Combustible Gas Sensors

Introduction

This Note describes the characteristics of sensors measuring Lower Explosive Limit (LEL) percentages of combustible gases and vapors. It compares pellistor-type and NDIR LEL sensors and describes handling of sensor poisons. Lists of Correction Factors (CFs) that are used in mPower instruments are included, along with CFs used in EMEA countries.

Pellistor-Type LEL Sensors

Pellistor LEL Sensor

- Are low cost
- Measure all volatile combustible gases including hydrogen
- Require oxygen
- Are subject to catalyst poisons
- Are not good for heavy chemicals like diesel

Pellistor-type LEL sensors work by oxidizing combustible vapors that diffuse into the sensor using a heated catalytic bead. The additional heat released by oxidation changes the resistance in a Wheatstone bridge circuit, which is correlated to the gas concentration. Therefore, at least 10% by volume oxygen is required in the sampled gas for pellistor-type LEL sensors to sustain catalytic oxidation, and the calibration gas should have an air matrix instead of nitrogen. Advantages of Pellistor LEL sensors is that they are inexpensive and measure all volatile combustible gases present including hydrogen. A disadvantage is that they require the sample gas to diffuse through a flame-arresting frit and therefore they respond poorly to heavier compounds such as diesel fuel. Another important disadvantage is that the pellistor catalyst is subject to poisoning by certain compounds including silicones, hydrogen sulfide, acids, and chlorinated compounds.

NDIR-Type LEL Sensors

NDIR LEL Sensor

- Cost more but last longer
- Do not measure hydrogen
- Do not require oxygen
- Are not subject to poisons but can be affected by physical deposits
- Are OK for heavy compounds like diesel
- Have extended range versions up to 100% methane

Non-Dispersive Infrared (NDIR) sensors work by measuring the amount of light absorbed by the C-H bonds on hydrocarbons, such as methane and propane. Flammable compounds that do not contain any C-H bonds, such as hydrogen (H_2) and carbon disulfide (CS_2) cannot be measured. Therefore, NDIR sensors may underestimate the explosion hazard of an atmosphere and should not be used in any situation that has a possibility of containing H_2 or CS_2 gas at combustible levels. However, a major advantage is that NDIR sensors are not subject to the poisoning that affects pellistor-type LEL sensors. In addition, they do not require oxygen to function and can be used to measure hydrocarbons in inert atmospheres such as nitrogen or argon, and calibration gas for them can be supplied in pure nitrogen. By the same token, NDIR-LEL sensors may overestimate explosion hazard when not enough oxygen is present to support runaway combustion.

European vs US LEL Values

In 2010, Europe and other EMEA countries (Europe, Middle East and Africa) who require ATEX certification switched to using IEC (IEC60079) and EU (EN61779) standards that define LEL concentrations differently than the ISO10156 procedure used in the US. The US procedure measures LEL values in a static chamber, whereas the IEC/EU procedure uses a stirred gas

chamber that often results in slightly lower LEL values. The most important result is that the US still defines 100% LEL as 5.0 Vol% methane, while EMEA countries now use 4.4 Vol%. New CFs based on the IEC/EU LEL values are given in the table below.

Applying Correction Factors

The best accuracy is always obtained by using the same calibration gas as the gas to be measured. However, if methane is used to calibrate, the user can select any measurement gas from the list and multiply the reading by the CF to get the true LEL value:

True %LEL = %LEL Reading x CF

The table lists the LEL CF values that are programmed into POLI instrument firmware, based on US LEL values for pellistor sensors. If the user calls up one of these LEL measurement compounds, the factor will automatically be applied so the instrument reads correctly in units of the measured gas.

If the CF for EU/EMEA or NDIR sensor is needed, it must be programmed in as a custom factor using mPower Suite software (see section below, and Section 6 of the POLI Users Guide).

⚠ **CAUTION! NDIR Correction Factors are only useful up to about 20%LEL.** For most applications where early warning is desired and alarms are set around 10% or 20% LEL, NDIR factors can be used. However, NDIR sensors have very different linearities for methane vs other hydrocarbons, and therefore readings approaching 100% LEL are not accurate for a sensor calibrated with methane but used to measure other hydrocarbons, or vice versa. For non-methane hydrocarbons, better accuracy is obtained using a propane version of the NDIR LEL sensor. Contact mPower for details and availability.

Handling Poisons for Pellistor Sensors

Poisons and Inhibitors*:* As noted above, pellistor sensors can lose response when exposed to sensor poisons that either permanently deactivate the catalyst or temporarily reduce its response. Silicone compounds, such as those present in many lubricants and cleaners are the most common poisons and should be kept away from the sensor. Acids such as muriatic acid (HCl), sulfuric acid, nitric acid and acetic acid can corrode the sensor. Some VOCs such as chlorinated, nitrogen-containing and sulfur-containing compounds can form acids during combustion on the sensor and thus reduce response. Hydrogen sulfide and mercaptans also inhibitor sensor response, but sometimes just temporarily. Keep exposure to potential poisons as short and as low a concentration as possible.
Response Recovery: In some cases, response can be recovered simply by turning on the pellistor sensor and letting it run in clean air for several hours or days. For faster recovery, place the unit into diagnostic mode (using mPower Suite) and expose the LEL sensor to 100 %Vol methane for a few seconds or 20 %Vol methane for 5-10 seconds. This procedure raises the sensor temperature enough to burn off the surface and recover sensitivity. Longer exposure times do not help much because oxygen is needed for the process, but repeating the process once or twice may help.

Correction Factors for LEL Sensors Calibrated to Methane

Compound	100% LEL in Vol%		LEL CF Pellistor		LEL CF NDIR	
	US	EU/EMEA	US	EU/EMEA	US	EU/EMEA
Acetaldehyde	4.0	4.0	1.8	1.6		
Acetic Acid	4.0	4.0	3.4	3.0		
Acetic Anhydride	2.7	2.0	2.0	2.4		
Acetone	2.5	2.5	2.2	1.9	1.0	0.88
Acetylene	2.5	2.3	2.8	2.7		
Allyl Alcohol	2.5	2.5	1.7	1.5		
Ammonia	15.0	15.0	0.8	0.7		
Aniline	1.3	1.2	3.0	2.9		
Benzene	1.3	1.2	2.2	2.1		
Butadiene	2.0	1.4	2.5	3.1		
Butane, i-	1.8	1.3	1.7	2.1		
Butane, n-	1.9	1.6	2.0	2.1	0.30	0.31
Butanol, t-	2.4	2.4	1.8	1.6		
Carbon Monoxide	12.5	10.9	1.2	1.2		
Chlorobenzene	1.3	1.4	3.0	2.5		
Cyclohexane	1.3	1.2	2.5	2.4		
Dichloroethane, 1, 2-	6.2	6.2	1.5	1.3		
Dichloromethane	13.0	13.0	1.0	0.9		
Ethane	3.0	2.4	1.4	1.5	0.30	0.33
Ethanol	3.3	3.1	1.7	1.6	0.52	0.49
Ethene	2.7	2.3	1.4	1.4	1.0	1.0
Ethyl Acetate	2.0	2.2	2.2	1.8	0.52	0.42
Ethylbenzene	0.8	1.0	2.8	2.0		
Ethylene Oxide	3.0	2.6	2.3	2.3	0.26	0.26
Ethyl Ether	1.9	1.9	2.3	2.0		
Ethyl Mercaptan	2.8	2.8	1.8	1.6		
Gasoline	1.3	1.3	2.1	1.8		
Heptane,n-	1.1	1.1	2.4	2.1		
Hexane,n-	1.1	1.0	2.3	2.2	0.24	0.23
Hydrogen	4.0	4.0	1.1	1.0	NR	NR
Isobutylene	1.8	1.6	1.5	1.5		
Isopropanol	2.0	2.0	2.6	2.3	0.42	0.37
Methane	5.0	4.4	1.0	1.0	1.0	1.0
Methanol	6.0	5.5	1.5	1.4	0.67	0.64
Methyl Acetate	3.1	3.2	2.2	1.9		
Methyl Bromide	10.0	10.0	1.1	1.0		
Methyl Chloride	8.1	8.1	1.3	1.1	1.5	1.3
Methylcyclohexane	1.2	1.2	2.6	2.3		
Methyl Ether	3.4	3.4	1.7	1.5		
Methyl Ethyl Ketone	1.4	1.4	2.6	2.3	0.58	0.51
Methyl Mercaptan	3.9	3.9	1.6	1.4		
Naphthalene	0.9	0.9	2.9	2.6		
Nonane, n-	0.87		~3			
Octane,n-	1.0	1.0	2.9	2.6		
Pentane	1.5	1.1	2.2	2.6	0.27	0.32
Phosphine	1.6	1.6	0.3	0.3		
Propane	2.1	1.7	1.6	1.7		
Propene	2.0	2.0	1.5	1.3	0.52	0.46
Propylamine,n-	2.0	2.0	2.1	1.8		
Propylene Oxide	2.3	2.3	2.6	2.3		
Toluene	1.1	1.0	2.6	2.5	0.36	0.35
Triethylamine	1.2	1.2	2.5	2.2		
Turpentine	0.8	0.8	2.9	2.6		
Vinyl Chloride	3.6	3.6	1.8	1.6		
Xylene,m-	1.1	1.1	2.7	2.4	0.45	0.40
Xylene,o-	0.9	0.9	3	2.6	0.45	0.40
Xylene,p-	1.1	1.1	2.8	2.5	0.45	0.40

Propane or Pentane Calibration for Pellistor Sensors
Sensor poisons are especially important to avoid when measuring non-methane compounds and using correction factors. This is because poisons often de-activate response to methane more than to other VOCs like propane and pentane, which means that the correction factor changes. Fortunately, if calibrating with methane, the other compounds will over-respond and the error will be on the safe side. To prevent false alarms one can calibrate with pentane or propane (or whatever VOC is being measured). In this case the factors in the table below need to be adjusted by dividing by the CF of the calibration gas. For example, if propane (CF = 1.6) is used to calibrate for measurements of gasoline (CF = 2.1), the new CF is calculated as 2.1/1.6 = 1.3. The POLI instrument does all these calculations automatically so the user can simply select the calibration gas as propane and measurement gas as gasoline, and the concentrations will display correctly.

⚠ **WARNING!** Use propane or pentane calibration only in areas known NOT to contain methane. Otherwise, as sensor response degrades, methane could give false low readings resulting in an undetected explosion hazard.

Propane or Butane Calibration for NDIR Sensors [Note CAUTION! Above on NDIR CFs]
At present there are no CF Lists for NDIR Sensors built into mPower instrument firmware or mPower Suite. Therefore, we offer the following work-around procedures:

1) The **best option** is to use propane or butane LEL gas to calibrate directly. The gas name will be Methane while the response will be in Butane/Propane equivalents (the responses of these two gases are almost the same)

If only methane gas is available for calibration, there are two options:

2) **POLI or MUNI**: 2.2% or 2.5% CH_4 (50%LEL) to calibrate while having the span value at 15.5%LEL (calculated as CF of 0.31 x 50%LEL). The gas name will be Methane while the response will be in Butane/Propane equivalents.
3) **POLI Only**: Set up a custom LEL factor as described in the POLI manual. For methane calibration in EMEA countries the LEL factor for butane is 0.31. Then make sure the span gas is selected as Methane and Measurement Gas as this Butane User Gas. Calibrate normally using 2.2% CH_4 (50%LEL) while having the span value at 50 %LEL. The gas name and response will be for Butane/Propane.