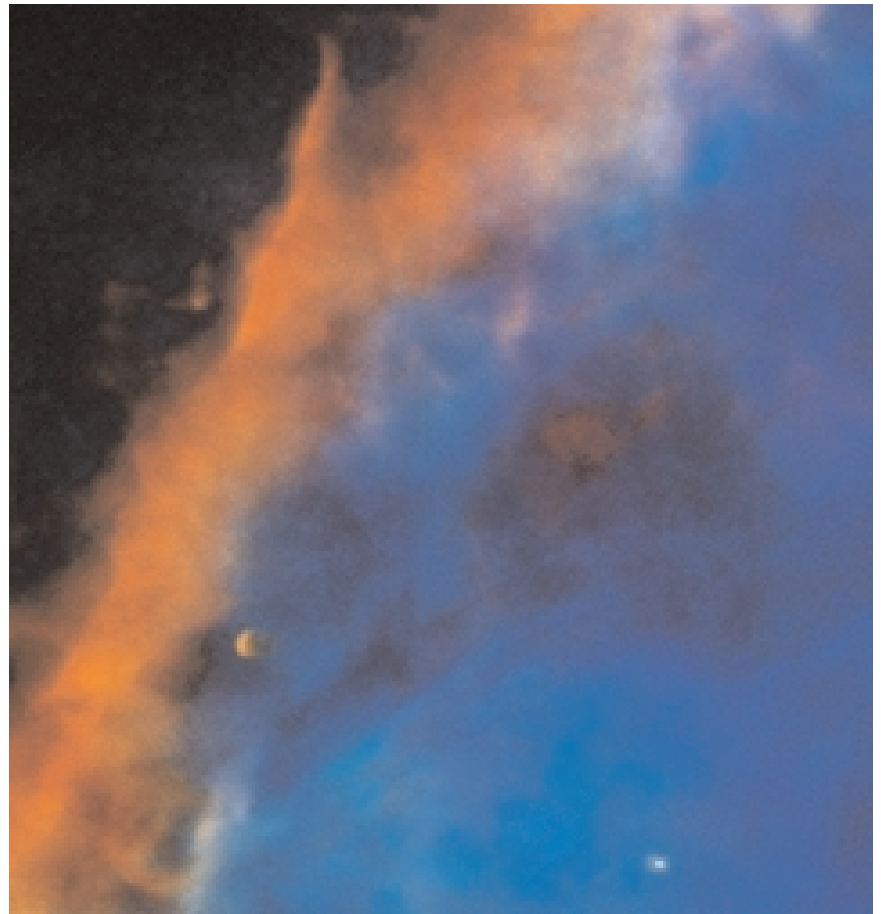




\$19.95

A Practical Guide to Gas Detection

Combustible and toxic gas detection principles



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Due to the large number of existing hazardous vapors, all with specific physical and chemical properties, there are many different technologies available for detection including catalytic, infrared (both point and open path systems), metal oxide semiconductor (MOS) and electrochemical detection and measurement techniques.

The intent of this guide is to furnish the user with information concerning the principles of combustible and toxic gas detection, and to provide assistance in the selection, placement, and use of gas detection equipment.

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Definitions & Concepts

Combustible Material

A combustible material is a solid, liquid, or gas that may undergo the chemical reaction of combustion. Combustion occurs when an organic chemical (or other substances such as hydrogen or sulfur) is oxidized to produce energy, water, and carbon dioxide. For example, the combustion of the common combustible gas, methane:



If the concentrations of the reactants (i.e., methane and oxygen) fall within the explosive limits of methane, and an ignition source is present, the released energy will produce an explosion.

Explosive Range

The explosive range is the concentration range of a combustible gas or vapor (% by volume in air) in which an explosion can occur upon ignition. In other words, the region between the LFL and the UFL (see following definitions) of a gas or vapor. The explosive range varies with the particular gas or vapor. See Figure 1, a generic example of Explosive Range, for clarification.

Lower Flammable Limit (LFL), Lower Explosive Limit (LEL)

The lower flammable limit or lower explosive limit is the lower concentration limit of an explosive range for a combustible mixture. At or above the LFL a combustible gas or vapor will support a self-propagating flame when mixed with air and ignited. A mixture below this concentration level is considered too "lean" to burn.

Upper Flammable Limit (UFL), Upper Explosive Limit (UEL)

The upper flammable limit or upper explosive limit is the upper concentration limit of the explosive range for a combustible mixture. Above the UFL, the mixture is considered "too rich" to cause an explosion.

Flash Point (FP)

The flash point is the temperature at which a liquid or volatile solid gives off vapor sufficient to form an ignitable mixture with the air near the surface of the liquid or within the test vessel. In general, any gas or vapor with a flash point below ambient temperature should be monitored.

Ignition Point (IP)

The ignition point is the minimum temperature required to initiate or cause self-sustained combustion in any substance in the absence of a spark or flame.

Relative Vapor Density

The vapor density is the weight of vapor per unit volume, compared to the weight of the same volume of air at a given temperature and pressure. The substance is lighter than air if the vapor density is less than 1, and heavier than air if the vapor density is greater than 1.

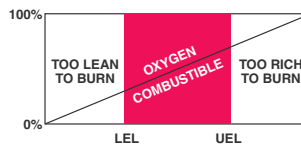


FIGURE 1
Explosive Limits of Gases and Vapors.

Combustible Materials

The combustibility of a particular substance depends on its physical properties, the ignition point, and the flash point.

PHYSICAL AND CHEMICAL PROPERTIES

Table 1 provides physical and chemical properties of many combustible materials including: its name, formula, molecular weight, boiling point, relative vapor density, flash point, flammability limits in air, and ignition temperature. If confused as to what these properties mean, refer back to the “**Definitions & Concepts**” portion of this chapter for clarification.

Note:

This is NOT a complete listing. Refer to NFPA 325 “Guide to Fire Hazard Properties of Flammable Liquids, Gases and Solids” for a more complete listing.¹²

TABLE 1 — Properties of Combustible Materials

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
acetaldehyde	CH ₃ CHO	44.1	20	1.52	-38	4	57	140
acetic acid	CH ₃ COOH	60.0	118	2.07	40	5.4	16	485
acetic anhydride	(CH ₃ CO) ₂ O	102.1	140	3.52	54	2.7	10	(334)
acetone	(CH ₃) ₂ CO	58.1	56	2.0	-19	2.15	13	535
acetonitrile	CH ₃ CN	41.1	82	1.42	5	–	4.4	523
acetyl chloride	CH ₃ COCl	78.5	51	2.7	4	5.0	–	300
acetylene	CH≡CH	26.0	-84	0.9	–	1.5	100	305
acrylonitrile	CH ₂ =CHCN	53.1	77	1.83	-5	3	17	480
allyl chloride	CH ₂ =CHCH ₂ Cl	76.5	45	2.64	<-20	3.2	11.2	485
allylene	CH ₃ C=CH	40.1	-23	1.38	–	1.7	–	–
ammonia	NH ₃	17.0	-33	0.59	–	15	28	630
amyl acetate	CH ₃ COOC ₅ H ₁₁	130.2	147	4.48	25	1.0	7.1	375
aniline	C ₆ H ₅ NH ₂	93.1	184	3.22	75	1.2	8.3	617
benzaldehyde	C ₆ H ₅ CHO	106.1	179	3.66	65	1.4	–	190
benzene	C ₆ H ₆	78.1	80	2.7	-11	1.2	8	560
benzyl chloride	C ₆ H ₅ CH ₂ Cl	126.6	179	4.36	60	1.2	–	585
bromobutane	CH ₃ (CH ₂) ₂ CH ₂ Br	136.9	102	4.72	<21	2.5	–	265
bromoethane	C ₂ H ₅ Br	84.9	38	3.76	<-20	6.7	11.3	510
butadiene	H ₂ C=CHHC=CH ₂	54.09	-4	1.87	–	2.1	12.5	430
butane	C ₄ H ₁₀	58.1	-1	2.05	-60	1.5	8.5	365
butanol	CH ₃ (CH ₂) ₂ CH ₂ OH	74.1	118	2.55	29	1.7	9.0	340
butene	CH ₂ =CHCH ₂ CH ₃	56	-6	1.94	–	1.6	10	440
butanone	C ₂ H ₅ COCH ₃	72.1	80	2.48	-1	1.8	11.5	505
butyl acetate	CH ₃ COOCH ₂ (CH ₂) ₂ CH ₃	116.2	127	4.01	22	1.4	8.0	370
butylamine	(CH ₃) ₃ CNH ₂	73.1	63	2.52	-9	–	–	312
butyraldehyde	CH ₃ CH ₂ CH ₂ CHO	72.1	75	2.48	<-5	1.4	12.5	230

TABLE 1 — Properties of Combustible Materials (continued)

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
carbon disulfide	CS ₂	76.1	46	2.64	<-20	1.0	60	100
carbon monoxide	CO	28.0	-191	0.97	-	12.5	74.2	605
chlorobenzene	C ₆ H ₅ Cl	112.6	132	3.88	28	1.3	7.1	637
chlorobutane	CH ₃ (CH ₂) ₂ CH ₂ Cl	92.5	78	3.2	<0	1.8	10.1	460
chloroethane	C ₂ H ₅ Cl	64.5	12	2.22	-	3.6	15.4	510
chloroethanol	CH ₂ ClCH ₂ OH	80.5	129	2.78	55	5	16	425
chloroethylene	CH ₂ =CHCl	62.3	-14	2.15	-	3.8	29.3	470
chloromethane	CH ₃ Cl	50.5	-24	1.78	-	10.7	13.4	625
2-chloropropane	(CH ₃) ₂ CHCl	78.5	47	2.7	<-20	2.6	11.1	520
cresol	CH ₃ C ₆ H ₄ OH	108.1	191	3.73	81	1.1	-	555
crotonaldehyde	CH ₃ CH=CHCHO	70.1	102	2.41	13	2.1	15.5	(230)
cumene	C ₆ H ₅ CH(CH ₃) ₂	120.2	152	4.13	36	.88	6.5	420
cyclobutane	CH ₂ (CH ₂) ₂ CH ₂	56.1	13	1.93	-	1.8	-	-
cyclohexane	CH ₂ (CH ₂) ₄ CH ₂	54.2	81	2.9	-18	1.2	7.8	259
cyclohexanol	CH ₂ (CH ₂) ₅ CHOH	100.2	161	3.45	68	1.2	-	300
cyclohexanone	CH ₂ (CH ₂) ₅ CO	98.1	156	3.38	43	1.4	9.4	419
cyclohexene	C ₆ H ₁₀	82.1	83	2.83	<-20	1.2	-	310
cyclohexylamine	C ₆ H ₁₁ NH ₂	99.2	134	3.42	32	-	-	290
cyclopropane	CH ₂ CH ₂ CH ₂	42.1	-33	1.45	-	2.4	10.4	495
decahydronaphthalene	C ₁₀ H ₁₈	138.2	196	4.76	54	0.7	4.9	260
decane	CH ₃ (CH ₂) ₈ CH ₃	142.3	173	4.9	96	0.8	5.4	205
diacetone alcohol	CH ₃ COCH ₂ C(CH ₃) ₂ OH	116.2	166	4.0	58	1.8	6.9	640
diaminoethane	NH ₂ CH ₂ CH ₂ NH ₂	49.0	116	2.07	34	-	-	385
dibutyl ether	(C ₄ H ₉) ₂ O	130.2	141	4.48	25	1.5	7.6	185
dichlorobenzene	C ₆ H ₄ Cl ₂	147.0	179	5.07	66	2.2	9.2	(640)
1,1-dichloroethane	CH ₃ CHCl ₂	99.0	57	3.42	-10	5.6	16	440

TABLE 1 — Properties of Combustible Materials (continued)

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
dichloroethylene	$\text{ClCH}=\text{CHCl}$	97.0	32	3.55	-10	9.7	12.8	440
dichloropropane	$\text{CH}_3\text{CHClCH}_2\text{Cl}$	113.0	96	3.9	15	3.4	14.5	555
diethylamine	$(\text{C}_2\text{H}_5)_2\text{NH}$	45.1	56	2.53	<-20	1.7	10.1	310
diethylaminoethanol	$(\text{C}_2\text{H}_5)_2\text{NCH}_2\text{CH}_2\text{OH}$	117	161	4.04	60	–	–	–
diethyl ether	$(\text{C}_2\text{H}_5)_2\text{O}$	74.1	34.5	2.55	<-20	1.7	36	170
diethyl oxalate	$(\text{COOC}_2\text{H}_5)_2$	146.1	180	5.04	76	–	–	–
diethyl sulfate	$(\text{C}_2\text{H}_5)_2\text{SO}_4$	154.2	208	5.31	104	–	–	–
di-isobutylene	C_8H_{16}	112	105	3.87	2	–	–	305
dimethylamine	$(\text{CH}_3)_2\text{NH}$	45.1	7	1.55	–	2.8	14.4	400
dimethylaniline	$\text{C}_6\text{H}_3(\text{CH}_3)_2\text{NH}_2$	121.2	194	4.17	63	1.2	7	370
dimethyl ether	$(\text{CH}_3)_2\text{O}$	46.1	-25	1.59	–	3.7	27.0	–
dioxane	$\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2$	88.1	101	3.03	11	1.9	22.5	379
dioxolane	$\text{OCH}_2\text{CH}_2\text{OCH}_2$	74.0	74	2.55	2	–	–	–
ethane	CH_3CH_3	30.1	-89	1.04	–	3.0	15.5	515
ethanethiol	$\text{C}_2\text{H}_5\text{SH}$	62.1	35	2.11	-20	2.8	18	295
ethanol	$\text{C}_2\text{H}_5\text{OH}$	46.1	78	1.59	12	3.3	19	425
ethanolamine	$\text{HOCH}_2\text{CH}_2\text{NH}_2$	61.0	172	2.1	85	–	–	–
ethoxyethanol	$\text{HOCH}_2\text{CH}_2\text{OC}_2\text{H}_5$	90.0	135	3.1	95	1.8	15.7	235
ethyl acetate	$\text{CH}_3\text{COOCH}_2\text{CH}_3$	88.1	77	3.04	-4	2.1	11.5	460
ethyl acrylate	$\text{CH}_2=\text{CHCOOC}_2\text{H}_5$	100.0	100	3.45	9	1.8	–	–
ethylbenzene	$\text{C}_2\text{H}_5\text{C}_6\text{H}_5$	106.2	136	3.66	15	1.0	6.7	431
ethyl cyclobutane	$\text{C}_2\text{H}_5\text{CHCH}_2\text{CH}_2\text{CH}_2$	84.2	–	2.0	<-16	1.2	7.7	210
ethyl cyclohexane	$\text{C}_2\text{H}_5\text{CH}(\text{CH}_2)_4\text{CH}_2$	112.2	131	3.87	14	0.9	6.6	262
ethyl cyclopentane	$\text{C}_2\text{C}_5\text{CH}(\text{CH}_2)_3\text{CH}_2$	98.2	103	3.4	1	1.1	6.7	260
ethyl formate	$\text{HCOOCH}_2\text{CH}_3$	74.1	54	2.55	<-20	2.7	16.5	440
ethyl methyl ether	$\text{CH}_3\text{OC}_2\text{H}_5$	60.0	8	2.09	–	2.0	10.1	190

TABLE 1 — Properties of Combustible Materials (continued)

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
ethylene	CH ₂ =CH ₂	28.1	-104	0.97	–	2.7	34	425
ethylene oxide	CH ₂ CH ₂ O	44.0	11	1.52	–	3.7	100	440
ethyl mercaptan	C ₂ H ₅ SH	62.1	35	2.11	<-20	2.8	18	295
ethyl methyl ketone	CH ₃ COCH ₂ CH ₃	72.0	80	2.48	-1	1.8	11.5	505
formaldehyde	HCHO	30.0	-19	1.03	–	7	73	424
hexane	CH ₃ (CH ₂) ₄ CH ₃	86.2	69	2.79	-21	1.2	7.4	233
hexanol	CH ₃ (CH ₂) ₄ CH ₂ OH	102.2	157	3.5	63	1.2	–	–
heptane	C ₇ H ₁₆	100.2	98	3.46	-4	1.1	6.7	215
hydrogen	H ₂	2.0	-253	0.07	–	4.0	75.6	560
hydrogen cyanide	HCN	27.0	26	.90	-18	5.6	40	(538)
hydrogen sulfide	H ₂ S	34.1	-60	1.19	–	4.3	45.5	270
isopropyl nitrate	(CH ₃) ₂ CHONO ₂	105	105	–	20	2	100	175
kerosene			150	–	38	0.7	5	210
metaldehyde	(CH ₃ CHO) _n n=4 to 6		112	6.07	36	–	–	–
methane (firedamp)	CH ₄	16.0	-161	0.55	–	5	15	595
methanol	CH ₃ OH	32.0	65	1.11	11	6.7	36	455
methoxyethanol	CH ₃ OCH ₂ CH ₂ OH	76.1	124	2.63	39	2.5	14	285
methyl acetate	CH ₃ COOCH ₃	74.1	57	2.56	-10	3.1	16	475
methyl acetoacetate	CH ₃ COCH ₂ CO ₂ CH ₃	116	170	4.0	67	–	–	280
methyl acetylene	CH ₃ C≡CH	40.1	-23	1.4	–	1.7	–	–
methyl acrylate	CH ₂ =CHCOOCH ₃	86.1	80	3.0	-3	2.8	25	–
methylamine	CH ₃ NH ₂	31.1	-6	1.07	–	5	20.7	430
methylcyclohexane	CH ₃ CH(CH ₂) ₄ CH ₂	98.2	101	3.38	-4	1.15	6.7	260
methylcyclohexanol	CH ₃ C ₆ H ₁₀ OH	114	168	3.93	68	–	–	295
methyl formate	HCOOCH ₃	60.1	32	2.07	<-20	5	23	450
2-methylpentane	C ₃ H ₇ CH(CH ₃)C ₂ C ₅	86.2		2.97	<-20	1.2	–	–

TABLE 1 — Properties of Combustible Materials (continued)

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
naphtha (Petroleum)			35	2.5	-6	0.9	6	290
naphthalene	C ₁₀ H ₈	128.2	218	4.42	77	0.9	5.9	528
nitrobenzene	C ₆ H ₅ NO ₂	123.1	211	4.25	88	1.8	–	480
nitroethane	CH ₃ CH ₂ NO ₂	75	115	2.58	27	–	–	410
nitromethane	CH ₃ NO ₂	61.0	101	2.11	36	–	–	415
nitropropane	CH ₃ CH ₂ CH ₂ NO ₂	89.0	131	3.06	49	–	–	420
nonane	C ₉ H ₂₀	128.3	151	4.43	30	0.8	5.6	205
nonanol	CH ₃ (CH ₂) ₇ CH ₂ OH	144.3	178	4.97	75	0.8	6.1	–
octane	CH ₃ (CH ₂) ₆ CH ₃	114.2	126	3.93	13	1.0	3.2	210
octaldehyde	C ₄ H ₉ CH(C ₂ H ₅)CHO	128.0	163	4.42	52	–	–	–
octanol	CH ₃ (CH ₂) ₆ CH ₂ OH	130.2	195	4.5	81	–	–	–
paraformaldehyde	HO(CH ₂ O) _n H n=8 to 100		25	–	70	–	–	300
paraldehyde	C ₆ H ₁₂ O ₃	132.0	124	4.56	17	1.3	–	235
pentane	C ₅ H ₁₂	72.2	36	2.48	<-20	1.4	8.0	285
pentanol	C ₅ H ₁₁ OH	88.0	138	3.04	34	1.2	10.5	300
pentylacetate	CH ₃ COOC ₅ H ₁₁	130.0	147	4.48	25	1.0	7.1	375
phenol	C ₆ H ₅ OH	94.1	182	3.24	75	–	–	605
propane	CH ₃ CH ₂ CH ₃	44.1	-42	1.56	–	2.0	9.5	470
propanol	CH ₃ CH ₂ CH ₂ OH	60.1	97	2.07	15	2.15	13.5	405
propylamine	C ₃ H ₇ NH ₂	59.1	32	2.04	<-20	2.0	10.4	320
propylene	CH ₃ CH=CH ₂	42.1	-48	1.5	–	2.0	11.7	455
pyridine	N(CH) ₄ CH	79.1	115	2.73	17	1.8	12.0	550
p-cymene	CH ₃ C ₆ H ₄ CH(CH ₃) ₂	134.2	177	4.62	47	0.7	5.6	435
styrene	C ₆ H ₅ CH=CH ₂	104.2	145	3.6	30	1.1	8.0	490
tetrahydrofuran	CH ₂ (CH ₂) ₂ CH ₂ O	72.1	64	2.49	-17	2.0	11.8	260
tetrahydrofurfuryl alcohol	C ₄ H ₇ OCH ₂ OH	102.1	178	3.52	70	1.5	9.7	280

TABLE 1 — Properties of Combustible Materials (continued)

Compound	Formula	MW	B.P. (°C)	Rel. Vap. Dens.	F.P. (°C)	Flammability Limits in Air		I.T. (°C)
						LEL (%Vol)	UEL (%Vol)	
toluene	C ₆ H ₅ CH ₃	92.1	111	3.18	6	1.2	7	535
toluidine	CH ₃ C ₆ H ₄ NH ₂	107.2	200	3.7	85	–	–	480
triethylamine	(C ₂ H ₅) ₃ N	101.2	89	3.5	<0	1.2	8	–
trimethylamine	(CH ₃) ₃ N	59.1	3	2.04	–	2.0	11.6	190
trimethylbenzene	(CH ₃) ₃ C ₆ H ₃	120.0	165	4.15	–	–	–	470
trioxane	OCH ₂ OCH ₂ OCH ₂	90.1	115	3.11	45	3.6	29	410
turpentine	mixture	–	149	–	35	0.8	–	254
xylene	C ₆ H ₄ (CH ₃) ₂	106.2	144	3.66	30	1.0	6.7	464

MW = Molecular Weight (g/mol)

B.P. = Boiling Point

Rel. Vap. Dens. = relative vapor density

F.P. = flash point

LFL = lower flammable limit

UFL = upper flammable limit

I.T. = ignition temperature

Note:

Data from IEC (North America)

and Hawley's Condensed

Chemical Dictionary.

Combustible Gas Detection

Two types of combustible gas detection are addressed in this chapter:

- Catalytic
- Infrared Absorption

A general description of the sensing theory, the advantages, and the limitations are presented.

CATALYTIC SENSOR

Theory of Operation

The most traditional and frequently used combustible gas detection method employs catalytic oxidation.

The catalytic gas sensor (or Pellistor) usually consists of a pair of platinum wire wound resistors encased by a bead of ceramic, such as alumina. The active catalytic bead is coated with a catalyst, such as platinum or palladium; the reference catalytic bead remains untreated. This matched pair is then enclosed behind a flameproof sinter. In operation, the beads are resistively heated to temperatures ranging from 300°C to 700°C.

When a combustible gas comes in contact with the catalytic surface, it is oxidized. Heat is released, causing the resistance of the wire to change. The concentration of gas present may be found by placing the sensor pair into a Wheatstone bridge circuit to sense the resistance change. Depending on the concentration of gas present, the Wheatstone arrangement produces a differential voltage between the active and reference beads.

The reference bead, or passive bead, maintains the same electrical resistance in clean air as the active bead, but does not catalyze the combustible gas. This attempts to compensate for variations in the ambient temperature, humidity, altitude, etc.

An example of a typical catalytic gas sensor is given in Figure 2.

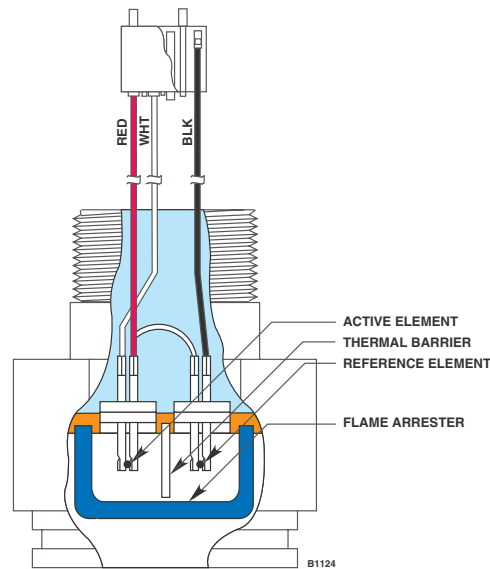


FIGURE 2
Diagram of a Catalytic Sensor

CATALYTIC SENSOR

Advantages

There are several benefits in choosing catalytic sensors for detecting the presence of combustible gases.

- Capable of detecting the greatest possible range of combustible vapors, including hydrocarbon and acetylene
- Good repeatability and accuracy
- Fast response time
- Low initial cost
- Good service life (typically 3 to 6 years)

CATALYTIC SENSOR

Limitations

The output of the catalytic sensor, in millivolts, has a linear relationship with the concentration of the combustible gas present. Although, it is possible to measure up to 100% LFL with catalytic sensors, use of catalytics is not recommended over 100% LFL. At high combustible gas concentrations, there may be insufficient oxygen to catalyze all of the combustible gas. In this instance, the output may decrease and indicate a concentration of less than 100% LEL. Other restrictions of catalytic sensing technology include:

- Requires oxygen levels greater than 10% to ensure oxidation
- Requires routine calibration (typically every three months)
- Require either a constant current or voltage power source (i.e., transmitter/card)
- Can only determine the general presence of combustible gases, not the specific chemicals or the types of gases.
- Susceptible to poisoning from a variety of substances, such as silicones, halogens (halon, chlorine, fluorine, bromine, freon), phosphate esters, tetraethyl lead, acid and pvc vapors, and other corrosive materials.
- Consumptive technology – exposure to high concentrations of combustible gas or for extended periods of time can consume the sensing element, thus requiring recalibration or replacement of the sensor.
- Non fail-safe, meaning the sensor is unable to detect if it is poisoned.
- As with any diffusion based point detector, a number of detectors may be required to monitor a hazardous area.

INFRARED ABSORPTION

Theory of Operation

The infrared (IR) method of gas detection relies on the IR absorption characteristics of gases to determine their presence and concentration. IR gas detectors consist of an IR light source (transmitter) and light detector (receiver) to measure the intensity both at the absorption wavelength and a non-absorbed wavelength. If gas is present in the optical path, it will affect the intensity of light transmitted between the light source and the detector. This change in intensity provides the data for determining that a specific gas, or type of gas is present.

This method works only for gases that can absorb infrared radiation. Most hydrocarbon based gases absorb IR radiation at around 3.4 micrometers, which is transparent to both water and carbon dioxide vapors. See Figure 3 for an example of an IR spectrum.

IR gas detection is rooted in the principles expressed in the Beer-Lambert Law.

$$T = I / I_0 = \exp(-aLc)$$

Defined as: the ratio of the intensity of light leaving (I) the sampling area to the intensity of light entering (I_0) the sampling area (otherwise known as the T , the transmittance of IR) is proportional to the exponential of the absorption coefficient of the particular gas (a), the concentration of the gas (c), and the length of sampling area (L).

Note:

IR gas detectors measure transmission. This signal is not, however, linear with gas concentration. Thus, signal processing algorithms are required to provide a linear output with gas concentration.

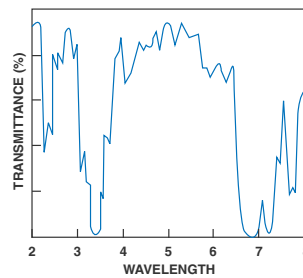


FIGURE 3
Spectrum Example

Types of IR Detection

Combustible IR gas detection can take one of two forms: either the **point detector** or the **open path detector**. The primary difference between point detectors and open path is the size of the IR path and its relationship to the gas/vapor sample source. The self-contained point detector has a smaller IR path than the open path detector, and is used to monitor fixed areas of space. The open path detector usually consists of a separate transmitter and receiver, which monitor much larger areas of space. Consequently, in some instances a single open path detector serves the function of multiple point detectors.

POINT DETECTION

Theory of operation

Point detectors follow the same principles of operation as described previously for infrared detection. The point detector operates on a short fixed path (30 to 150 mm) between the IR light source and the light detector, assuming uniform concentration along this path. IR light is passed through a sample of the gas/vapor, and received at the sensor(s). The active sensor is set in the absorption band of the gas being monitored, while the reference sensor is not. The ratio of the wavelengths are compared to determine if the gas/vapor is present.

POINT DETECTION

Advantages

A rapidly growing trend in combustible gas detection is the use of point IR detectors rather than catalytic detectors. Point IR detectors offer:

- Immune to poisoning from contaminants.
- Low maintenance.
- Factory calibrated.
- Unaffected by prolonged exposure to gas or high gas concentrations.
- Unaffected by changes in oxygen level.
- Fail-safe, meaning the sensor is able to detect and indicate conditions in which it is blind to gas.

POINT DETECTION

Limitations

Point IR detectors do have limitations, such as:

- Only detect hydrocarbon-based gases/vapors. It is not possible to use IR in the detection of hydrogen (H_2), carbon disulfide (CS_2) or acetylene, for example.
- As with all diffusion-based point detectors, a number of individual detectors may be required to monitor a hazardous area.

OPEN PATH DETECTION

Theory of operation

The open path IR detectors consist of a IR light source (transmitter) and an IR light detector (receiver), usually positioned at opposite ends of the open surveillance path (typically 10 – 100 m). As the IR beam reaches the receiver, it passes through a focusing lens and then passes through two narrow band IR filters – an active and a reference wavelength. The detector computes the ratio between the two signals (Figure 4).

The instrument's output is a function of gas concentration times the length of the surveillance path, and is expressed in units of LFL - m, ppm - m or % LFL - m. (The unit of LFL - meters is defined as: one LFL - m equals 100% LFL over a path of one meter.) Consequently, a small dense cloud of gas and a large dispersed cloud of gas could produce the same output. See Figure 5 for clarification.

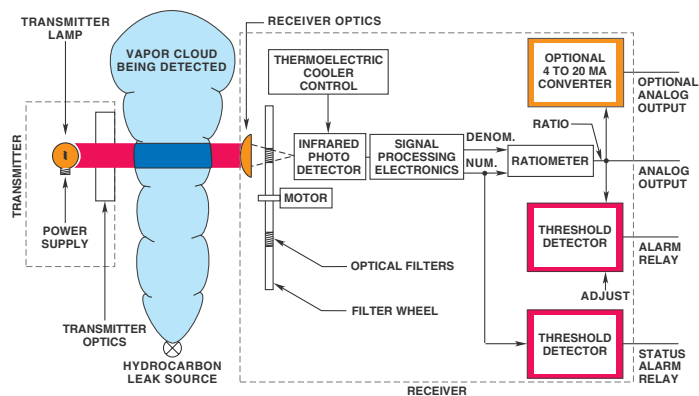


FIGURE 4
Open Path Detection Example

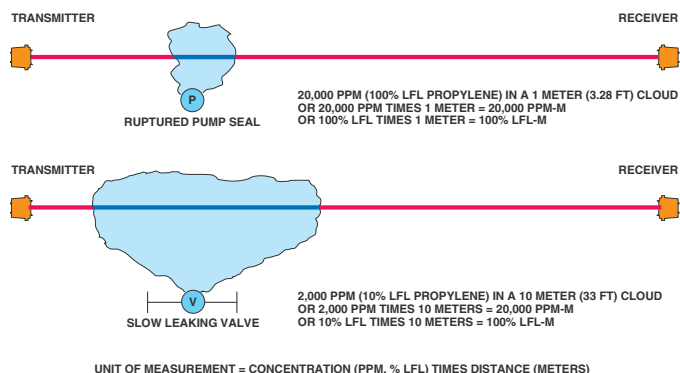


FIGURE 5
Illustration of a 2000 ppm-m gas open path output
for various concentrations and cloud sizes

OPEN PATH DETECTION**Advantages**

Open path IR is most effective for general area, perimeter and straight line monitoring because it can monitor large areas with a minimum number of instruments. Some examples include, monitoring a bank of heat exchangers, a row of pumps, tunnels, and pipelines. The benefits experienced with open path detection include:

- Greatest possible coverage – some commercially available units are capable of detecting vapors over distances of 100 meters.
- Immune to poisoning from contaminants.
- Low maintenance.
- Unaffected by prolonged exposure to gas or high gas concentrations.
- Unaffected by changes in oxygen level.
- Fail-safe, meaning the sensor is able to detect and indicate conditions in which it is blind to gas.

OPEN PATH DETECTION**Limitations**

Since a larger space is under evaluation it is more susceptible to the following:

- Obstructions in the beam path such as dust, rain, snow, mobile equipment, personnel, etc.
- Weight of the gas/vapor in comparison to the surrounding atmosphere.
- Only detect hydrocarbon-based gases/vapors. It is not possible to use IR in the detection of hydrogen (H₂), carbon disulfide (CS₂) or acetylene based substances.
- It is more difficult to identify the specific location of a gas/vapor leak, or cloud concentration.
- Susceptible to condensation unless external optical surfaces are heated.

Open Path systems are recommended for use in conjunction with point IR detectors or catalytic sensor systems for optimal combustible gas detection within a hazardous area.

Toxic gases form another group of potentially hazardous chemicals. These differ from combustible materials in terms of the mechanisms and effects of exposure. Many toxic gases are also combustible, in which case the potential for personnel exposure and hazards will be the determining factors in selecting the appropriate detection method.

A toxic substance may be defined as a chemical compound that can cause a wide range of damage to humans, ranging from minor irritations to the most extreme situation leading to death. Toxic chemicals may be ingested, inhaled, or absorbed through the skin. The effects of toxic substances vary by:

- Physical properties of the chemical.
- Length of exposure in units of time.
- Concentration in air of the toxic chemical often measured in parts per million (ppm) or milligrams per cubic meter (mg m^{-3}).
- Individual susceptibility.

Gas detection methods are used to continuously monitor and measure the concentration of toxic gases, and insure that it falls within safe limits. Limits for short and long term exposure to toxic gases have been established by occupational safety and health agencies such as Occupational Safety and Health Organization (OSHA) in the United States and Control of Substances Hazardous to Health (COSHH) in the United Kingdom. For specific information on individual toxic chemicals refer to the appropriate Material Safety Data Sheets (MSDS), which include:

- Chemical's identity
- Manufacturer and contact information
- Hazardous Ingredients and Identity information (i.e., exposure limits)
- Fire and Explosion Hazard Data (i.e., flash point, firefighting procedures, flammability limits)
- Reactivity Data (i.e., health hazards, emergency first aid, routes of entry)
- Precautions for Safe Handling and Use
- Control Measures (i.e., gloves, protective equipment)

The MSDS in Europe differ from those in the US; additional transport and regulatory information is provided in Europe. There are many sources for obtaining MSDS on toxic chemicals such as:

- Company's collection of MSDS on chemicals used at your facility
- Internet
- Chemical manufacturer
- Local Environmental or Occupational Health Offices
- A chemistry library
- Chemical handbooks.

Note:

The format may vary depending on the source, however, the information provided will be consistent.

Definitions & Concepts**Threshold Limit Value (TLV)**

The threshold allowable time-weighted average, expressed in parts per million (ppm) or parts per billion (ppb) or milligrams per cubic meter (mg m^{-3}), for personnel exposure over a normal 8 hour workday and 40 hour workweek.⁴ For optimal protection from toxic gases, typically a full scale range of 3 to 10 times the TLV of gas being monitored is selected. Exposure below the TLV generally does not have negative health effects.

Short Term Exposure Limit (STEL)

The STEL is the maximum concentration for a continuous exposure for up to 15 minutes, provided that the TLV is not exceeded.⁴

Long Term Exposure Limit (LTEL)

The LTEL is the maximum concentration for exposure under an 8 hour time weighted average period.¹⁰ TLV is the more commonly used term for this concentration.

Immediate Danger to Life and Health (IDLH)

The maximum concentration from which one could escape within minutes without any escape-impairing symptoms or irreversible harm effects.⁴

Lethal Concentration 50 (LC₅₀)

The concentration of a material in air that is expected to kill 50% of a group of test animals inhaling it.⁴

Toxic Gases

The occupational exposure standards for several common toxic substances are provided in Table 2.

TABLE 2 — Occupational Exposure Standards

Toxic Gas	Formula	Density*	LTEL		STEL	
			ppm	mg m ³	ppm	mg m ³
Ammonia	NH ₃	.596	25	17	35	24
Carbon Dioxide	CO ₂	1.53	5000	9000	15000	27000
Carbon Monoxide	CO	.968	50	55	300	330
Chlorine	Cl ₂	2.49	1	3	3	9
Hydrogen Sulfide	H ₂ S	1.19	10	14	15	21
Nitrogen Dioxide	NO ₂	1.04	3	5	5	9
Ozone	O ₃	1.66	0.1	0.2	0.3	0.6
Sulfur dioxide	SO ₂	2.26	2	5	5	13

*With reference to air = 1.00

Note:

For a complete listing of occupational exposure standards for toxic substances refer to OSHA in the United States and COSHH in the United Kingdom.

To demonstrate the hazardous effects of toxic gases Table 3 presents the effects of exposure to one of the most common toxic gases encountered in industry, hydrogen sulfide (H₂S).

TABLE 3 — Effects of H₂S

PPM Level	Time	Effect
170 – 300	1 hour	Maximum permissible exposure level
50 – 100	1 hour	mild eye / respiratory irritation
200 – 300	1 hour	marked eye / respiratory irritation
500 – 700	.5 to 1 hour	unconsciousness, death
+1000	minutes	rapid unconsciousness, cessation of respiration, death

Note:

For further information consult the IDLH Sheets from NIOSH.¹¹

Toxic Gas Detection

Two types of toxic gas detection are addressed in this portion of the manual:

- Electrochemical
- Metal Oxide Semiconductor (MOS)

A general description of the theory behind the technology, the advantages, and the limitations are presented.

ELECTROCHEMICAL

Theory of operation

Electrochemical sensors, or cells, are most commonly used in the detection of toxic gases. They are available with different numbers of electrodes determined by the target gas, device stability and cost.

The two-electrode electrochemical cell consists of an active (or sensing electrode) and a counter electrode connected externally via a load resistor, as shown in Figure 6. These electrodes are enclosed in a case with a permeable membrane for diffusion of the gas, which is submerged in an electrolyte.

As diffusion occurs, an oxidation or reduction reaction occurs at the active electrode. An exchange of electrons between the active element and the gas produces a change in the potential of the active electrode, while the counter electrode balances the reaction. The active electrode potential must fall within a specific range for a reaction to occur. As the target gas concentration increases, current flows causing the counter electrode to become polarized. If the gas level continues to rise, the potential of the active electrode will eventually exceed the permitting range.

When this occurs the output becomes non-linear, thus limiting the maximum measurable concentration point.

In an attempt to compensate for this limitation a third electrode, called the reference electrode is employed. The active electrode is held at a fixed potential relative to the reference electrode. The counter electrode while free to polarize, no longer has any affect on the active electrode. Thus, the cell is able to detect vapors over a much greater concentration range, The three-electrode electrochemical cell configuration is shown in Figure 7.

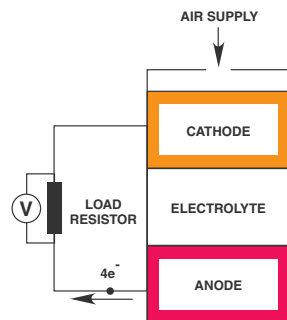


FIGURE 6
Two-electrode electrochemical cell
(oxygen cell shown)

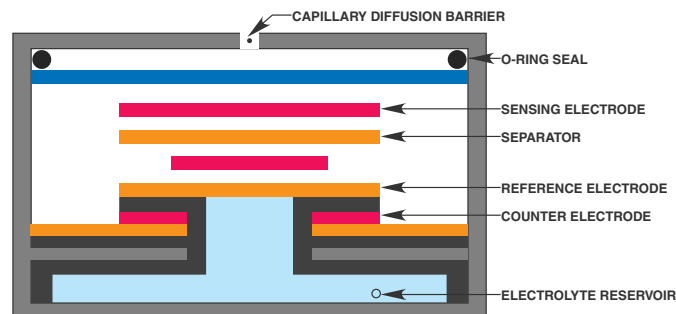


FIGURE 7
Three-electrode electrochemical cell

ELECTROCHEMICAL**Advantages**

Advantages of electrochemical sensors include:

- Highly sensitive.
- Low power (i.e., intrinsically safe operation).
- Good specificity to target gas/vapor.
- Direct linear output of current to gas concentration.
- Real zero.

ELECTROCHEMICAL**Limitations**

There are limitations to using electrochemical cells such as:

- Consumptive technology, electrolyte evaporates (this varies with the sensor's design and manufacturer) in arid conditions.
- Restrictions in some cold temperature environments.
- Requires routine calibration.
- As with all point detectors a number of devices may be required to monitor a hazardous area.
- Non fail-safe, meaning the sensor is unable to detect if it is poisoned.

MOS DETECTORS

Theory of operation

Metal oxide semiconductor (MOS) detectors are most frequently used for detecting hydrogen sulfide gas. An MOS device usually consists of a gas sensitive resistive film, a platinum heater element and an insulation medium. The gas sensitive film, traditionally, is made from a basic material of tin oxide or tungsten oxide combined with other oxides, catalyst or inhibitors to increase the selectivity of the device. Figure 8 presents a diagram of a typical MOS detector.

MOS sensors measure changes in electrical conductivity due to the presence of gas/vapor. In the presence of gas/vapor the MOS sensor produces a change in electrical conductivity.

In clean air, oxygen is adsorbed at the surface of the MOS sensor which strips electrons from the active material and forms a potential barrier, causing the resistance to increase. If a reducing gas is present, such as H_2S , the sensor surface will adsorb the vapor and become reduced, lowering the sensor resistance. This change in resistance may be logarithmically correlated to the concentration of the gas/vapor present. The operating temperature of the MOS sensor usually exceeds 100°C to speed up the rate of reaction, reduce ambient temperature effects, and provide greater degree of selectivity.

MOS DETECTORS

Advantages

Advantages of MOS sensors include:

- Quick response
- Long life
- Operate in low humidity
- Detects refrigerant gases, e.g. Freons, CFCs and HFCs.
- Wide operating temperature range
- Able to detect a broad range of vapors, including combustible gases

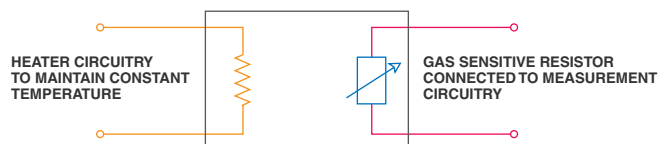


FIGURE 8
Diagram of a MOS detector

MOS DETECTORS

Limitations

Despite the advantages mentioned above, this method is not commonly employed due to:

- Must be frequently checked as the calibration tends to drift more than other technologies, they "go to sleep."
- Non-specific to target gas/vapor.
- High sensitivity to atmospheric disturbances such as rain and humidity changes.
- Affected by changes in oxygen level.
- As with all diffusion-based point detectors, a number of individual detectors may be required to monitor a hazardous area.
- Indirect measurement technique.
- Non fail-safe, meaning the sensor is unable to detect if it is poisoned.

This chapter of the guide contains suggestions as to what type of detection method is suitable for different applications. Typical gas detection applications, along with the relevant gases to be monitored, basic guidelines for detector placement, and other considerations for proper installation and usage will be provided.

What type of gas detection method should be used?

As illustrated in Chapter 2 and Chapter 4 of this manual, there are 4 main types of gas detection:

- Catalytic and Infrared (IR) for combustible gases.
- MOS and Electrochemical for toxic gases.

Suggestions for selecting detection technology for an application:

1. The type of gas – combustible or toxic – and its associated danger potential.
In **toxic gas applications**, a full scale range should be chosen that is greater than the TLV. (This allows you to set alarm points at concentration ranges above or below the TLV in situations where gas levels are hazardous.)
2. The potential risks that could result from a leak, such as
 - level of toxicity and the effects of exposure to personnel for toxic substances
 - explosion potential and magnitude for combustible gases (Remember, that an explosion will only occur if the concentration falls within the explosive range, oxygen is present, and there is an ignition source)
 - value of the equipment or process within the area under investigation

3. Review plant safety policy, insurance requirements/incentives, and regulatory or legal requirements/incentives for additional information regarding hazard protection and the need for gas detection equipment.
4. The amount of funds available to purchase gas detection systems, and life cycle cost analysis for maintenance, particularly calibration.

After these issues are addressed, the appropriate detection method may be determined. Some tips for when to use which method are provided in Table 4. Table 5, which lists many common industries and the types of hazardous gases in their processes may be of use.

Note:

These tables are intended as guides only, and do not include every possible industry or every possible hazard within each industry. Each situation should be carefully examined to determine all possible risks and to determine the best possible gas detection equipment.

TABLE 4 — Guidelines for Detection Method Selection

Combustible Gas Detection		Toxic Gas Detection	
IR for:	Catalytic for:	Electrochemical for:	MOS for:
<ul style="list-style-type: none"> Hydrocarbon applications Anaerobic areas Corrosives/caustics Wastewater Areas with constant background combustible gases Situations where cost of ownership is a concern 	<ul style="list-style-type: none"> Hydrocarbon applications with wide variety of vapors present Cost of ownership is not a concern Non-hydrocarbon monitoring (hydrogen) Low initial costs Applications where oxygen is always present Application where target gas should not normally be present 	<ul style="list-style-type: none"> Low humidity is not an issue Require high repeatability and consistency Applications where oxygen is normally present Application where target gas should not normally be present 	<ul style="list-style-type: none"> High temperature and/or low humidity applications (e.g., deserts) Applications where oxygen is always present Areas where ambient conditions are fairly stable

TABLE 5 — Typical Gas Detection Installations and Gases

Industry	Gas
Aircraft Hangars	Combustibles
Battery & UPS Rooms	H ₂
Biowaste/Mulch Pits	Methane, H ₂ S
Chemical, Solvent, & Paint Storage	Combustibles
Coal Storage Areas and Domes	Combustibles, CO, O ₂
Furnace Rooms, Kilns, Incinerators	Combustibles, CO, O ₂ , SO ₂ , NO ₂
Gaseous Fuel Storage Spheres	Combustibles
Ground Vaults	Combustibles, O ₂ , other toxics
Integrated Circuit Manufacturing	Combustibles and toxics
Landfill & Land Reclamation Sites	Methane, H ₂ S
Liquid Fuel Storage, Tank Farms	Combustibles
Nuclear Power Plants	Combustibles, H ₂
Oil and Natural Gas Drilling Sites	Combustibles, H ₂ S
Offshore Platforms	Combustibles, H ₂ S, other toxics
Paint & Powder Spray Booths	Combustibles
Paper & Pulp Mills	Combustibles, H ₂ S, Cl ₂ , other toxics
Petroleum & Petrochemical Refineries	Combustibles, H ₂ S, O ₂ , CO
Pipeline Compressors & Drive Packages	Combustibles and toxics
Printing Operations	Combustibles
Propane-powered Vehicles	Combustibles
Public Institutions	Combustibles and toxics
Restaurants & Kitchens	Combustibles
Rocket Staging & Launch Pads	Combustibles and toxics
Ships & Boats	Combustibles
Steam & Gas Turbines	Combustibles, H ₂ , CO, O ₂
Tunnels & Parking Garages	Combustibles, CO, O ₂
Wastewater Treatment Plants	Methane, H ₂ S, Cl ₂ , O ₂
Welding Shops	Combustibles and toxics

Where should the sensor be placed?

While various regulatory authorities have put forth gas detection system design and performance requirements (see Chapter 6), there are no “third party”^{*} rules that define optimum detector placement, or quantity requirements for an application.

There are, however, factors that should be considered when determining the best sensor locations within a hazardous area. While some factors result in hard-fast rules that apply to all gas detection applications, other factors will vary depending upon the specific situation. General guidelines are provided below to help identify the best locations of detectors for optimal performance.

^{*} Instrumentation Society of America (ISA) offers the following standards:

- RP92.0.02, Installation, Operation and Maintenance of Toxic Gas Instruments, Hydrogen Sulfide
- RP12.13, Part II, Installation, Operation and Maintenance of Combustible Gas Detection Instruments

Indoor vs. Outdoor Hazardous Areas:

No other single property has a larger impact on vapor dispersion characteristics and gas detection capability than the environmental setting of the application.

Indoor settings usually mean that the overall hazardous area is well contained. In addition, air flow characteristics are usually fairly consistent, and can be identified and often controlled. Ceilings and walls usually are the likely areas for gas accumulation and area delineation. Point(s) of human contact are usually easily identifiable. These factors help the application engineer to select the optimum detector locations.

Outdoor settings mean the air flow characteristics of the hazardous area are less controllable. Typically, there are no clear areas of likely gas accumulation, and often there are multiple points for potential human contact. Prevailing winds, if present, may be variable at best. These areas present the application engineer with a challenge which requires comprehensive application analysis, and ultimately sound

engineering judgement, to identify and select optimum detector locations.

General Sensor Placement Guidelines:

1. Density of gas(es) to be monitored
 - If the density of the gas/vapor is less than air (1.29 g/cc at normal conditions) the gas/vapor will rise, in still air, so the detector should be placed near the ceiling. (Refer to Table 1 and Table 2 for the relative densities of many combustible and toxic gases.)
 - If the density of the gas/vapor is greater than air (1.29 g/cc at normal conditions) the gas/vapor will settle, in still air, the detector should typically be placed 18 to 24 in (45.7 to 61 cm) above the floor or ground, or in some instances inches above where the gas would settle. (Refer to Table 1 and Table 2 for the relative densities of many combustible and toxic gases.)

- If the density of the gas/vapor is approximately equal to that of air (1.29 g/cc at normal conditions), the detector should be placed at or near breathing level, or near leakage point.
- The density of a gas is effected by temperature. Heating will decrease the density, making the gas lighter. Cooling will increase the density of the gas, making it heavier. Heating or cooling a gas by 30°C (54°F) will change the density of the gas by approximately 11%.

2. Air movement

The velocity and direction of air will affect the distribution of vapors or gases or both. To resolve this issue, the detectors should be placed where the currents with the maximum concentration of the gas being monitored reside. Smoke generator tests are often helpful to identify dead air spaces.

- Pressurized vapors will be distributed based upon location of leak.

3. Gas/vapor source
 - The detector will only correctly sense gases or vapors for which it is calibrated. Verify that the potential gas or vapor source is in agreement with the detector calibration.
 - The location and nature of potential sources of gases/vapors need to be evaluated. These may include pressure, amount of source, source temperature, and distance. The detector should be placed where leaks of gas/vapor may occur. For help in finding potential gas/vapor sources review process and instrumentation diagrams (PID), facility maps, and hazardous-area classification drawings.
 - Common areas for gas/vapor releases include pump and compressor seals, instrumentation sources, valve seals, gaskets, sample points and less frequently process piping.
4. Ignition source

For combustible gas detection applications, sources of ignition should be identified. The detector should be placed between the potential source of the gas/vapor and the ignition source.
5. Ambient temperature

Determine the maximum ambient high temperature, including all hot surfaces (e.g., motors, pumps, or steam lines).

 - As a general precaution, the maximum ambient temperature plus a safety factor of 50°C to 60°C should be less than the flash point of the gas being monitored. (Refer to Table 1 for the flash points of many combustible gases.)
6. Gas Dispersion

A hazardous gas or vapor may travel from its source or create a cloud that expands as it moves. Other factors such as density, temperature, and air movement as mentioned before effect this behavior. If it is possible to predict where the gas will move, place a sensor at that location.
7. Volatility

Detectors should be placed near the source for hazardous liquids with low volatility. Heavy vapors such as gasoline require some air movement to disperse vapors.
8. Vibration

Excessive vibration can damage the detector, producing unreliable results. To avoid this, attach the detector to a firm base.
9. Accessibility

Ensure that the detector is placed in a convenient location for future maintenance and calibration requirements.
10. Structural arrangements

Physical or thermal barriers (e.g., walls, troughs, or partitions) may disrupt typical gas dispersion patterns – allowing the vapor/gas to accumulate. If this is a potential problem, determine the dispersion patterns of the gas/vapor and place detectors accordingly.

Note:

If an explosion occurs obstacles such as vessels and pipes may become dislodged in a violent manner, thus creating further danger.

11. Location of Personnel

Particularly in situations dealing with toxic gases, it is extremely important to consider where people at your facility are likely to gather. Review Process Instrumentation Diagrams (PIDs), facility maps, and hazardous-area classification drawings to find these locations. A sensor should always be placed between the leak source and the people.

12. Mechanical damage and contamination

- Detectors should be placed in suitable locations to avoid damage from normal operations (e.g., cranes, traffic, exhausts, washdowns) at your facility.
- Precautions (i.e., additional sensors) should be taken to protect any expensive equipment or valuables at a facility from damage caused by gas leaks, such as corrosion.

Are there any other precautions to be taken when installing Gas Detectors?

1. When multiple gases/vapors are present, sensors should be calibrated to detect the gas that provides the least amount of relative sensor output at concentrations up to 100% LFL.
2. Generally, a diffusion-based gas detector can be considered to provide adequate coverage for a distance of 18 ft (5.5 m), according to the Christian Michelsen Institute, Norway.
3. For outside applications, careful consideration of prevailing wind conditions, which can disperse the gas in various directions and greatly reduce the measured concentration at the detector, is required.
4. For indoor applications, be aware that a confined area will increase the danger or hazard potential, or both, of the gas due to higher explosion pressures caused by contaminant of the explosion.
5. A dust cover or rain shield is recommended for dirty, dusty, wet, and outside applications.
6. For catalytic applications, verify that the sensor is installed facing downwards.
7. Sensor wiring should be routed away from other high current ac or dc wiring.

Note:

This is for unobstructed space only. It is not suitable for indoor applications.

Government law, insurance companies, and/or company policy require product approvals from authorized organizations throughout the world to maintain protection of personnel and property. This chapter describes the different organizations around the world and the guidelines that are used to ensure product quality and performance, thus eliminating potential hazards.

APPROVAL AGENCIES

Approval agencies perform testing in accordance with standards developed by committees which are made up of representatives from industry, government, and approval agency authorities. These organizations differ geographically. Det-Tronics works with many approval bodies from across the globe; Table 6 lists these organizations and their respective countries.

TABLE 6 — Approval Agencies

World Area	Approval Agency
Australia	SIMTARS, SSL
Belgium	ISSeP
Brazil	CEPEL
Canada	CSA
China	Government of CHINA
Denmark	DEMKO
Germany	PTB, TUV, BVS, DMT
Norway	DNV
Russia	VNIIEF, VNIIFTRI, VNIIPO
United Kingdom	BASEEFA, SIRA
United States	ITS, FMRC, UL, NEMA

Note:

Countries without approval agency may follow the IEC standards.

HAZARDOUS LOCATION PRODUCT APPROVAL National Electrical Code

In North America, equipment is classified for use in hazardous locations by the National Electrical Code (NEC) as part of a Class, Division, Group, and Temperature Code. The "Class" defines the general nature of the hazardous material in the surrounding atmosphere (Table 7). The "Division" defines the probability of hazardous material being present in an ignitable concentration in the surrounding atmosphere (Table 8). The "Group" defines the hazardous material in the surrounding atmosphere (Table 9). The "Temperature Code" indicates the maximum surface temperature of the apparatus or components based on -40°C to $+40^{\circ}\text{C}$ ambient temperature limits (-50°C to $+40^{\circ}\text{C}$ in Canada) (Table 10). The temperature code is assumed "T5" unless specified otherwise.

TABLE 7 — Classes defined by the National Electrical Code

Class I	Locations where flammable gases or vapors may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.
Class II	Locations where combustible or electrically conductive dusts may be present in the air in quantities sufficient to produce ignitable mixtures.
Class III	Locations where easily ignitable fibers or flyings not normally suspended in air may be present in quantities sufficient to produce ignitable mixtures.

TABLE 8 — Divisions defined by the National Electrical Code

Division 1	Locations in which the probability of the atmosphere being hazardous is high due to flammable material being present continuously, intermittently, or periodically.
Division 2	Locations which are presumed to be hazardous only in an abnormal situation.

TABLE 9 — Groups as defined by the National Electrical Code

Group A	Flammable Gases and Vapors (Class I)			Flammable Dusts and Debris (Class II)		
	Group B	Group C	Group D	Group E	Group F	Group G
Acetylene, or gases or vapors of equivalent hazards	Hydrogen, or gases or vapors of equivalent hazards	Ethylene, or gases or vapors of equivalent hazards	Propane, or gases or vapors of equivalent hazards	Conductive metal dust	Carbon dust	Flour, starch, or grain dust

TABLE 10 — Temperature Codes

North American Temperature Code	IEC Temperature Code	Max Surface Temp °C	Max Surface Temp °F
T1	T1	450	842
T2	T2	300	572
T2A		280	536
T2B		260	500
T2C		230	446
T2D		215	419
T3	T3	200	392
T3A		180	356
T3B		165	329
T3C		160	320
T4	T4	135	275
T4A		120	248
T5	T5	100	212
T6	T6	85	185

INTERNATIONAL ELECTROTECHNICAL COMMITTEE (IEC)

The IEC consists of close to 40 countries, attempting to establish international standards for electrical products. The IEC uses "Gas Groups," "Zones," and "Temperature Codes" to classify equipment for use in hazardous locations. The "Gas Groups" define the hazardous material in the surrounding atmosphere (Table 11). The "Zone" defines the probability of hazardous material being present in an ignitable concentration in the surrounding atmosphere (Table 12). The "Temperature Code" indicates the maximum surface temperature of the apparatus or components based on -20°C to $+40^{\circ}\text{C}$ ambient temperature limits (Table 10).

TABLE 11 — Gas Groups defined by the IEC

Gas Group	Representative Atmosphere
IIC	Acetylene, hydrogen, or gases or vapors of equivalent hazards.
IIB	Ethylene, or gases or vapors of equivalent hazards.
IIA	Propane, or gases or vapors of equivalent hazards.
I	Methane, or gases or vapors of equivalent hazards.

TABLE 12 — IEC Zones

Zone 0	An explosive concentration of gas or vapor is present continuously or is present for long periods of time.
Zone 1	An explosive concentration of gas or vapor is likely to be present for short periods of time under normal operating conditions.
Zone 2	An explosive concentration of gas or vapor is likely to be present for very short periods of time due to an abnormal condition.
Zone 20	An explosive atmosphere of dust is present continuously or is present for long periods of time.
Zone 21	An explosive atmosphere of dust is likely to be present for short periods of time under normal operating conditions.
Zone 22	An explosive atmosphere of dust is likely to be present for very short periods of time due to an abnormal condition.

Comparison of Classification Codes

Table 13 presents a comparison of the National Electrical Code and International Electrotechnical Committee hazardous location classification nomenclatures.

TABLE 13 — NEC and IEC Comparison

NEC	IEC
Class I, Division 1	Zone 0 and Zone 1
Class I, Division 2	Zone 2
Class II, Division 1	Zone 20 and Zone 21
Class II, Division 2	Zone 22
Class III, Division 1	None
Class III, Division 2	None

Fill in the following information to guide you in the selection and placement for different applications at your site.

1. Provide a general description of the application in which the detector(s) will be placed (for example, environmental conditions, equipment conditions, equipment present and locations).

2. List all combustible and toxic gases and/or vapors which may be present at the site under surveillance.

Gas or Vapor Name	Toxic or Combustible	Concentration	Notes

3. Required measuring range(s): _____

4. Are there any other substances present (for example, dust)? If so, please list:

5. A) Is detection in:
 - Normal oxygen environment (21 Vol %)
 - Oxygen deficient environment
 - Oxygen enriched environment

- B) Estimate the concentration of oxygen present in the atmosphere: _____

6. Ambient temperature ranges for the application:

Minimum: _____ °C °F

Maximum: _____ °C °F

Normal: _____ °C °F

7. Ambient humidity range for the application:

Minimum RH: _____%

Maximum RH: _____%

8. Pressure range for the application:

Minimum: _____ kPa psi

Minimum: _____ kPa psi

Maximum: _____ kPa psi

9. Velocity range of the application:

Minimum: _____ m/sec ft/sec

Maximum: _____ m/sec ft/sec

10. List any potential contaminants (poisons) that may affect the performance of the detectors.

11. Define the classification for the application:

Class: _____

Zone/Division: _____

Group: _____

12. Are any additional accessories necessary?

13. Other considerations or precautions.

Associated Apparatus

Apparatus in which the circuits are not necessarily intrinsically safe, but are relied upon to maintain intrinsic safety in hazardous locations by providing intrinsically safe outputs.

Boiling Point

The temperature of a liquid at which its vapor pressure is equal to the atmospheric pressure of the environment.

Calibration

The capability to adjust the instrument to "zero" and to set the desired "span."

Dust Ignition proof

A protection concept that prevents dust from entering an enclosure and will not allow arcs, sparks or heat generated inside the enclosure to cause ignition of the exterior accumulations or atmospheric suspensions of a specified dust on or near the enclosure.

Explosion-proof/Flame-proof

A protection concept that requires electrical equipment to be capable of containing an internal explosion of a specific flammable vapor-air mixture, thereby not allowing the propagation of ignition temperature gases to the external environment which may be potentially explosive. In addition, the equipment must operate at a safe temperature with respect to the surrounding atmosphere.

Flammable Materials

Flammable materials are a special group of combustible materials that rapidly burn and are easily ignited. The flash point of a liquid clarifies this further. The Flash Point (FP) of a flammable liquid is below 100°F (37.7°C), while the FP of a combustible liquid is at or above 100°F (37.7°C). The distinction between the behavior of the vapors of the combustible and flammable liquids must be considered for hazard protection, since it is the vapors that cause explosions.

Hazardous Chemical

Any chemical which is a physical or health hazard.⁴

Ingress Protection

Protection against ingress of solid foreign objects and/or water.

Intrinsic Safety

A protection concept that requires electrical equipment to be incapable of releasing sufficient electrical or thermal energy to cause ignition of a specific hazardous substance under "normal" or "fault" operating conditions.

Non-incendive/ Non-sparking

A type of protection which requires electrical equipment to be non-sparking and incapable of releasing sufficient electrical or thermal energy to cause ignition of a specific hazardous substance under "normal" operating conditions.

Ordinary Locations

A location where potentially explosive substances are not present. Electrical equipment certified for use in these locations must not present a shock or fire hazard.

Performance Approval

An approval stating the the instrument is certified to operate correctly under set of stringent conditions.

Pressurized

A type of protection by which the entry of a surrounding atmosphere into the enclosure of electrical apparatus is prevented by maintaining a protective gas at a higher pressure inside the enclosure than that of the surrounding atmosphere.

Purging

The passing of a quantity of protective gas through an enclosure so that any explosive atmosphere present in the enclosure is reduced to a concentration significantly below the lower explosive limit.

Shipping

Equipment designed to meet specific criteria for use on ocean-going vessels. The equipment must comply with humidity, vibration, temperature, and enclosure requirements established by each approval authority.

Special

A concept which has been adopted to permit the certification of those types of electrical equipment which, by their nature, do not comply with the requirements specified for equipment with established types of protection; but which can be shown to be suitable for use in prescribed zones or hazardous areas.

Sprays (or Mists)

Medium sized releases of fuel that are mixed with air upon release. Found typically at pipe gaskets, pump seals and valve stem failures under high pressure.

Vapor Pressure

The pressure of a vapor at any given temperature that is in equilibrium with its liquid or solid form.

References

For additional information on any of the topics mentioned in this manual or any other issues related to the detection of combustible and toxic gases, the following list of resources is suggested:

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