Using PIDs For 10% Of LEL Decisions

One of the many requirements for entering confined spaces called for in 29 CFR 1910.146 (OSHA's confined space entry standard) is the measurement of confined spaces for flammable gases. Prior to entry of a confined space, the level of flammable gases must be below 10% of LEL (lower explosive limit). The most common sensor used for measuring LEL is the Wheatstone bridge/catalytic bead/pellistor sensor ("Wheatstone bridge"). While useful in a wide variety of applications, in some settings Wheatstone bridge LEL sensors either don't have enough sensitivity to a particular chemical, or chemicals used in the environment can render the Wheatstone bridge sensor inoperable. In these types of circumstances, PIDs (photoionization detectors) can provide an alternative, highly accurate, and poison-free means of measuring 10% of LEL for confined space entry.

LEL Sensors Explained

A Wheatstone bridge LEL sensor is simply a tiny electric stove with two burner elements. One element has a catalyst (such as platinum) and one doesn't. Both elements are heated to a temperature that normally would not support combustion. However, the element with the catalyst "burns" gas at a low level and heats up relative to the element without the catalyst. The hotter element has more resistance and the Wheatstone bridge measures the difference in resistance between the two elements, which correlates to LEL. Unfortunately, Wheatstone bridge sensors fail to an unsafe state; when they fail, they indicate safe levels of flammable gases. Failure and/or poisoning of Wheatstone bridge LEL sensor can only be determined through challenging Wheatstone bridge sensors with calibration gas.

LEL Sensor Limitations

1. "Heavier" hydrocarbon vapors have difficulty diffusing into the LEL sensor and reduce its output
2. Common chemicals can poison LEL sensors.

1. "Heavier" hydrocarbon vapors have difficulty diffusing into LEL sensors and reduce their output

Some "Heavier" (low vapor pressure/high flashpoint) hydrocarbon vapors have difficulty diffusing through the sintered metal flame arrestor on LEL sensors. This flame arrestor is necessary to prevent the sensor itself from starting a fire and does not prevent gases like methane, propane and ethane from reaching the Wheatstone bridge. However, low vapor pressure/high flashpoint hydrocarbons like gasoline, diesel, turpentine, solvents, etc., diffuse through the flame arrestor slower, so less vapor reaches the Wheatstone bridge and the sensor gives little to no response.

2. Common Chemicals can poison LEL sensors

Under the best of situations, it is difficult for Wheatstone bridge LEL sensors to measure many hydrocarbons. However, common industrial chemicals can degrade and destroy LEL sensor performance. Some act very quickly (acute poisons) and some act over time (chronic poisons). As with human toxicity, Wheatstone bridge LEL sensor "poisoning" is dosage dependent.

Acute LEL Sensor Poisons:

- Silicone containing compounds
- Lead-containing compounds
- Sulfur-containing compounds
- Phosphates and phosphorous-containing compounds
- Hexamethyldisilazane (HMDS)

Just a few parts per million (ppm) of these compounds are sufficient to degrade the sensing performance of a Wheatstone bridge LEL sensor. Silicon is most common of these acute poisons and it is found in a wide range of products, including lubricants, adhesives, silicone rubbers (including caulking and sealant compounds), waxes & polishes, firefighting and vapor suppression foams and others.

Chronic LEL Sensor Poisons

- Hydrogen Sulfide
- Halogenated Hydrocarbons (Freons, trichloroethylene, methylene chloride)
- Styrene

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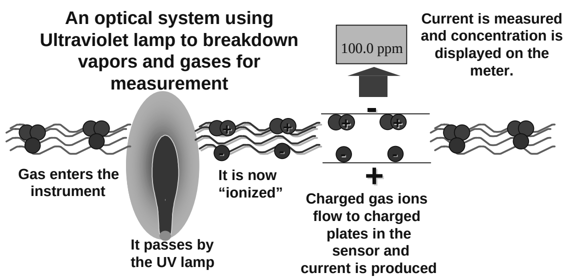
Also called “inhibitors,” chronic LEL sensor poisons don’t act as quickly on Wheatstone bridge sensors. Often, exposure to clean air will allow the sensor to “burn off” these compounds. But when operated in an atmosphere containing these chemicals Wheatstone bridge LEL sensor output ultimately falls to zero (for more information, reference Technical Note TN-144: Handling LEL Sensor Poisons).

What Is A PID?

A photoionization detector measures VOCs (volatile organic compounds) and other toxic gases in concentrations from ppb up to 10,000 ppm. A PID is a very sensitive broad-spectrum monitor, not unlike a “low-level LEL monitor.”

How does a PID work?

A PID uses an ultraviolet (UV) light source (*Photo*=light) to break down chemicals to positive and negative ions (*ionization*) that can easily be measured



with a *detector*. The detector measures the charge of the ionized gas and converts the signal into current. The current is then amplified and displayed on the meter as “ppm.” After measurement, the ions re-form the original gas or vapor. RAE PIDs are not dependent on oxygen to make a measurement and PIDs fail safe. When the PID lamp fails to light the PID provides a “lamp” alarm so operators immediately know that it is not working.

PIDs: Alternatives for 10% of LEL

Photo Ionization Detectors (PIDs) are sensitive hydrocarbon sensors originally designed to measure ppm levels of hydrocarbons for the environmental industry. PIDs are uniquely suited for measuring hydrocarbon mixtures. Because PIDs use an optical technology, they are resistant to the poisons that can ruin Wheatstone bridge sensors. Recent breakthroughs in PID technology make them compact, rugged and affordable enough for confined space entry. (For a detailed explanation of PIDs, refer to Application Note AP-000.)

PIDs: More Accurate 10% of LEL Sensors

Based upon the following chart, one can see that PIDs will provide the most consistent readings for a decision at 10% of LEL in a hydrocarbon environment when compared to a Wheatstone bridge LEL sensor when measuring Jet Fuel:

Sensor	Display	Actual (ppm)
PID Display	800	800
PID low (-10%)	720	720
PID high (+10%)	880	880
LEL Sensor Display	10	800
LEL Sensor low (-3%)	**7**	***560***
LEL Sensor high (+3%)	**13**	***1040***

Sensor accuracy affects user confidence. At 10% of LEL, a PID is clearly the more accurate sensor:

- PID range of uncertainty: 160 ppm
- LEL Sensor range of uncertainty: 480 ppm

So a Wheatstone bridge LEL sensor has three times the range of uncertainty relative to a PID for measuring 10% of jet fuel LEL. In reviewing over 175 common flammable chemicals seen by a PID it was found that LEL sensors have three times the range of uncertainty relative to a PID for measuring 10% of LEL.

OSHA’s Stand on LEL sensors

29 CFR 1910.146 is a performance based standard and does not specify they type of sensor required. In paragraph (c)(5)(ii)(C) the requirement is simply stated:

> “Before an employee enters the space, the internal atmosphere shall be tested, with a calibrated direct-reading instrument, for oxygen content, for flammable gases and vapors, and for potential toxic air contaminants, in that order.”

Just as 29 CFR 1910.146 does not specify that a fuel-cell oxygen sensor be used for determining oxygen level (even though this is the most prevalent sensor

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for this measurement), 29 CFR 1910.146 does not specify Wheatstone bridge sensors for flammability measurements. The critical statement is that it must be a “calibrated direct-reading instrument...for flammable gases and vapors.”

As long as the PID can measure all of the flammable vapors ever expected in the confined space environment then it can be used for making 10% of LEL decisions.

Even if the PID can’t see all of the flammable gases in a confined space, it still can be used to supplement the readings of other flammability sensors.

Steps for Using a PID for 10% of LEL for a Single Specific Chemical

1. Make sure the PID is sensitive to the chemical (the Correction Factor should be less than 10).
2. Find the LEL of the chemical, and multiply by 10,000 to get the LEL in parts per million (ppm).
3. Divide this number by 10, and you have the 10% of LEL in ppm.
4. Set the high alarm in the PID to 10% of LEL in ppm (many times the low alarm is utilized for a toxicity alarm).

Example:

1. Styrene’s ionization potential is 8.43 eV and the Correction Factor with a 10.6eV lamp is 0.4. So, the PID is very sensitive to styrene and measuring styrene with a PID is a good fit (refer to AP-211: PIDs for Continuous Monitoring of VOCs).
2. Styrene’s LEL is 0.9% by volume, or 9,000 ppm.
3. 10% of LEL for styrene is 900 ppm.
4. Set the High PID alarm to 900 ppm in units of styrene. The low alarm is typically set to 20/50/100 ppm (AGCHI/NIOSH/OSHA limits), depending on the end user’s preference.

Making a 10% of LEL decision with a PID in a Mixture with Varying Make-up of Chemicals

Many times we can identify the chemicals present, but their relative concentrations vary throughout a process. Or, in situations like HazMat Response, one cannot predict the chemicals present or their relative concentrations. Therefore, we have to look at another way of using the PID to make LEL decisions. Setting alarms in a varying or unknown mixture means that you have to simultaneously interpret both the flammability (LEL) and PID sensitivity (Correction Factors) for all of the chemicals involved.

Fortunately, this is easier than it sounds. Every mixture has a compound that is the most flammable and “controls” the setpoint for the whole mixture. Determine that chemical, and you can determine a conservative setpoint for the entire mixture. The basic assumption is that if we are safe for the “worst” chemical in a mixture we will be safe for all of the others.

1. Express 10% LELs in equivalent units
2. Look for the compound with the lowest 10% LEL in equivalent units.
3. Set the PID for that setpoint, and you are safe for all of the chemicals in the mixture.

Table 1:

Chemical Name	10% LEL ppm
Ethanol	3300
Toluene	1100
Acetone	2500

Table 1 is a simple example where ethanol appears to be the least flammable compound and toluene appears to be the most flammable, because it has the lowest 10% LEL. This is because most people are accustomed to making decisions solely on flammability.

Users of meters rarely take into account that meters have varying sensitivities to different chemicals. Therefore, Table 1 only provides half of the decision-making equation. The 10% LEL is expressed in units of different chemicals. When trying to use a PID to make a decision regarding which is the “worst” chemical, one might be comparing 1000 apples to 100 pineapples. What is required is to express the 10% LEL in a common unit of measurement.

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Because PIDs are calibrated to isobutylene, and Correction Factors are expressions of PID sensitivity to a chemical relative to isobutylene, this is easy to do. First let's look at this theoretically:

10% $LEL_{Chemical}$: 10% LEL in chemical units (ppm).

$$CF = \frac{\text{PID Isobutylene Response} \times \text{Concentration of gas (ppmv)}}{\text{Conc. of isobutylene (ppmv)} \times \text{Response of gas on PID}}$$

$$10\%\ LEL_{Isobutylene} = \frac{10\%\ LELchemical\ (ppmv)}{CFchemical}$$

So, to get the 10% LEL in units of isobutylene, we divide the exposure limit in chemical units by the ratio of chemical units to isobutylene units.

Table 2:

Chemical Name	**10.6 eV CF**	**10% $LEL_{Chemical}$**	**10% $LEL_{Isobutylene}$**
Ethanol	12	3300	**275**
Toluene	0.50	1100	**2200**
Acetone	1.1	2500	**2273**

In Table 2, the far right column expresses all of the LELs in equivalent units of isobutylene. Now the chemicals can be compared on equal footing. One can compare apples to apples. While ethanol does not have as low a 10% LEL as toluene, the low PID sensitivity to Ethanol combined with the highest 10% LEL in the table makes Ethanol the "controlling compound" when the 10% LELs are expressed in equivalent isobutylene units. In this example, the PID is left on an isobutylene measurement scale and the alarm is set to 275 ppm. As long as the PID does not alarm, then we are below 10% of LEL for all of these three chemicals.

Important: In the rest of this discussion, 10% LELs in "Isobutylene Units" calculated by–

$$10\%\ LEL_{Isobutylene} = \frac{10\%\ LELchemical\ (ppmv)}{CFchemical}$$

–are called RAE Units 10% LEL (RU 10% LEL) because their calculation involves a RAE PID Correction Factor, which should only be applied to RAE Systems PIDs. Similar calculations can be done for any other PID brand that has a published list of Correction Factors.

Note: Setting alarm limits this way is the most conservative, restrictive approach, required by the limited information.

Comparing RAE Systems PIDs for 10% of LEL Decisions with NFPA 325

There are 1,475 flammable liquids, gases and volatile solids listed in NFPA 325. Of these 1,475 chemicals, only 393 (27%) have LELs listed in NFPA 325. Of these 393 chemicals with LELs listed, RAE Systems has correction factors for 117 (30%), so the PID can be used to make a 10% of LEL.

The 1000 ppm = 10% of LEL Rule

Using the RAE Unit logic allows one to use the PID to help determine LELs. Table 3 is a list of 128 NFPA 325 chemicals and 178 total flammable chemicals. A RAE PID with a 10.6 eV lamp (the most common PID lamp) set to the following alarms and not beeping provides 10% of LEL protection from:

- **75 NFPA 325 chemicals (110 total) at a 1000 ppm alarm**, including major solvents like xylene, toluene, MEK, MPK, and acetone
- **96 NFPA 325 chemicals (141 total) at a 500 ppm alarm**, from isobutyl acetate to vinyl bromide.
- **116 NFPA 325 chemicals (165 total) at a 250 ppm alarm,** from n-hexane to vinyl bromide.
- **126 NFPA 325 chemicals (175) at a 100 ppm alarm**, from naphtha to vinyl bromide.

Upon examining Table 3: "10% of LEL for Common Chemicals When Measuring on an Isobutylene Scale," one can see that for most common industrial chemicals a setpoint of 1,000 ppm in isobutylene units is an appropriate alarm for 10% of LEL. This provides a conservative setpoint for all liquid fuel products, aromatics (benzene, styrene, xylene, etc.), ketones (MEK, MIBK, etc.) and many other common industrial chemicals. Some chemicals, like the alcohols, require more conservative setpoints.

Setting an alarm to 100 ppm would provide the highest level of protection, but it would also provide the most alarms. Too many alarms would be like

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"the boy who cried wolf" and would reduce user confidence in the PID.

Examples:

Aircraft Wingtank Entry: Difficulty Measuring Jet Fuel with Wheatstone bridge and Silicone Poisoning
Commercial and Military aircraft maintenance programs are quickly standardizing on PIDs for confined space entry in aircraft wingtanks. Not only do Wheatstone bridge sensors have tremendous difficulty in measuring a low vapor pressure/high flashpoint flammable liquid like jet fuel, but silicon, an acute poison for Wheatstone bridge sensors, is present in many chemicals used in aircraft maintenance from hydraulic fluids to sealants. 10% of LEL for jet fuel is 800 ppm. The high PID alarm is set to 800 in units of jet fuel. This also provides protection for 10% of LEL for all of the flammable liquids used in aircraft maintenance including aromatics and ketones (refer to AP-200: PIDs and Aircraft Wingtank Entry).

Paper Plant: Difficulty Measuring Turpentine with a Wheatstone bridge
Turpentine is a low vapor pressure/high flash point flammable liquid that is extremely difficult to measure with a Wheatstone bridge sensor. An experienced worker measured a confined space prior to a welding operation in a paper plant and detected no flammable vapors. However, the welding operation ignited turpentine vapors that went undetected by the properly functioning and calibrated Wheatstone bridge LEL sensor. Subsequently this facility standardized on PIDs with a high alarm set to 800 ppm (10% of LEL in ppm) for confined space entries.

Deodorant Filling Plant: Acute Silicone Poisoning
In addition to flammable solvents and propellants, deodorants contain sizable amounts of silicone compounds. Wheatstone bridge LEL sensors typically last days or weeks in these applications. In contrast, PID optics are unaffected in these conditions and provide a reliable tool for 10% of LEL measurement. Due to the nature of some propellants, 11.7 eV lamps may be needed in these types of facilities to be able to measure all of the propellants. While an 11.7 eV lamp does not last as long as the standard 10.6 eV PID lamp, it can last longer than the Wheatstone bridge sensor in these environments and it fails safe.

Gasoline Tank Remediation: TEL Poisoning
Tetra Ethyl Lead (TEL) historically was used as an octane booster in gasolines but was regulated out of existence because of its human toxicity. However, TEL still can be found when removing old underground storage tanks. One contractor repeatedly replaced LEL sensors until it was determined that the old tanks did contain trace amounts of TEL. When doing underground work, it is always important to have a Wheatstone bridge sensor to be able to measure methane (PIDs can't measure methane). But the most immediate threat during the tank remediation was gasoline flammability, and the PID provides consistent, reliable results even when TEL is present.

Styrene Plants: Chronic Styrene Poisoning.
Styrene monomer polymerizes at temperatures above 200^{o} F (93^{o} C). Most Wheatstone bridge LEL sensors operate at or above this temperature. Therefore, styrene will polymerize on the hot catalyst, eventually rendering it inoperable. Exposure to clean air can help to reverse this process, but air that is completely free of styrene is rarely found in plants producing styrene. Therefore, the Wheatstone bridge LEL sensors in these facilities have short lives. PIDs have been used in many styrene plants to provide continuous monitoring of styrene vapors for toxicity using a threshold of 20/50/100 ppm (AGCIH/NIOSH/ OSHA limits), depending on the end user's preference. A high PID alarm of 900 ppm in styrene units provides a very accurate 10% of LEL alarm.

PIDs As Part of an Integrated Approach to 10% of LEL Measurement

PIDs are one more detective tool for making gas monitoring decisions.

Important! If a PID is used as the sole means of measuring flammable gases and vapors, one must be absolutely sure that the PID can measure all of the flammable gases expected in the environment.

Used alone, or in concert with other techniques of measuring flammable gases (Wheatstone bridge, infrared), PIDs can help boost operator confidence in

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their gas monitors by an accurate and reliable means of measuring 10% of LEL for many flammable gases.

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NFPA: *NFPA 325 Guide to Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids*, 1994 Edition, Quincy, MA

NIOSH: *Pocket Guide to Chemical Hazards,* NIOSH Publications, Cincinnati, OH 1994

RAE Systems: Correction Factors and Ionization Potentials (Technical Note TN-106)

RAE Systems: TN-144: Handling LEL Sensor Poisons

RAE Systems: AP-200: PIDs and Aircraft Wingtank Entry

RAE Systems: AP-211: PIDs for Continuous Monitoring of VOCs

RAE Systems: Applications and Technical Notes Guide, "Principles of Confined Space Gas Dectection"

Table 3: RAE Unit 10% of LEL for common chemicals when measuring on an isobutylene scale:

Note: NFPA 325 Chemicals are in bold Italics below.

Chemical Name	CF	LEL (%)	LEL ppm	10% of LEL	RU 10% LEL
Vinyl bromide	***0.40***	***9***	***90000***	***9000***	***22500***
Dichloroethene, t-1,2-	0.45	9.7	97000	9700	21556
Trichloroethylene	***0.54***	***8***	***80000***	***8000***	***14815***
Dichloroethene, c-1,2-	0.80	9.7	97000	9700	12125
Vinylidene chloride	***0.85***	***6.5***	***65000***	***6500***	***7647***
Methyl mercaptan	***0.60***	***3.9***	***39000***	***3900***	***6500***
Tetraethyl lead (as Pb)	***0.30***	***1.8***	***18000***	***1800***	***6000***
Methyl bromide	1.70	10	100000	10000	5882
Dimethyl disulfide	0.20	1.1	11000	1100	5500
Trichlorobenzene (1,2,4-)	***0.5***	***2.5***	***25000***	***2500***	***5435***
Methyl sulfide	0.44	2.2	22000	2200	5000
Ethyl mercaptan	***0.60***	***2.8***	***28000***	***2800***	***4667***
Ethylamine	***0.80***	***3.5***	***35000***	***3500***	***4375***
Ethyl sulfide	0.51	2.2	22000	2200	4314
Methylamine	1.20	4.9	49000	4900	4083
Methyl styrene(alpha-)	***0.50***	***1.9***	***19000***	***1900***	***3800***
Hexamethyldisilazane, 1,1,1,3,3,3-	0.24	0.8	8000	800	3333
Chlorobenzene	***0.40***	***1.3***	***13000***	***1300***	***3250***
Bromopropane,1-	1.50	4.6	46000	4600	3067
Chemical Name	**CF**	**LEL (%)**	**LEL ppm**	**10% of LEL**	**RU 10% LEL**
Toluidine, o-	0.50	1.5	15000	1500	3000
Mesitylene	0.35	1	10000	1000	2857
Dimethylformamide, N,N-	***0.80***	***2.2***	***22000***	***2200***	***2750***
Aniline	***0.48***	***1.3***	***13000***	***1300***	***2708***
Pyridine	***0.68***	***1.8***	***18000***	***1800***	***2647***
Pinene, a-	***0.31***	***0.8***	***8000***	***800***	***2581***
Diacetone alcohol	***0.70***	***1.8***	***18000***	***1800***	***2571***
Dimethylhydrazine, 1,1-	***0.78***	***2***	***20000***	***2000***	***2564***
Xylene, m-	***0.43***	***1.1***	***11000***	***1100***	***2558***
Xylene, p-	***0.45***	***1.1***	***11000***	***1100***	***2444***
Isoprene	***0.63***	***1.5***	***15000***	***1500***	***2381***
Butadiene	***0.85***	***2***	***20000***	***2000***	***2353***
Trimethylamine	***0.85***	***2***	***20000***	***2000***	***2353***
Turpentine	***0.35***	***0.8***	***8000***	***800***	***2286***
Furfural	***0.92***	***2.1***	***21000***	***2100***	***2283***
Acetone	***1.10***	***2.5***	***25000***	***2500***	***2273***
Benzene	***0.53***	***1.2***	***12000***	***1200***	***2264***
Dimethyl acetamide, N,N-	***0.80***	***1.8***	***18000***	***1800***	***2250***
Styrene	***0.40***	***0.9***	***9000***	***900***	***2250***
Toluene	***0.50***	***1.1***	***11000***	***1100***	***2200***
Vinyl actetate	***1.20***	***2.6***	***26000***	***2600***	***2167***
Naphthalene	***0.42***	***0.9***	***9000***	***900***	***2143***
Methyl hydrazine (Monomethyl hydrazine)	***1.20***	***2.5***	***25000***	***2500***	***2083***
Benzoyl chloride	***0.6***	***1.2***	***12000***	***1200***	***2000***
Dichloro-1-propene, 2,3-	1.30	2.6	26000	2600	2000
Diethylenetriamine	1.00	2	20000	2000	2000
Crotonaldehyde	***1.10***	***2.1***	***21000***	***2100***	***1909***
Methyl t-butyl ether	0.91	1.7	17000	1700	1868
Dimethylamine	***1.50***	***2.8***	***28000***	***2800***	***1867***
Diethylamine	***0.97***	***1.8***	***18000***	***1800***	***1856***
Xylenes (o-, m-, p- isomers).	0.49	0.9	9000	900	1837
Benzyl chloride	***0.60***	***1.1***	***11000***	***1100***	***1833***
Ethyl silicate	0.71	1.3	13000	1300	1831
Dioxane, 1,4-	***1.10***	***2***	***20000***	***2000***	***1818***
Isobutylene	1.00	1.8	18000	1800	1800
Phenol	***1.00***	***1.8***	***18000***	***1800***	***1800***
Vinyl chloride	***2.00***	***3.6***	***36000***	***3600***	***1800***
Butene, 1-	***0.90***	***1.6***	***16000***	***1600***	***1778***
Isopropyl ether	***0.80***	***1.4***	***14000***	***1400***	***1750***
Vinyl-2-pyrrolidinone, 1-	***0.80***	***1.4***	***14000***	***1400***	***1750***
Diethyl ether	***1.10***	***1.9***	***19000***	***1900***	***1727***
Benzyl cyanide	***0.60***	***1***	***10000***	***1000***	***1667***
Dicyclopentadiene	0.48	0.8	8000	800	1667
Cumene	***0.54***	***0.9***	***9000***	***900***	***1667***
Gasoline #1	***0.85***	***1.4***	***14000***	***1400***	***1647***
Methyl ethyl ketone	***0.86***	***1.4***	***14000***	***1400***	***1628***
Cyclohexene	0.80	1.3	13000	1300	1625
Methyl-2-pyrrolidinone, N-	0.80	1.3	13000	1300	1625
Pentanone(2-) (Methyl propyl ketone)	***0.93***	***1.5***	***15000***	***1500***	***1613***
Propylene glycol monomethyl ether acetate	***1.00***	***1.6***	***16000***	***1600***	***1600***

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Petroleum distillates	0.71	1.1	11000	1100	1549
Ammonia	9.70	15	#####	15000	1546
Butylamine, n-	1.10	1.7	17000	1700	1545
Ethyl benzene	0.52	0.8	8000	800	1538
Xylene, o-	0.59	0.9	9000	900	1525
Chemical Name	**CF**	**LEL (%)**	**LEL ppm**	**10% of LEL**	**RU 10%LEL**
Hexene, 1-	0.80	1.2	12000	1200	1500
Hexone (Methyl isobutyl ketone)	0.80	1.2	12000	1200	1500
Diisopropylamine	0.74	1.1	11000	1100	1486
Piperylene, isomer mix	0.69	1	10000	1000	1449
Picoline, 3-	0.90	1.3	13000	1300	1444
Propene	1.40	2	20000	2000	1429
Gasoline #2, 92 octane	1.00	1.4	14000	1400	1400
Dichloro-1-propene, 1,3-	0.96	1.3	13000	1300	1354
Jet fuel JP-5	0.60	0.8	8000	800	1333
Jet fuel JP-8	0.60	0.8	8000	800	1333
Methoxyethoxyethanol, 2-	1.20	1.6	16000	1600	1333
Chloroprene (beta-)	3.00	4	40000	4000	1333
Triethylamine	0.90	1.2	12000	1200	1333
Ethoxyethanol (2-), (Cellosolve)	1.30	1.7	17000	1700	1308
Jet fuel JP-4	1.00	1.3	13000	1300	1300
Cyclohexylamine	1.20	1.5	15000	1500	1250
Methylcyclohexane	0.97	1.2	12000	1200	1237
Cyclohexanone	0.90	1.1	11000	1100	1222
Hydrogen sulfide	3.30	4	40000	4000	1212
Diesel Fuel #2	0.66	0.8	8000	800	1212
Propionaldehyde	1.90	2.3	23000	2300	1211
Benzyl alcohol	1.10	1.3	13000	1300	1182
Tetrahydrofuran	1.70	2	20000	2000	1176
Kerosene	0.60	0.7	7000	700	1167
Methyl isocyanate	4.60	5.3	53000	5300	1152
Propylene glycol monomethyl ether	1.40	1.6	16000	1600	1143
Methyl methacrylate	1.50	1.7	17000	1700	1133
Stoddard Solvent	0.71	0.8	8000	800	1127
Methyl ether	3.10	3.4	34000	3400	1097
Carbon disulfide	1.20	1.3	13000	1300	1083
Diethylaminopropylamine, 3-	1.30	1.4	14000	1400	1077
Isopar M Solvent	0.66	0.7	7000	700	1061
Allyl alcohol	2.40	2.5	25000	2500	1042
Nicotine	0.70	0.7	7000	700	1000
Phenyl ether, vapor	0.70	0.7	7000	700	1000
1000 PPM Alarm					
Hydrazine	3.00	2.9	29000	2900	967
Nitrobenzene	1.90	1.8	18000	1800	947
Cyclohexane	1.40	1.3	13000	1300	929
Butoxyethanol, 2-	1.20	1.1	11000	1100	917
Isooctane	1.20	1.1	11000	1100	917
Dichloroethyl ether	3.00	2.7	27000	2700	900
Benzonitrile	1.60	1.4	14000	1400	875
Diesel Fuel #1	0.93	0.8	8000	800	860
Diphenyl (Biphenyl)	0.70	0.6	6000	600	857
Bromobenzene	0.60	0.5	5000	500	833
Butyl alcohol (tert-)	2.90	2.4	24000	2400	828
Diethanolamine	2.00	1.6	16000	1600	800
Methyl acrylate	3.70	2.8	28000	2800	757
Butyl acetate, (tert-)	2.00	1.5	15000	1500	750
Ethanolamine	4.00	3	30000	3000	750
Methoxyethanol, 2-	2.40	1.8	18000	1800	750
Ethyl hexyl acrylate, 2-	1.10	0.8	8000	800	727
Acrolein	3.90	2.8	28000	2800	718

Chemical Name	CF	LEL (%)	LEL ppm	10% of LEL	RU 10%LEL
Caprolactam	2.00	1.4	14000	1400	700
Isopropyl acetate	2.60	1.8	18000	1800	692
Allyl chloride	4.30	2.9	29000	2900	674
Acetaldehyde	6.00	4	40000	4000	667
Butyl acetate, (n-)	2.60	1.7	17000	1700	654
Toluene-2, 4-diisocyanate (TDI)	1.40	0.9	9000	900	643
Ethyl acrylate	2.40	1.4	14000	1400	583
Decane	1.40	0.8	8000	800	571
Decane	1.40	0.8	8000	800	571
Nonane	1.40	0.8	8000	800	571
Butyl acetate, (sec-)	3.00	1.7	17000	1700	567
Octane, n-	1.80	1	10000	1000	556
Isobutyl acetate	2.60	1.3	13000	1300	500
500 PPM Alarm					
Propyl acetate, n-	3.50	1.7	17000	1700	486
Hexanol, 1-	2.50	1.2	12000	1200	480
Amyl acetate (n-)	2.30	1.1	11000	1100	478
Isoamyl acetate	2.10	1	10000	1000	476
Propylene glycol	5.50	2.6	26000	2600	473
Methyl acetate	6.60	3.1	31000	3100	470
Ethyl (S)-(-)-lactate	3.20	1.5	15000	1500	469
Phosphine	3.90	1.79	17900	1790	459
Isobutyl alcohol	3.80	1.7	17000	1700	447
Epichlorohydrin	8.50	3.8	38000	3800	447
Acetic Anahydride	6.10	2.7	27000	2700	443
Amyl acetate (sec-)	2.30	1	10000	1000	435
Ethyl acetate	4.60	2	20000	2000	435
Butyl alcohol (sec-)	4.00	1.7	17000	1700	425
Heptane, n-	2.80	1.05	10500	1050	375
Propyl alcohol (n-)	6.00	2.2	22000	2200	367
Propylene oxide	6.50	2.3	23000	2300	354
Isopropyl Alcohol	6.00	2	20000	2000	333
Naphtha (Coal tar) {10% aromatics-RAE}	2.80	0.9	9000	900	321
Undecane	2.00	0.6	6000	600	300
Butyl alcohol (n-)	4.70	1.4	14000	1400	298
Ethyl alcohol	12.00	3.3	33000	3300	275
Ethene	10.00	2.7	27000	2700	270
Hexane, n-	4.30	1.1	11000	1100	256
250 PPM Alarm					
Amyl alcohol	5.00	1.2	12000	1200	240
Amyl alcohol (sec-)	5.00	1.2	12000	1200	240
Ethylene oxide	13.00	3	30000	3000	231
Acrylic Acid	12.00	2.4	24000	2400	200
Ethylene glycol	16.00	3.2	32000	3200	200
Acetic Acid	22.00	4	40000	4000	182
Dimethyl sulfate	20.00	3.6	36000	3600	180
Pentane	8.40	1.5	15000	1500	179
Isopentane, & all pentane isomers	8.20	1.4	14000	1400	171
Naphtha (Coal tar) {purely aliphatic - RAE}	5.70	0.9	9000	900	158
100 PPM Alarm					
Propylene carbonate	62	1.8	18000	1800	29
Butane	67	1.6	16000	1600	24
Isobutane	100	1.6	16000	1600	16

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