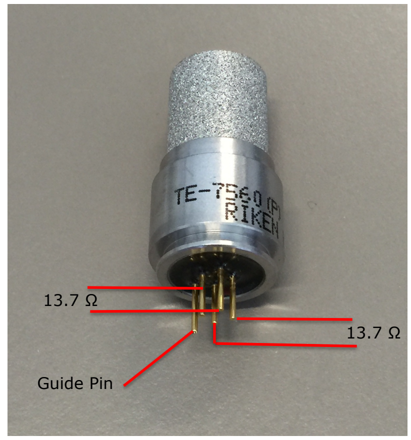
TC Troubleshooting

- TC sensors may open causing instrument to fail.
- Contamination can cause the sensor to respond improperly or become unstable.

TE-7560 H2
Detector



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Galvanic Oxygen Gas Sensor

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Galvanic Sensor

Principle of Operation

- The oxygen sensor is a galvanic fuel cell with a gas-permeable Teflon membrane at one end. Any gas that is in contact with the sensor membrane will diffuse through the membrane and dissolve in a thin layer of weak acetic acid gel electrolyte. Oxygen reduces at the gold cathode and lead oxidizes at the anode.
- At the cathode:
  - $O_2 + 2H_2O + 4e- \Rightarrow 4\,OH^-$
- At the anode:
  - $2Pb + 4OH^- \Rightarrow 2\,PbO + 2H_2O + 4e^-$
- The flow of electrons from the anode to the sensing cathode via an external electronic circuit is directly proportional to the amount of oxygen in the gas phase and varies linearly with the partial pressure of the oxygen in the gas stream. The electrolyte conducts the ionic current, generated by the migrating OH- groups.

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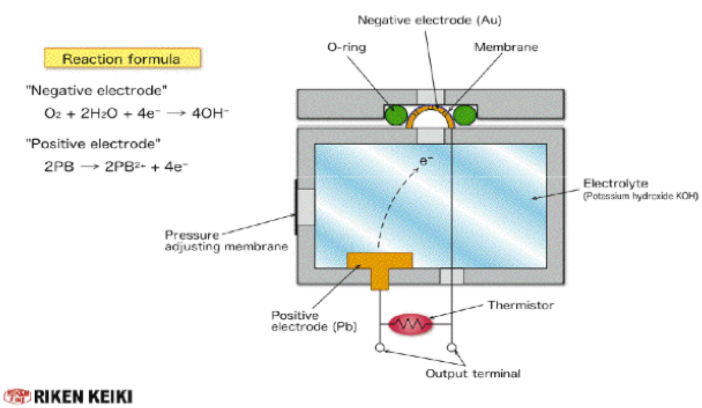
Galvanic Oxygen Sensor



Typical output: 11-18 mV in fresh air

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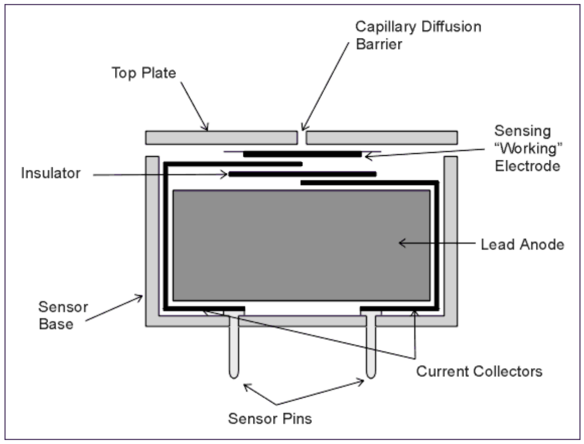
Oxygen Sensor Troubleshooting

Replace Sensor if:

- Voltage is outside specifications
- Unstable output
- Will not zero with N2 applied
- Leaking
- Corroded or contaminated

Capillary Oxygen Sensor

Capillary Oxygen Sensor



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Metal Oxide Semiconductor Gas Sensor

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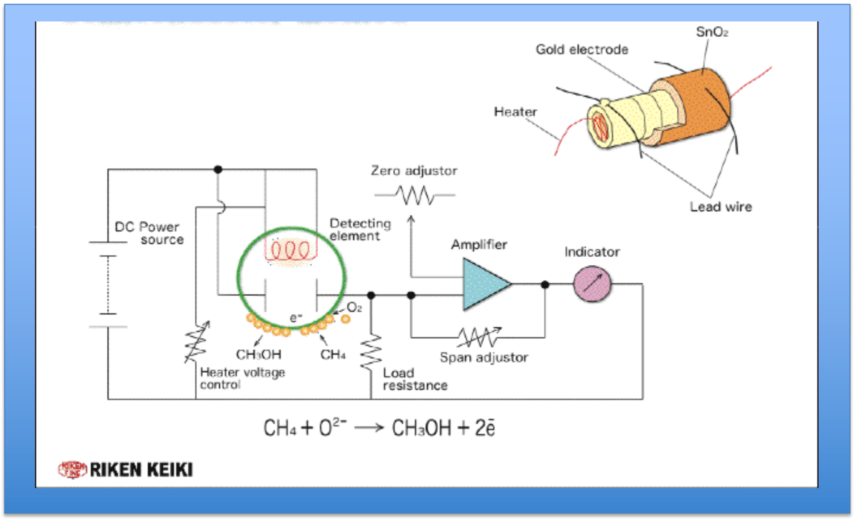
MOS Sensor



MOS Troubleshooting

- Contamination of oxide layer will cause unstable or erratic output
- Improper heater voltage will cause sensor to function improperly

MOS Sensor

- Non linear output
- Responds to many different gases, non-specific
- May respond to moisture
- Broadband gas sensor

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Infrared Gas Sensor

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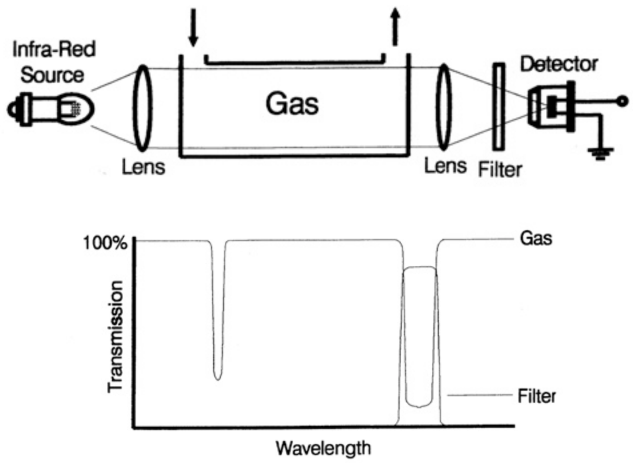
Sample Draw NDIR Sensor



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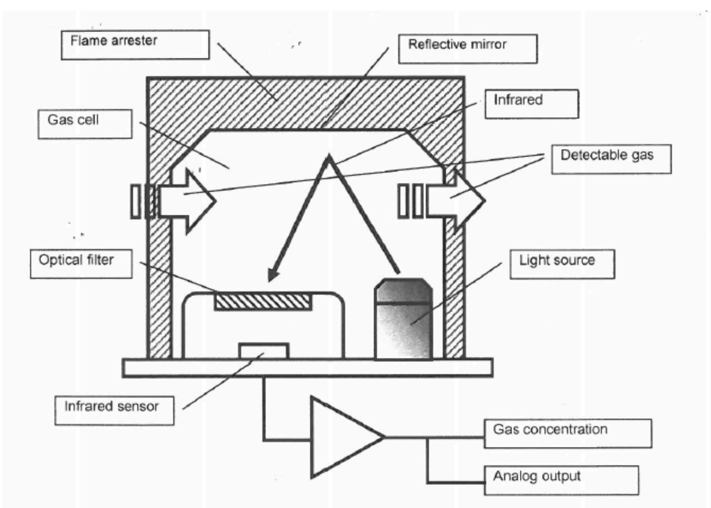
Diffusion IR Sensor



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NDIR Troubleshooting

- Contamination of the sensor will reduce energy reaching sensor causing high output. Contaminants consist of:
  - Dust
  - Moisture/Liquid
- Open IR source will cause output to peg upscale

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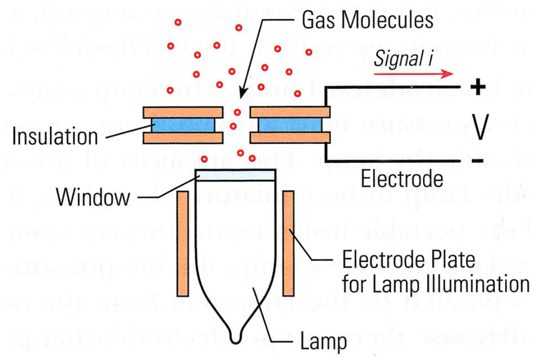
Photo Ionization Detector

- A PID is a broadband VOC detection technique



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RKI INSTRUMENTS

Partial List of PID Detectable Compounds

Chemical Name	Alternate Name	Formula	CAS no.	IE* (eV)	Lamp Photon Energy 11.7 eV	10.6 eV	10.0 eV
Acetaldehyde		C2H4O	75-07-0	10.23	1.5	3.4	ZR*
Acetamide		C2H5NO	60-35-5	9.69	NA*	2	NA
Acetic acid		C2H4O2	64-19-7	10.66	2.6	36.2	ZR
Acetic anhydride		C4H6O3	108-24-7	10.14	2	4.0	NA
Acetoin	3-Hydroxybutanone	C4H8O2	513-86-0	~9.8	NA	1	NA
Acetone	2-Propanone	C3H6O	67-64-1	9.69	1.4	0.7	1.2
Acetone cyanohydrin		C4H7NO	75-86-5	11.09	1	ZR	ZR
Acetonitrile		CH3CN	75-05-8	12.2	100	ZR	ZR
Acetophenone	Methyl phenyl ketone	C8H8O	98-86-2	9.29	NA	0.6	NA
Acetyl bromide		C2H3BrO	506-96-7	10.24	NA	3	NA
Acetylene		C2H2	74-86-2	11.4	2	ZR	ZR
Acetylglycine, N-		C4H7NO3	543-24-8	9.4	NA	2	NA
Acrolein		C3H4O	107-02-8	10.22	1.2	3.2	NA
Acrylic Acid		C3H4O2	79-10-7	10.6	2	2.7	ZR
Acrylonitrile		C3H3N	107-13-1	10.91	1.2	ZR	ZR
Alkanes, n-, C6+		CnH2n+2	N/A	~10	NA	1	NA
Allyl acetoacetate		C7H10O3	1118-84-9	~10	NA	1.5	ZR
Allyl alcohol		C3H6O	107-18-6	9.63	1.7	2.1	NA
Allyl bromide	3-Bromopropene	C3H5Br	106-95-6	9.96	NA	3.0	NA
Allyl chloride	3-Chloropropene	C3H5Cl	107-05-1	10.05	0.7	4.5	NA
Allyl glycidyl ether		C6H10O2	106-92-3	~10	NA	0.8	NA
Allyl propyl disulfide		C6H12S2	2179-59-1	~8.5	NA	0.4	NA
Ammonia		NH3	7664-41-7	10.18	5.7	8.5	NA
Amyl acetate, sec-		C7H14O2	628-63-7	9.9	1	1.8	2
Amyl alcohol		C5H12O	71-41-0	10	4	3.5	NA
Amyl alcohol, tert-		C5H12O	75-85-4	9.8	NA	1.5	NA
Anethole		C10H12O	104-46-1	~9	NA	0.4	NA
Aniline		C6H7N	62-53-3	7.70	NA	0.48	0.80
Anisole		C7H8O	100-66-3	8.21	1	0.5	NA
Anisyl aldehyde		C8H8O2	123-11-5	~9	NA	0.4	NA
Argon		Ar	7440-37-1		ZR	ZR	NA

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RKI INSTRUMENTS

Chemical Name	Alternate Name	Formula	CAS no.	IE* (eV)	Lamp Photon Energy 11.7 eV	10.6 eV	10.0 eV
Arsine		AsH3	7784-42-1	9.89	3	2.5	NA
Asphalt, petroleum fumes			8052-42-4	~9	NA	1.0	NA
Benzaldehyde		C7H6O	100-52-7	9.49	1	0.9	1.5
Benzene		C6H6	71-43-2	9.244	0.4	0.46	0.59
Benzene thiol	Thiophenol	C6H5SH	108-98-5	8.32	NA	0.7	0.8
Benzoic acid		C7H6O2	65-85-0	9.30	NA	0.7	NA
Benzonitrile	Cyanobenzene	C7H5N	100-47-0	9.62	2	0.7	0.8
Benzoquinone, o-		C6H4O2	583-63-1	9.3	NA	1	NA
Benzoquinone, p-		C6H4O2	106-51-4	10.01	NA	1	NA
Benzoyl bromide		C7H5BrO	618-32-6	9.65	NA	2	NA
Benzyl 2-phenylacetate		C15H14O2	102-16-9	~9	NA	0.5	NA
Benzyl acetate		C9H10O2	140-11-4	~9	NA	0.6	NA
Benzyl alcohol		C7H8O	100-51-6	8.26	0.9	1.3	1.1
Benzyl chloride		C7H7Cl	100-44-7	9.14	0.28	0.48	NA
Benzyl formate		C8H8O2	104-57-4	9.32	0.66	0.8	NA
Benzyl isobutyrate		C11H14O2	103-28-6	~9	NA	0.5	NA
Benzyl nitrile		C8H7N	140-29-4	9.39	NA	1	NA
Benzyl propionate		C10H12O2	122-63-4	~9	NA	0.5	NA
Benzylamine		C7H9N	100-46-9	7.56	NA	0.6	NA
Biphenyl	Diphenyl	C12H10	92-52-4	8.23	NA	0.4	0.6
Borneol		C10H18O	507-70-0	~9	NA	0.8	NA
Boron trifluoride		BF3	7637 07 2	15.5	ZR	ZR	ZR
Bromine		Br2	7726-95-6	10.55	0.74	15	ZR
Bromine pentafluoride		BrF5	7789-30-2	13.17	ZR	ZR	ZR
Bromo-2,2-dimethylpropane, 1-	Neopentyl bromide	C5H11Br	630-17-1	10.04	NA	2	NA
Bromo-2-chloroethane, 1-		C2H4BrCl	107-04-0	10.57	NA	8	ZR
Bromo-2-methylpentane, 1-		C6H13Br	25346-33-2	10.09	NA	2	NA
Bromoacetone		C3H5BrO	598-31-2	9.73	NA	1	NA
Bromoacetylene		C2HBr	593-61-3	10.31	NA	4	ZR
Bromobenzene		C6H5Br	108-86-1	8.98	0.2	0.3	0.3
Bromobutane, 1-		C4H9Br	109-65-9	10.13	NA	1	NA
Bromobutane, 2-		C4H9Br	78-76-2	10.01	NA	1.5	NA
Bromochloromethane		CH2ClBr	74-97-5	10.77	NA	ZR	ZR
Bromocyclohexane		C6H11Br	108-85-0	9.87	NA	3	NA
Bromoethane		C2H5Br	74-96-4	10.29	NA	5.0	NA
Bromoethanol, 2-		C2H5BrO	540-51-2	10.00	NA	2	NA
Bromoethyl methyl ether, 2-		C3H7OBr	6482-24-2	10.00	2	2.5	NA
Bromofluoromethane		CH2FBr	373-52-4	~11	NA	ZR	ZR
Bromoform	Tribromomethane	CHBr3	75-25-2	10.48	0.5	2.8	ZR
Bromopentane, 1-	n-Pentyl bromide	C5H11Br	110-53-2	10.1	NA	2	NA
Bromopropane, 1-	n-Propyl bromide	C3H7Br	106-94-5	10.18	0.6	1.3	NA
Bromopyridine, 3-		C5H4BrN	625-55-1	9.75	NA	2	NA
Bromopyridine, 3-		C5H4BrN	1120-87-2	9.94	NA	2	NA
Bromotrifluoromethane		CF3Br	75-63-8	11.78	NA	ZR	ZR
Bromotrimethylsilane		C3H9BrSi	2857-97-8	10.00	NA	2	NA
But-2-ynal		C4H4O	1119-19-3	10.2	NA	3	NA
But-3-ynal		C4H4O	52844-23-2	9.85	NA	1.5	NA
Butadiene diepoxide, 1,3-		C4H6O2	1464-53-5	10.00	1.2	4.0	NA
Butadiene, 1,3-		C4H6	106-99-0	9.07	1.1	0.8	0.8
Butane, n-		C4H10	106-97-8	10.63	2	44	ZR
Butanedione, 2,3-	Biacetyl, Diacetyl	C4H6O2	431-03-8	9.56	NA	0.4	NA
Butanoic acid		C4H8O2	107-92-6	10.17	NA	5.0	NA
Butanol, 1-		C4H10O	71-36-3	10.04	1.4	4.0	NA

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INSTRUMENTS

Electrochemical Toxic Gas Sensor

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INSTRUMENTS

Electrochemical Sensors

5 Key Factors that separate Riken sensors from the competition

- Electrode material
- Bias voltage
- Electrolyte
  - Sulfuric acid
  - Potassium Iodide
  - Potassium Iodate
- Reaction area of electrode
- Electrolyte reaction

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Electrochemical Sensors

- Long life (2+ years)
- Excellent stability
- High degree of selectiveness
- Easy to replace and calibrate

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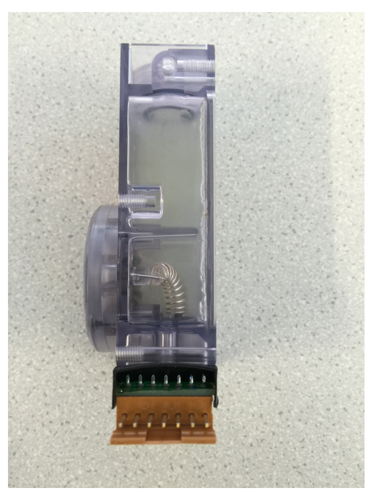
Electrochemical Sensors

- May require bias stabilization period
- Replace if:
  - Sensor has low span
  - Sensor is unstable
  - Unable to set zero
  - Electrolyte is contaminated
  - Sensor is leaking



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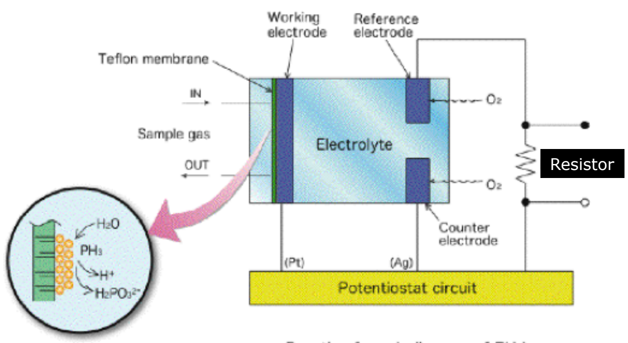
Electrochemical Sensors



Reaction formula (In case of PH_3)

Working electrode : $PH_3 + 3H_2O \rightleftarrows H_2PO^{3-} + 7H^+ + 6e^-$

Reference electrode : $3/2\ O_2 + 6H^+ + 6e^- \rightleftarrows 3H_2O$

Counter electrode : $1/2\ O_2 + 2H^+ + e^- \rightleftarrows H_2O$

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Sensor Troubleshooting

Symptom	Probable Cause	Corrective Action
• Catalytic bead LEL sensor will not zero	• Open or high offset sensor • Open wire in sensor circuit • Defective LEL sensor amplifier (if applicable)	• Replace sensor • Ring out sensor wiring, especially if sensor is remote mounted from controller or amplifier. Replace wiring as needed. • Replace amplifier as required. • Note: To assist in troubleshooting, swap sensor and/or amplifier from a known working unit to confirm problem. Also, relocate sensor and/or amplifier and attach directly to main controller to confirm if wiring problem.
• Catalytic bead LEL sensor readings are unstable or random spiking up or downscale	• Sensor element has intermittent connection or corroded • Loose wire • Noise created by EMI or RFI • Defective pre-amp • Defective amplifier	• Replace sensor • Tighten all wiring terminals • Make sure sensor wires are shielded and properly grounded. Note: Do not attach ground wires in the transmitter housing and at the controller. Tape off drain wire in the amplifier housing and connect the drain wire at the ground terminal at the controller. • If shielded and grounded correctly, increase alarm delay as needed
• Catalytic bead LEL sensor will not span with calibration gas	• Sensor catylast depleted and/or sensor is contaminated • Incorrect test gas • Incorrect sensor type • Incorrect amplifier or LEL sensor current setting	• Replace sensor • Verify proper gas concentration and that gas is in air if using a catalytic bead sensor • Make sure that the sensor being calibrated is for the proper gas. Example H2 specific sensor installed and calibrating using methane. • Make sure that amplifier current is properly set for the correct sensor

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Sensor Troubleshooting

Symptom	Probable Cause	Corrective Action
• Electrochemical toxic gas sensor will not zero in fresh air or with zero emissions air applied or will not span using calibration gas.	• Sensor is expired • Sensor pre-amp is bad • Amplifier (if applicable) is bad	• Replace sensor as required • Replace sensor pre-amp • Replace amplifier if needed. • Note: If there are other same sensors on the system that are working properly, swap components, such as sensor, then pre-amp then amp to determine what component has failed.
• Electrochemical toxic gas sensor will not span with test gas.	• Electrochemical sensor expired • Test gas expired • Incorrect test gas	• Replace sensor • Replace test gas • Verify that calibration gas is of the proper type and concentration
• Oxygen sensor can not be set to fresh air value (20.9%)	• Expired oxygen sensor • Sensor output too low or too high	• Replace oxygen sensor • For partial pressure oxygen sensors, measure across the White and Green wires for output. Normal output in fresh air should be between 12 and 18 mV DC. • Capillary oxygen sensors must be measured pluged into their respective preamp housing.
• Infrared LEL gas sensor will not zero with fresh air applied.	• Open IR source in sensor • Open wire in detector line	• Replace IR sensor • Ring out wires in sensor circuit to verify none are open or shorted.
• Infrared LEL gas sensor will not span with calibration gas.	• Sensor contaminated • Improper gas being used	• Replace IR LEL sensor • Verify that the test gas is the proper type for the sensor.

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Understanding Date Codes

- Each RKI Sensor has a date code to determine warranty begin date.
  - The date code may be a small adhesive label on the sensor or may be read from the serial number on the sensor.
  - Example: S/N 792D01278AT
    - Date code is 79 (Mfg. date)
    - First numeral is the year (2017)
    - Second numeral is the month (August)
    - Months are coded 1=Jan to 9= Sept. Oct.= X, Nov. = Y and Dec. = Z.
    - Note: Warranty for this sensor starts on December 2017 based upon D/C sticker 7Z.

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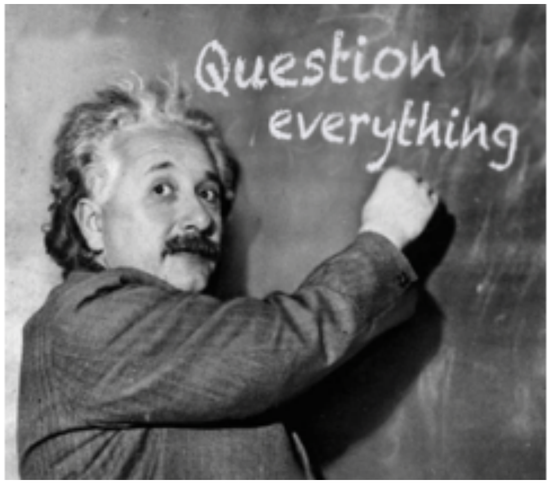
INSTRUCTIONS

Questions?



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