SENSOR SELECTION GUIDE

TOXIC AND COMBUSTIBLE GAS MONITORS

(Includes gas listings with TLV-TWA, STEL, IDLH, LEL, and UEL for most gases)

INTERNATIONAL SENSOR TECHNOLOGY

The Leader In Gas Detection Since 1972

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TABLE OF CONTENTS

1. INTRODUCTION

The detection of hazardous gases has always been a complex subject, making the choice of an appropriate gas monitoring instrument a difficult task. International Sensor Technology (IST) has been providing gas detection equipment to customers worldwide since 1972. Through this experience we have compiled this guide which will provide you with some insight into the various sensing methods used for gas detection and provide you with information about the different instruments available to you. It will help you to make an informed decision concerning which sensor type and which instrument is best suited to your particular application.

Discussion of sensing methods will focus on the following three sensor types: Solid State, Electrochemical, and Catalytic Bead. These are the most suitable and widely used sensors for ambient air monitoring, and all three of these types are available from IST. It should be noted that instruments utilizing these sensors are not intended for use as analytical laboratory devices. The readings provided by these sensors should be used primarily as indicators of whether an area is safe or not, much like a smoke detector. While these sensors are much more refined than smoke detectors, they are nonetheless subject to erroneous readings from interference gases and lack of periodic calibration, among other things. However, as long as these limitations are understood, the sensors will provide meaningful data and are a valuable tool for ambient air monitoring. Instruments using these sensors will respond quickly in the presence of gas, enabling alarms to be triggered and allowing personnel to take appropriate action. In addition, they are generally easy to use, require little maintenance, and are economically priced.

To date, no gas sensors exist which are 100% selective to a single gas. Achieving selectivity requires the use of an analytical instrument. Various analytical techniques have been employed for gas detection and find use in certain applications. Examples of such instruments include Fourier Transform Infrared (FTIR) analyzers, Gas Chromatographs, and Mass Spectrometers. These instruments can provide fairly accurate and selective gas readings. However, they are generally very expensive and, in addition, many suffer from limitations such as high maintenance, slow response time, large size, and difficulty of use, making them impractical for use as ambient air monitors. As ambient air monitors, they are typically used only as a last resort for applications in which a suitable sensor is not available.

2. SOLID STATE SENSORS

2.1 GENERAL

Solid state sensors were introduced in the 1970's and represented a major breakthrough in the field of ambient air monitoring. They are unique in the fact that they can detect both toxic and explosive gases, in concentrations as low as several ppm or as high as 100% LEL and above. Today, solid state sensors are available for the detection of over 150 different gases, including many which could otherwise only be detected using expensive analytical instruments. An added advantage of solid state sensors is that they have a long life expectancy, typically 10 years or more, and come with a three year warranty. They are also quite rugged—they can take occasional exposure to high gas concentrations without damage and are not poisoned by substances which often harm other sensor types. Many IST solid state sensors installed in the 1970's are still in operation today.

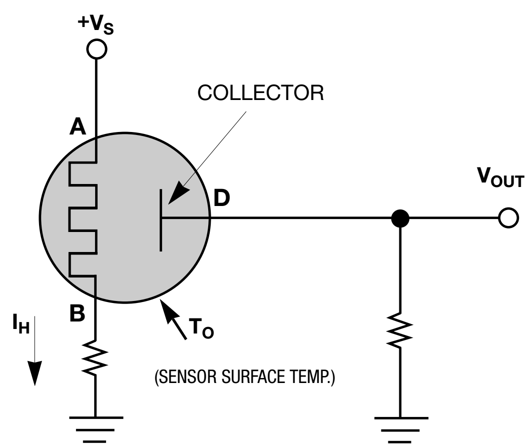

Figure 1.
Solid State Sensor

2.2 PRINCIPLE OF OPERATION

A solid state sensor consists of two electrodes embedded into a solid state metal oxide material. The presence of gas changes the resistance of the material, with the magnitude of change directly related to the gas concentration. The resistance change, and hence the gas concentration, is measured through the sensor's corresponding electronic circuitry. The sensor is kept at a specific operating temperature by applying a 'heater' voltage to it. The choice of heater voltage is critical in determining the response characteristics of the sensor. By varying this voltage and by using different materials and processing techniques, sensors can be made which are more sensitive to one gas or group of gases and less sensitive to others.

2.3 CHARACTERISTICS

Gases Detected:	*Refer to "Solid State Sensor Gas Data" table.*
Calibration Interval:	*30 days to 6 months, depending on the application.*
Expected Sensor Life:	*10 years or more. Comes with a 3 year warranty.*
Environmental:	
Temperature:	*-40° to +60°C* *-40° to +140°F*
Humidity:	*10% - 95%, non-condensing.*

3. CATALYTIC BEAD SENSORS

3.1 GENERAL

Catalytic bead sensors find use in applications requiring the detection of combustible gases where toxicity is of no concern. They only respond well to the higher gas concentrations, from 1000 ppm up to % LEL levels. Catalytic bead sensors are non-specific, and will respond to a wide variety of combustibles. The quality and performance of a catalytic bead sensor can vary from one manufacturer to another. Historically, catalytic bead sensors have been known to be susceptible to poisoning from H_2S, silicones, and other substances. However, recent developments have led to the introduction of catalytic bead sensors which are poison resistant. Among these is IST's Catalytic Sensor. In addition to being poison resistant, these and other well-made catalytic bead sensors will provide good stability and a long life expectancy.

3.2 PRINCIPLE OF OPERATION

A catalytic bead sensor consists of an active element and a reference element. At the heart of each of the elements is a heated platinum coil whose resistance varies with temperature. As long as both elements are at the same temperature, their resistances will be equal. In the presence of gas, however, the active element will burn the gas on its surface, raising the temperature of the platinum coil, while the reference element will show no response to the gas. Hence, a differential is created in the resistances of the two elements. When both elements are placed in a Wheatstone bridge circuit, this differential acts to throw the bridge out of balance, producing a signal which is proportional to the gas concentration. Because catalytic sensors operate on the combustion principle, they must be used in environments containing oxygen.

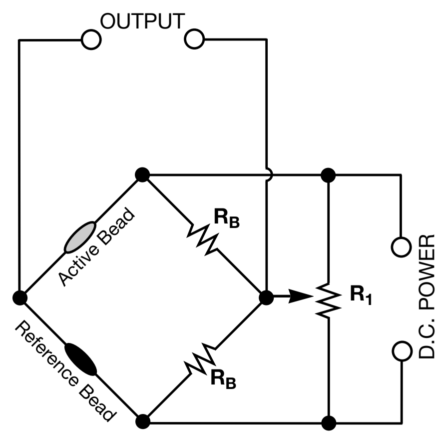

Figure 2. Catalytic Bead Sensor

3.3 CHARACTERISTICS

Gases Detected:	*Combustible gases in % LEL ranges.*
Calibration Interval:	*Depends on application 1 month is typical.*
Expected Sensor Life:	*2 years typical. Comes with a 1 year warranty.*
Environmental:	
Temperature:	*-40° to +75°C* *-40° to +167°F*
Humidity:	*0 - 99%, non-condensing.*

4. ELECTROCHEMICAL SENSORS

4.1 GENERAL

The oldest electrochemical sensors, used for O_2 monitoring, date back to the 1950's. Today, electrochemical sensors are available for the detection of about a dozen toxic gases in ppm ranges, including CO, H_2S, and NH_3. For some gases, electrochemical sensors can exhibit fairly good sensitivity and selectivity and therefore are a popular choice for certain applications. They have an added advantage in that they require low power to operate. However, dryout of the electrolyte used in these sensors can result in a reduced life, and the sensor is also subject to poisoning which can lead to the need for frequent calibration, premature drift, and sensor failure. These sensors also should not be exposed to high gas concentrations for long periods of time, as this will dramatically reduce their useful life.

4.2 PRINCIPLE OF OPERATION

Electrochemical sensors operate by reacting with the gas of interest and producing a signal proportional to the gas concentration. A typical electrochemical sensor consists of a sensing electrode, a counter electrode, and a reference electrode separated by a thin layer of electrolyte. Gas which comes in contact with the sensor first passes through a diffusion barrier, which is designed to limit the amount of gas entering the sensor. Gas diffusing through the barrier reacts at the surface of the sensing electrode by either oxidation or reduction. Reactions are catalyzed by electrode materials specially developed for the gas of interest. As an example, for a Carbon Monoxide Sensor, the gas would react at the sensing electrode according to the following equation:

$$CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-.$$

Similarly, electrochemical sensors for other gases would produce reactions based on the gas they are designed to detect. Selectivity can be achieved through the choice of the electrode material, electrolyte, operating voltage, and through selective filtration.

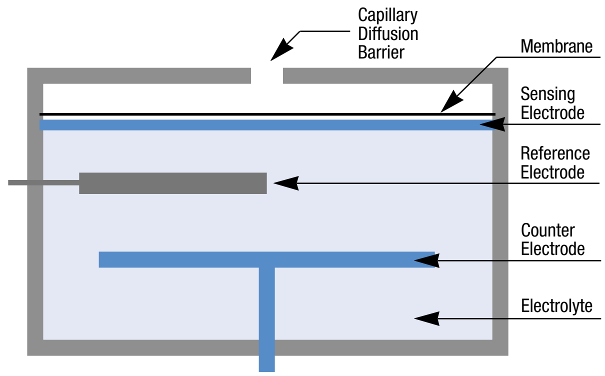

Figure 3. Electrochemical Sensor

4.3 CHARACTERISTICS

Gases Detected:

Following is a partial list of typical gases and ranges available for detection using electrochemical sensors. Other gases/ranges are also available.

GAS	FORMULA	TYPICAL RANGES (in PPM except O_2)
Ammonia	NH_3	50
Carbon Monoxide	CO	20, 50, 100, 200, 300, 500, 1000, 2000, 3000, 4000,10000, 20000, 40000
Chlorine	Cl_2	5, 10, 20, 30, 50, 100, 200,
Hydrogen	H_2	50, 200, 300, 500, 1000, 2000, 20000, 30000, 50000
Hydrogen Chloride	HCl	5, 10, 20, 30, 50, 100, 200
Hydrogen Cyanide	HCN	100
Hydrogen Sulfide	H_2S	5, 10, 20, 30, 50, 100, 200, 300
Nitric Oxide	NO	10, 20, 30, 50, 100, 200, 300, 500, 1000, 2000
Nitrogen Dioxide	NO_2	5, 10, 20, 30, 50, 100, 200, 300
Oxygen	O_2	0 - 25%, 0- 30% Oxygen
Sulfur Dioxide	SO_2	5, 10, 20, 30, 50, 100, 200, 300, 500,1000, 2000

Calibration Interval: *1-2 times per month typical.*

Expected Sensor Life: *1-2 years typical.*

Environmental:

Temperature: *-5° to +40°C +23° to +104°F Continuous.*

-15° to +50°C +5° to +122°F Intermittent.

Humidity: *15 to 90% non-condensing Continuous.*

0 to 99% non-condensing Intermittent.

5. SENSOR SELECTION

Gas monitoring generally consists of two categories: Toxic Gas monitoring and Combustible Gas monitoring. In actuality, many gases are both toxic and combustible. Carbon monoxide, for example, has a TLV of 25 ppm and also has a Lower Explosive Limit (LEL) of 12.5% by volume, or 125,000 ppm. Thus, it is the concentration range of the gas to be monitored which determines whether the monitoring fits into the category of toxic or combustible. Toxic gases are normally associated with low gas concentrations in the ppm range, while combustible gases are associated with high gas concentrations in the %LEL range.

For monitoring toxic gases, either a solid state or, where available, an electrochemical sensor can be used. For monitoring combustible gases, either a solid state or catalytic bead sensor can be used. This section will present a comparison of these sensor types to help you determine which sensor may be best for your particular application.

As mentioned previously, when using any of these sensors, it is important to remember that they will not be 100% specific to the gas of interest. Depending on the gas to be monitored and the sensor type chosen, you may encounter varying degrees of interference from other gases which are present in your environment. Additionally, for toxic gases especially, the choice of the appropriate concentration range to monitor is very important. For example, if you are monitoring to protect workers from toxic gases, typically a full scale range of 3 to 10 times the TLV of the gas being monitored is chosen. It is important to remember that the TLV for a gas is defined as a SAFE level which workers can be exposed to for the entire work day. Thus, it is wise to choose a full scale range which is higher than the TLV to enable you to set alarm points at concentration ranges above the TLV, where the gas levels are hazardous. For combustible monitoring, a range of 100% LEL is typically chosen, and other ranges are available.

5.1 COMBUSTIBLE GAS MONITORING

For combustible gas monitoring, either a solid state or catalytic bead sensor can be used. Solid state sensors are rugged and have a long life expectancy. It is not uncommon for a solid state sensor to operate for 10 years or more without needing replacement. They are resistant to poisoning and can take occasional exposure to high gas concentrations without damage.

Catalytic bead sensors are also quite rugged. As mentioned earlier, several manufacturers now offer catalytic bead sensors which are poison resistant. Additionally, the typical life expectancy has been improved to two years. One of the main differences between catalytic bead and solid state sensors is that solid state sensors tend to be more sensitive. Catalytic bead sensors are only sensitive to combustible gases in high concentrations and will not see any concentration lower than about 1000 ppm. If the user does not indicate a specific gas to calibrate to, they are typically calibrated to methane, and because of this they are less sensitive to most other combustibles. As a result, they are less likely to produce a reading than a solid state sensor exposed to the same gases. In some instances, this characteristic can make them more practical, as they are less likely to produce spurious alarms due to "interference" gases. This is advantageous in situations where the user wants to detect only one particular combustible gas, and doesn't want other lower level combustibles which may also be present to be detected.

The choice between the two sensors therefore involves two major considerations: life expectancy and interferences. If interference gases are not a problem in your application, then a solid state sensor is usually the best choice. It will likely perform better than a catalytic bead sensor in applications where multiple combustible gases are present and the user wants to detect all of them. It will also provide years of trouble free operation and save on sensor replacement costs. However, in applications where interference gases present a problem, the catalytic bead sensor may be the way to go. It still has a fairly good life expectancy and will be more selective than the solid state sensor.

5.2 TOXIC GAS MONITORING

For toxic gas monitoring, the two sensors which can be used are solid state or electrochemical. Solid state sensors are available to detect over 150 toxic gases, while electrochemical sensors exist for approximately 15 to 20. As a result, for a large majority of gases, the choice of sensors is limited to solid state. Thus, in comparing the two sensors, the discussion only applies to those gases detected by electrochemical sensors.

One of the major differences between the sensors is the life expectancy. While solid state sensors have a long, predictable life expectancy, a typical electrochemical sensor lasts only one or two years, and sometimes much less. Additionally, it is important to note that not all electrochemical sensors are the same and the life expectancy of the sensors can vary greatly depending on the gas being monitored. For example, while a CO sensor will typically last over a year, a comparable ammonia sensor periodically exposed to even relatively small amounts of gas will have a much shorter life.

The response characteristics of both solid state and electrochemical sensors can vary depending on which toxic gas is being monitored. Therefore, the comparison of the two sensors must be done on a gas by gas basis. Following are some general points about the two sensors for various gases:

5.2.1 Carbon Monoxide

Both the solid state and electrochemical sensors for CO utilize charcoal filters to block interference gases and as a result both are fairly selective. Because of the long life of the solid state sensor, it is made so that the charcoal filter can be replaced without replacing the sensor itself. The charcoal filter on an electrochemical sensor is not replaceable.

The readings of solid state sensors for CO can be affected by humidity. Specifically, in very low humidity, they tend to read low and as a result it becomes important to add moisture to the sample whenever calibrating the sensor using a compressed gas bottle. Without doing so, the sensor may be improperly calibrated and give inaccurate readings.

Humidity does not have this affect on the electrochemical sensor and therefore it may produce more stable readings overall. In the long term, though, these sensors will require more frequent replacement and will need more frequent calibration than a solid state sensor, and these factors should all be weighed when choosing between the sensors.

5.2.2 Hydrogen Sulfide

For H_2S, the solid state sensor performs very well with excellent response and selectivity. For H_2S applications, it is generally recommended to use a solid state sensor because these applications tend to be in hostile environments, where a solid state sensor will fare much better than an electrochemical sensor.

While electrochemical sensors will respond well on a short term basis, they ultimately do not survive long and require replacement too frequently. As a result, they should not be used in systems with large numbers of sensors, as the replacement costs of the sensors will be extremely high. A better application for them is in portable instruments, where they are not constantly exposed to the harsh environment. Even under these conditions, though, the sensor will require periodic replacement.

5.2.3 Chlorine/Hydrogen Chloride

These gases are very active and corrosive, and regardless of whether a solid state or electrochemical sensor is used, the monitoring of these gases is very difficult. Monitoring ranges are typically low, and because the gases are so active, it becomes virtually impossible to prepare an accurate calibration mixture with confidence.

Solid state sensors used in these applications tend to be sensitive and read upscale. As a result, they sometimes have problems with false alarms. On the other hand, electrochemical sensors tend to lose sensitivity quickly in this environment and therefore need to be checked frequently for proper operation. They can provide a false sense of security by showing low or zero readings when, in fact, the sensor is simply insensitive.

5.2.4 Ammonia

Electrochemical sensors for ammonia have a very short life span. The sensor's life is dramatically reduced from exposure to gas, even in low concentrations. Solid state sensors are therefore a much better choice for ammonia applications. They perform well over a long period of time and have been used extensively in refrigeration applications.

6. SENSOR INSTALLATION NOTES

There are no set rules regarding where sensors must be located, however the judgment of trained personnel and good common sense should always be used. Sensors which are properly installed can save hours of maintenance and provide trouble free operation. Following are some guidelines for installing sensors:

1. In order to select meaningful sensor locations, a specific objective should be defined. Study the building or plant layout to determine the location of various equipment, machinery, control valves, doors, vents, etc. as well as the general air flow pattern. Observe locations where gas is likely to leak from or accumulate. Generally, sensors should be located where they will indicate an average reading of the area in which the sensor is to cover.

2. It is recommended that sensors be mounted approximately 5 or 6 feet from the ground to enable easy access for maintenance and calibration. Also, avoid installing sensors too close to walls or the floor. These surfaces can absorb and emit gases with changes in temperature, affecting the reading of the sensor. At least 6" of clearance from any surface should be provided.

3. Gases have different densities, and some are lighter than air while others are heavier. However, this does not mean that sensors should be installed on the floor or ceiling to monitor these gases. Gases disperse easily and develop a concentration gradient, which means, for example, that a gas which is heavier than air will still be detected several feet off the ground. An important point to remember is that sensors must be accessible for calibration and maintenance, so installing them on the floor or ceiling is normally not a good idea.

4. In areas of new construction, sensors should be installed after operations such as sandblasting, painting, welding, etc. are completed. During such operations, sensors present should be protected by using a sensor plug, such as IST's P/N F44-P which installs over the rainshield. Remember that the sensor will not be operative with the plug installed, so remember to remove the plug when reactivating the instrument.

5. Don't install the sensor near sources of steam. Steam will damage the sensor.

6. Don't install sensors next to sources which are constantly leaking gas.

7. The number of sensors required for an application depends on a number of factors, including the plant layout, air flow pattern, type of gas to be monitored, and the degree of protection required. Choosing the proper number of sensors is a matter of common sense. Gas sensors are similar to smoke detectors, meaning they will only detect gas which directly comes in contact with the sensor. Thus, the sensor relies on the dispersion of the gas in order to detect it.

7. DEFINITIONS

1. Threshold Limit Values (TLV's): TLV's represent conditions under which nearly all workers may be repeatedly exposed day after day without adverse health effects. The accuracy of these TLV's, issued by the American Conference of Governmental Industrial Hygienists (ACGIH), are subject to variation and the latest TLV Documentation should be consulted. The categories of Threshold Limit Values (TLV's) are defined as follows:

A. Threshold Limit Value - Time-Weighted Average (TLV-TWA): These values represent the time-weighted average concentrations of substances to which nearly all workers may be repeatedly exposed for a normal 8-hour workday and a 40-hour workweek, day after day, without adverse effect.

B. Threshold Limit Value—Short-Term Exposure Limit (TLV-STEL): STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day.

2. Immediately Dangerous to Life or Health (IDLH): IDLH concentrations represent the maximum concentrations from which one could escape within 30 minutes without a respirator, in the event of respirator failure, without experiencing any escape-impairing (e.g., severe eye irritation) or irreversible health effects. These values are obtained from *NIOSH: Pocket Guide to Chemical Hazards, 1990 Edition.*

3. Flammable (Explosive) Limits — Lower Explosive Level (LEL) and Upper Explosive Level (UEL): LEL and UEL are usually expressed as percent by volume of the material in air (or other oxidant). A substance below the Lower Explosive Level (LEL) is too "lean" to burn, while a substance above the Upper Explosive Level is too "rich" to burn. These values are obtained from *NFPA 325M - Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids, 1991 Edition*.

4. Parts Per Million (PPM) and Percent By Volume: PPM and Percent By Volume are volumetric units of measurement commonly used in gas monitoring. For instance, one PPM of Hydrogen Sulfide in ambient air would mean that there is one part of hydrogen sulfide for every million parts of air. One Percent By Volume equals 10,000 PPM (1 % by Volume = 10,000 PPM).

8. SOLID STATE SENSOR GAS DATA

The following gases are available for detection using IST's Solid State Sensors. The full-scale ranges listed are standard ranges available. For toxic gas monitoring, ranges are typically chosen which are higher than the TLV so that hazardous levels will be detected (TLV is defined as a SAFE level). For combustible gases, the typical range is 0-100 % LEL. Other ranges can also be provided—please contact IST for information. The following information is valid as of 3/95.

GAS	TLV-TWA	STEL	IDLH	LEL	UEL	FULL-SCALE RANGES
Acetic Acid	10 ppm	15 ppm	1000 ppm	4%	19.9%	100, 200 ppm
Acetone	750 ppm	1000 ppm	20,000 ppm	2.5%	12.8%	100, 200, 500, 1000, 5000 ppm, % LEL
Acetonitrile	40 ppm	60 ppm	4000 ppm	3%	16%	100 ppm
Acetylene				2.5%	100%	50 ppm, % LEL, 3% by Volume
Acrolein (Acrylaldehyde)	0.1 ppm	0.3 ppm	5 ppm	2.8%	31%	50 ppm
Acrylic Acid	2 ppm	—		2.4%	8%	100 ppm
Acrylonitrile	2 ppm	—	500 ppm	3%	17%	50, 60, 80, 100, 200, 500 ppm, % LEL
Allyl Alcohol	2 ppm	4 ppm	150 ppm	2.5%	18%	% LEL
Allyl Chloride	1 ppm	2 ppm	300 ppm	2.9%	11.1%	200 ppm
Ammonia	25 ppm	35 ppm	500 ppm	15%	28%	50, 70, 75, 100, 150, 200, 300, 400, 500, 1000, 2000, 2500, 4000, 5000 ppm, 1%, 2%, 10% by Vol., 10%, 25%, 100% LEL
Anisole						100 ppm
Arsenic Pentafluoride						5 ppm
Arsine	0.05 ppm	—	6 ppm			1, 10 ppm
Benzene	10 ppm	—	3000 ppm	1.2%	7.8%	50, 75, 100, 1000 ppm, % LEL
Biphenyl	0.2 ppm	—		0.6%	5.8%	50%, 100% LEL
Boron Trichloride						500 ppm
Boron Trifluoride	—		100 ppm			500 ppm
Bromine	0.1 ppm	0.2 ppm	10 ppm			20 ppm
Butadiene	2 ppm	—	20,000 ppm	2%	12%	50, 100, 3000 ppm, % LEL
Butane	800 ppm			1.9%	8.5%	400, 1000 ppm, 100%, 200% LEL
Butanol	—		8000 ppm	1.4%	11.2%	1000 ppm, 100% LEL
Butene				1.6%	10%	100% LEL
Butyl Acetate	200 ppm	—	10,000 ppm	1.7%	7.6%	100 ppm, % LEL
Carbon Disulfide	10 ppm	—	500 ppm	1.3%	50%	50, 60, 100 ppm, 5% by Volume
Carbon Monoxide	25 ppm	—	1500 ppm	12.5%	74%	50, 100, 150, 200, 250, 300, 500, 1000, 3000, 5000 ppm, 3%, 5% by Volume, % LEL
Carbon Tetrachloride	5 ppm	10 ppm	300 ppm			50, 100, 10000 ppm
Cellosolve Acetate						100 ppm
Chlorine	0.5 ppm	1 ppm	30 ppm			10, 20, 50, 100, 200 ppm
Chlorine Dioxide	0.1 ppm	0.3 ppm	10 ppm			10, 20 ppm
Chlorobutadiene	10 ppm	—		4%	20%	100% LEL
Chloroethanol	—			4.9%	15.9%	200 ppm
Chloroform	10 ppm	—	1000 ppm			50, 100, 200 ppm
Chlorotrifluoroethylene				8.4%	16%	100% LEL
Cumene	50 ppm	—	8000 ppm	0.9%	6.5%	100% LEL
Cyanogen Chloride	—					20 ppm
Cyclohexane	300 ppm	—	10,000 ppm	1.3%	8%	100 ppm, 100% LEL
Cyclopentane	600 ppm	—		1.5%		50 ppm
Deuterium				5%	75%	50%, 100% LEL
Diborane	0.1 ppm	—	40 ppm	0.8%	88%	10, 50 ppm
Dibromoethane		—				50 ppm
Dibutylamine				1.1%		100% LEL
Dichlorobutene	0.005 ppm	—				1% by Volume
Dichloroethane (EDC)	10 ppm	—	4000 ppm	5.4%	11.4%	50, 100 ppm, % LEL
Dichlorofluoroethane						100, 1000 ppm
Dichloropentadiene						50 ppm
Dichlorosilane				4.1%	99%	50, 100 ppm
Diesel Fuel						50 ppm, 100% LEL
Diethyl Benzene				0.7%	6%	100% LEL
Diethyl Sulfide						10 ppm
Difluorochloroethane				6.2%	17.9%	100% LEL
Difluoroethane (152A)						100% LEL
Dimethyl Ether				3.4%	27%	100% LEL
Dimethylamine (DMA)	5 ppm	15 ppm	2000 ppm	2.8%	14.4%	30, 50 ppm
Epichlorohydrin	2 ppm	—	250 ppm	3.8%	21%	50, 100, 500, 1000 ppm
Ethane	—	—		3%	12.5%	1000 ppm
Ethanol	1000 ppm	—		3.3%	19%	200, 1000, 2000 ppm, % LEL
Ethyl Acetate	400 ppm	—	10,000 ppm	2%	11.5%	200, 1000 ppm, % LEL
Ethyl Benzene	100 ppm	125 ppm	2000 ppm	0.8%	6.7%	200 ppm, % LEL
Ethyl Chloride	1000 ppm	—	20,000 ppm	3.8%	15.4%	100 ppm, % LEL
Ethyl Chlorocarbonate						1% by Volume
Ethyl Ether			19,000 ppm			100, 800, 1000 ppm, % LEL
Ethylene	—	—		2.7%	36%	100, 1000, 1200 ppm, % LEL
Ethylene Oxide	1 ppm		800 ppm	3%	100%	5, 10, 20, 30, 50, 75, 100, 150, 200, 300, 1000, 1500, 2000, 3000 ppm, % LEL
Fluorine	1 ppm	2 ppm	25 ppm			20, 100 ppm
Formaldehyde	—		30 ppm	7.3%	7%	15, 50, 100, 500, 1000 ppm
Freon-11	—	1000 ppm	10,000 ppm			1000, 2000, 5000 ppm
Freon-12	1000 ppm		50,000 ppm			1000, 2000, 3000 ppm
Freon-22						100, 200, 500, 1000, 2000 ppm
Freon-113	1000 ppm	1250 ppm	4500 ppm			100, 200, 500, 1000, 2000 ppm, 1% by Vol.
Freon-114	1000 ppm	—	50,000 ppm			1000, 2000, 20000 ppm
Freon-123						1000 ppm
Fuel Oil or Kerosene				0.7%	5%	100% LEL
Gasoline	300 ppm	500 ppm		1.3%	7.1%	100, 1000, 2000, 20000 ppm., % LEL
Germane						10, 50 ppm
Heptane	400 ppm	500 ppm	5000 ppm	1.05%	6.7%	1000 ppm, % LEL

SOLID STATE SENSOR GAS DATA

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GAS	TLV-TWA	STEL	IDLH	LEL	UEL	FULL-SCALE RANGES
Hexane	50 ppm	—	5000 ppm	1.1%	7.5%	50, 100, 200, 2000, 2500, 3000 ppm, % LEL
Hexene						% LEL
Hydrazine	0.1 ppm	—	80 ppm	2.9%	9.8%	5, 10, 20, 100, 1000 ppm, 1% by Volume
Hydrogen	—	—		4%	75%	50, 100, 200, 500, 1000, 2000, 5000 ppm, 3%, 5% by Vol., 2% to 100% LEL
Hydrogen Bromide	—	3 ppm	50 ppm			50 ppm
Hydrogen Chloride	—	5 ppm	100 ppm			50, 100, 200, 400, 500, 1000 ppm
Hydrogen Cyanide	—	4.7 ppm	50 ppm	5.6%	40%	20, 30, 50, 100, 200, 1000, 10000 ppm
Hydrogen Fluoride	—		30 ppm			20, 50, 100, 200 ppm
Hydrogen Sulfide	10 ppm	15 ppm	300 ppm	4%	44%	5, 10, 20, 30, 50, 100, 300, 1000 ppm, % LEL
Isobutane				1.8%	8.4%	1000, 3000 ppm, % LEL
Isobutylene				1.8%	9.6%	% LEL
Isopentane				1.4%	7.6%	1000 ppm
Isoprene				1.5%	8.9%	% LEL
Isopropanol	400 ppm	500 ppm	12,000 ppm	2%	12.7%	200, 400, 500, 1000 ppm, % LEL
JP4				1.3%	8%	1000 ppm, % LEL
JP5						1000, 5000 ppm, % LEL
Methane	—	—		5%	15%	100, 200, 1000, 1500, 2000, 5000 ppm, 1%, 2% by Volume, 100%, 200% LEL
Methanol	200 ppm	250 ppm	25,000 ppm	6%	36%	200, 300, 400, 500, 1000, 2000, 5000 ppm, 15%, 30%, 100% LEL
Methyl Acetate	200 ppm	250 ppm	10,000 ppm	3.1%	16%	30 ppm
Methyl Acrylate	10 ppm	—	1000 ppm	2.8%	25%	60 ppm
Methyl Bromide	5 ppm	—	2000 ppm	10%	16%	20, 50, 60, 100, 500, 1000, 10000, 40,000 ppm
Methyl Butanol				1.2%	9%	% LEL
Methyl Cellosolve			2000 ppm			% LEL
Methyl Chloride	50 ppm	100 ppm	10,000 ppm	8.1%	17.4%	100, 200, 300, 2000, 10000 ppm, % LEL
Methyl Ethyl Ketone	200 ppm	300 ppm		1.4%	11.4%	100, 500, 1000, 4000 ppm, 100% LEL
Methyl Hydrazine	—		50 ppm	2.5%	92%	5 ppm
Methyl Isobutyl Ketone	50 ppm	75 ppm				200, 500, 2000 ppm, 50%, 100% LEL
Methyl Mercaptan	0.5 ppm		400 ppm	3.9%	21.8%	30 ppm
Methyl Methacrylate	100 ppm		4000 ppm	1.7%	8.2%	100 ppm, % LEL
Methyl-Tert Butyl Ether	40 ppm	—				100% LEL
Methylene Chloride	50 ppm	—	5000 ppm	13%	23%	20, 100, 200, 300, 400, 500, 600, 1000, 2000, 3000, 5000 ppm, % LEL
Mineral Spirits				0.8%		200, 3000 ppm, % LEL
Monochlorobenzene	10 ppm	—		1.3%	9.6%	100% LEL
Monoethylamine	5 ppm	15 ppm	4000 ppm			30, 100, 1000 ppm
Morpholine	20 ppm	—	8000 ppm	1.4%	11.2%	500 ppm
Naptha			10,000 ppm	1.1%	5.9%	1000 ppm, 100% LEL
Natural Gas						1000, 2000 ppm, 2%, 4% by Volume, % LEL
Nitric Oxide	25 ppm	—	100 ppm			20, 50 ppm
Nitrogen Dioxide	3 ppm	5 ppm				20, 50, 100 ppm
Nitrogen Trifluoride	10 ppm	—				50, 500, 1000 ppm
Nonane	200 ppm	—		0.8%	2.9%	2000 ppm
Oxygen						25% by Volume
Pentane	600 ppm	750 ppm	15,000 ppm	1.5%	7.8%	200, 1000 ppm, % LEL
Perchloroethylene	25 ppm	100 ppm	500 ppm		None	200, 1000, 2000, 20000 ppm
Phenol	5 ppm	—	250 ppm	1.8%	8.6%	100 ppm
Phosgene	0.1 ppm	—	2 ppm			50 ppm
Phosphine	0.3 ppm	1 ppm	200 ppm			3, 5, 10, 20, 30, 50 ppm
Phosphorus Oxychloride	0.1 ppm	—				200 ppm
Picoline						% LEL
Propane	—	—	20,000 ppm	2.1%	9.5%	100, 1000 ppm, 100% LEL
Propylene	—	—		2%	11.1%	100, 200, 1000, 5000 ppm, %LEL
Propylene Oxide			2000 ppm	2.3%	36%	100 ppm, % LEL
Silane	5 ppm	—				10, 20, 50 ppm
Silicon Tetrachloride						1000 ppm
Silicon Tetrafluoride						1000 ppm
Styrene	50 ppm	100 ppm	5000 ppm	0.9%	6.8%	200, 300 ppm, % LEL
Sulfur Dioxide	2 ppm	5 ppm	100 ppm			50, 100 ppm
Tetrahydrofuran	200 ppm	250 ppm	20,000 ppm	2%	11.8%	200, 300, 1000 ppm, % LEL
Tetraline				0.8%	5%	100 ppm
Toluene	50 ppm	—	2000 ppm	1.1%	7.1%	50, 100, 200, 500, 2000, 5000 ppm, % LEL
Toluene Diisocyanate	0.005 ppm	0.02 ppm	10 ppm	0.9%	9.5%	15 ppm
Trichloroethane	10 ppm	—	500 ppm	7.5%	12.5%	50, 100, 500, 1000 ppm, 1% by Volume
Trichloroethylene	50 ppm	100 ppm	1000 ppm	8%	10.5%	50, 100,200,300, 500, 1000, 2000 ppm, %LEL
Triethylamine (TEA)	1 ppm	5 ppm	1000 ppm	1.2%	8%	100 ppm
Trifluoroethanol						25, 100 ppm
Trimethylamine (TMA)	5 ppm	15 ppm		2%	11.6%	50 ppm
Tungsten Hexafluoride						50 ppm
Turpentine	100 ppm	—	1500 ppm	0.8%		% LEL
Vinyl Acetate	10 ppm	15 ppm		2.6%	13.4%	1000 ppm, % LEL
Vinyl Chloride	5 ppm			3.6%	33 %	20, 50, 100, 200, 400, 500, 1000, 4000, 10000 ppm, 10%, 100% LEL
Vinylidene Chloride	5 ppm	20 ppm		6.5%	15.5%	50 ppm
Xylene	100 ppm	150 ppm	1000 ppm	0.9%	6.7%	100, 200, 300, 1000 ppm, 1% by Volume

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