



## **Confined Space Entry**



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## **Characteristics of Confined Spaces**

- ***Large enough for worker to enter***
- ***Are not designed for continuous worker occupancy***
- ***Limited openings for entry and exit***

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## Large enough to enter



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## Meeting basic CS criteria

- **Limited means of entry and exit**
- **Not designed for continuous occupancy**



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## Permit Required Confined Spaces

- **One or more of the following:**
  - **Hazardous atmosphere (known or potential)**
  - **Material with the potential for engulfment**
  - **Inwardly sloping walls or dangerously sloping floors**
- or
- **Contains any other serious safety hazard**

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## Typical Confined Spaces

- **Storage tanks**
- **Ship compartments**
- **Process vessels**
- **Boilers**
- **Sewers**
- **Tunnels**
- **Underground utility vaults**
- **Pipelines**
- **Storm drains**



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## ***Some confined spaces are open topped***

- ***Pits***
- ***Degreasers***
- ***Open-topped water tanks***
- ***Ship holds***
- ***Excavations***

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## ***Confined Space Entry Requirements***



- ***OSHA 29 CFR 1910.146  
“Permit-Required Confined  
Spaces”***

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## 1910.146 General Requirements



- **Employers Must:**
  - **Identify Confined Space hazard areas**
  - **Inform employees by posting signs where feasible**
  - **Prevent entry by unauthorized persons**

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## 1910.146 General Requirements

- **Employers Must:**
  - **Establish procedures and practices to allow safe entry (Permit system)**
  - **Train employees**
  - **Provide required equipment**
  - **Control hazards where possible through engineering or work practices**

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## 1910.146 General Requirements

- **Employers Must:**
  - **Ensure procedures and equipment necessary for rescue**
  - **Protect entrants from external hazards**
  - **Enforce established procedures**

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## 1910.146 General Requirements

- **Employers must provide required equipment:**
  - **Testing and monitoring**
  - **Ventilation**
  - **Communications**
  - **Lighting**
  - **Barriers**
  - **Other personal protective equipment**
  - **Any required rescue and emergency equipment**

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**Work in confined spaces can produce dangerous atmospheric conditions**

- **Welding**
- **Painting**
- **De-greasing**
- **Scraping**
- **Sandblasting**
- **Mucking**
- **Inerting**



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**Before entry it is mandatory to determine that the CS atmosphere is safe!**

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## Monitor and ventilate continuously

- **Many accidents result from changes in the CS atmosphere which occur after the entry is initiated**
- **Monitoring determines the air is safe, ventilation keeps it that way**
- **The only way to pick up changes before they become life threatening is to monitor continuously!**



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## Three basic kinds of atmospheric hazards

- **Oxygen (deficiency and enrichment)**
- **Flammable gases and vapors**
- **Toxic contaminants**

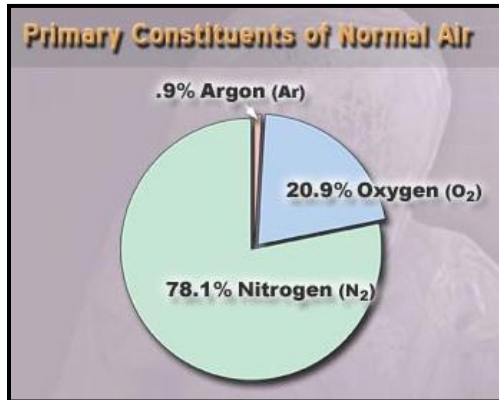
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## Composition of fresh air

- 78.1 % Nitrogen
- 20.9 % Oxygen
- 0.9 % Argon
- 0.1 % All other gases
  - Water vapor
  - CO<sub>2</sub>
  - Other trace gases



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## Oxygen Deficiency

- Air is oxygen deficient whenever concentration is less than 19.5%

### Definitions of Oxygen-Deficient Air

29 CFR 1910.146 (PRCS)	< 19.5%
29 CFR 1910.134 (Respiratory Protection)	< 19.5% <sup>1</sup>
ANSI Z117.1-1995 (Confined Spaces)	< 19.5%
ANSI Z88.2-1992 (Respirator Practices)	16.0% <sup>2</sup>
ACGIH (TLV Booklet)	18.0%

**Notes:**

<sup>1</sup> Oxygen content below 16% at sea level is considered IDLH -- Oxygen deficient.

<sup>2</sup> Oxygen partial pressure <122 mmHg. Confined space with <20.9% oxygen is IDLH, unless source of oxygen reduction is understood and controlled.

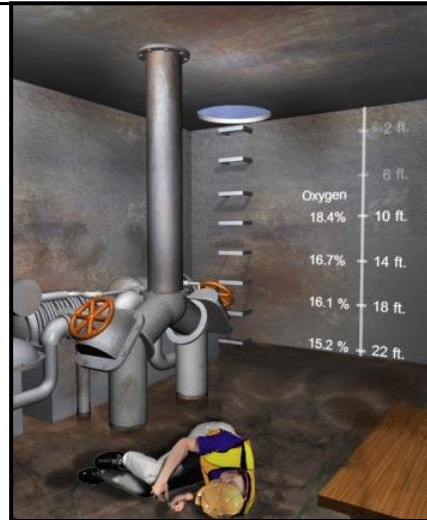
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## Causes of Oxygen Deficiency

- **Displacement**
- **Microbial action**
- **Oxidation**
- **Combustion**
- **Absorption**



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## Symptoms of Oxygen Deficiency

<b>20.9 %</b>	<b>Oxygen content in fresh air</b>
<b>19.5 % - 12 %</b>	<b>Impaired judgment, increased pulse and respiration, fatigue, loss of coordination</b>
<b>12 % - 10 %</b>	<b>Disturbed respiration, poor circulation, worsening fatigue and loss of critical faculties, symptoms within seconds to minutes</b>
<b>10 % - 6 %</b>	<b>Nausea, vomiting, inability to move, loss of consciousness, and death</b>
<b>6 % - 0 %</b>	<b>Convulsions, gasping respiration, cessation of breathing, cardiac arrest, symptoms immediate, death within minutes</b>

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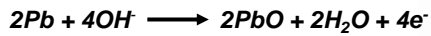


## Fuel Cell Oxygen Sensors

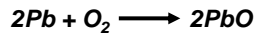
- Sensor generates electrical current proportional to the O<sub>2</sub> concentration
- Sensor used up over time (usually last one to three years)
- Oxygen reduced to hydroxyl ions at cathode:



- Hydroxyl ions oxidize lead (anode):



- Overall cell reaction:



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## Explosive or Flammable Atmospheres

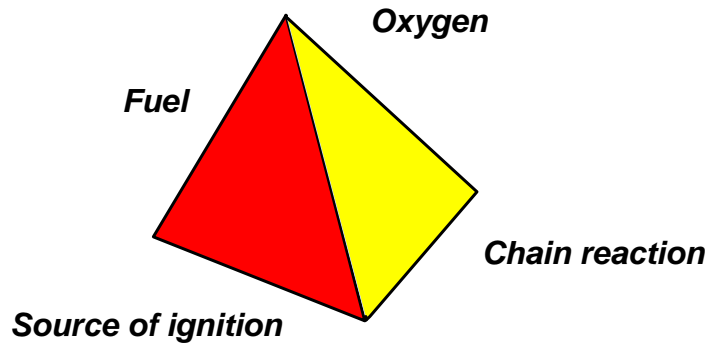


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## *Fire Tetrahedron*



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## *Lower Explosive Limit (L.E.L.)*

- *Minimum concentration of a combustible gas or vapor in air which will ignite if a source of ignition is present*

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## Upper Explosive Limit (U.E.L.)

- **Most but not all combustible gases have an upper explosive limit**
  - **Maximum concentration in air which will support combustion**
  - **Concentrations which are above the U.E.L. are too “rich” to burn**

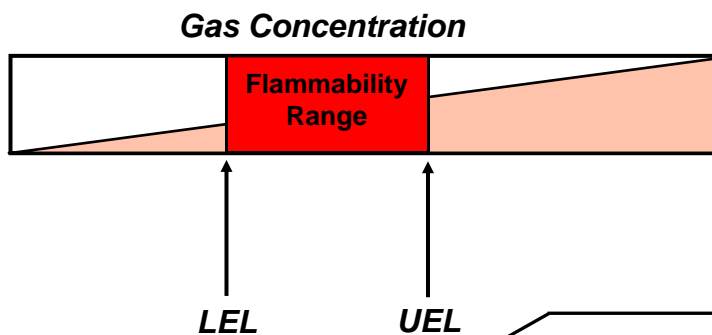
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## Flammability Range

- **The range between the L.E.L. and the U.E.L. of a combustible gas or liquid**
- **Concentrations within the flammable range will burn or explode if a source of ignition is present**



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## Different gases have different flammability ranges

	LEL	UEL
<b>Methane</b>	5 %	15 %
<b>Propane</b>	2.2 %	9.5 %
<b>Acetone</b>	2.6 %	12.8 %
<b>Ammonia</b>	16 %	25 %
<b>Carbon monoxide</b>	12.5 %	74 %
<b>Ethylene oxide</b>	3 %	100 %
<b>Hydrogen sulfide</b>	4.3 %	46 %

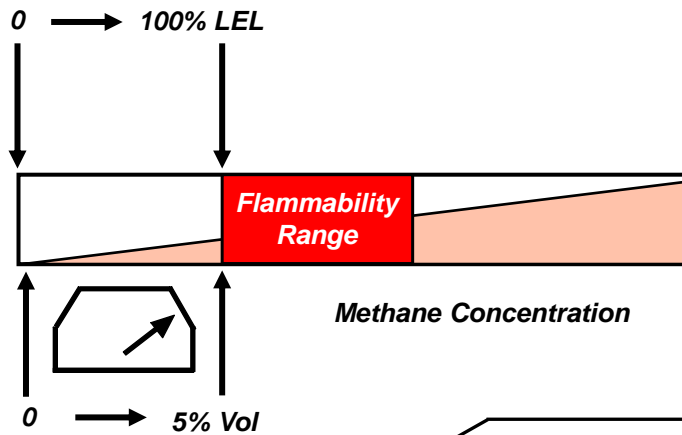
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## Combustible Gas/Vapor Instruments Read in "Percent LEL"

- The Lower Explosion Limit (LEL) concentration for methane is 5.0% volume



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## Catalytic “Hot Bead” Combustible Sensor

- *Detects combustible gas by catalytic oxidation*
- *When exposed to gas oxidation reaction causes bead to heat*
- *Requires oxygen to detect gas!*



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## Toxic Gases and Vapors



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## **Exposure Limits defined in three ways:**

- ***Time Weighted Average (TWA)***
- ***Ceiling***
- ***Short Term Exposure Limit (STEL)***

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## **Carbon Monoxide**

- ***Produced as a by product of incomplete combustion***
- ***Associated with internal combustion engine exhaust***
  - ***Vehicles***
  - ***Pumps***
  - ***Compressors***

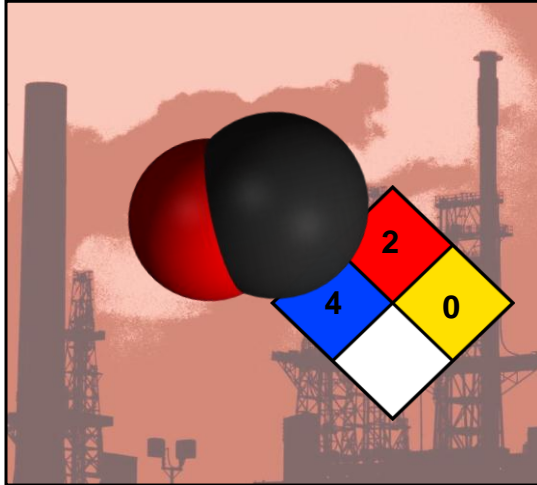
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## Symptoms of Carbon Monoxide Exposure

- **Headaches**
- **Fatigue**
- **Nausea and other "Flu-like" symptoms**
- **Loss of consciousness**
- **Brain damage**
- **Coma**
- **Death**



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## Exposure Limits for Carbon Monoxide

	8-Hr TWA	STEL	Ceiling
<b>Federal USA OSHA PEL</b>	50 ppm	NA	NA
<b>NIOSH REL</b>	35 ppm	NA	200 ppm
<b>TLV</b>	25 ppm	NA	NA
<b>UK OEL</b>	30 ppm	200 ppm	NA
<b>French VL</b>	50 ppm	NA	NA
<b>DFG MAK</b>	30 ppm	60 ppm peak for any 15-min period, (as average value), maximum 4 per shift separated by at least 1-hour	

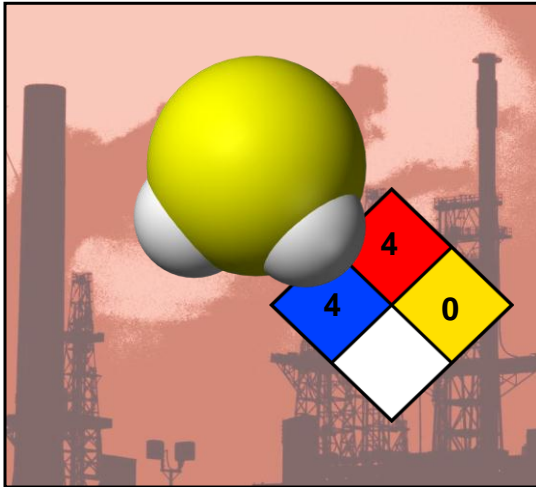
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## Characteristics of Hydrogen Sulfide

- **Colorless**
- **Smells like “rotten eggs” (at low concentrations)**
- **Heavier than air**
- **Corrosive**
- **Flammable (LEL is 4.3 %)**
- **Soluble in water**
- **Extremely toxic!**



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## Toxic effects H<sub>2</sub>S

>1.0 PPM	Smell
100 PPM	Rapid loss of smell
200 – 300 PPM	Eye inflammation, respiratory tract irritation after 1 hour, loss of consciousness with time
500 – 700 PPM	Death in 30 min. – 1 hr.
1000 PPM	Immediate respiratory arrest, loss of consciousness, followed by death

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## Exposure limits for H<sub>2</sub>S

### Federal USA OSHA PEL

	8-Hour TWA	STEL	Acceptable Ceiling Concentration	Acceptable Max Peak Above Ceiling for an 8-Hour Shift	
				Concentration	Maximum Duration
	NA	NA	20 ppm	50 ppm	10-minutes once only if no other measurable exposure occurs during shift
REL	10 ppm	15 ppm	NA	NA	NA
TLV (2010)	1.0 ppm	5.0 ppm	NA	NA	NA
UK OEL	10 ppm	15 ppm	NA	NA	NA
FR VL	5 ppm	10 ppm	NA	NA	NA
DFG MAK	10 ppm	NA	20 ppm peak in any 10-min period, (as momentary ceiling value), maximum 4 per shift		



## Substance-specific electrochemical sensors

- Gas diffusing into sensor reacts at surface of the sensing electrode
- Sensing electrode made to catalyze a specific reaction
- Use of selective external filters further limits cross sensitivity



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## Calibration

- **Verify accuracy on a regular basis is to guard against any unexpected loss of sensitivity**
- **Document!**



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## Regulatory Requirements

- **OSHA 1910.146 requires use of a “calibrated” instrument**
- **This means (per OSHA CPL 2.100) that the instrument must be maintained and calibrated according to manufacturer guidelines**



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## Record Keeping

- **Documentation is critical!**
- **Without good records you cannot defend or explain your procedures**
- **If you don't have the records to prove it was being done right -- it wasn't!**



DS400 Instrument Service Report									
Date/Time	Identification	Details	Test	Sensor	Test	Zero	Obs		
2009-06-01 08:59	Instrument Dok User	D-800 S/N07122146 version 3.24 D-8400 S/N09053144 version 2.14 LAR'S BOETTNER	CAL	H2S	200PPM	PASS	PASS	PASS	
			CAL	CO	200PPM	PASS	PASS	PASS	
			CAL	O2	10V/O2	PASS	PASS	N/A	
			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	
2009-06-01 09:08	Instrument Dok User	D-800 S/N00054845 version 3.24 D-8400 S/N09053144 version 2.14	Bump	H2S	200PPM	PASS	PASS	PASS	
			Bump	CO	200PPM	PASS	PASS	PASS	
			Bump	O2	10V/O2	PASS	PASS	PASS	
			Bump	LEL	50LEL	PASS	PASS	PASS	
			Bump	LEL	Alarm	PASS	PASS	PASS	
			Bump	Visual	Alarm	PASS	PASS	PASS	
2009-06-01 09:12	Instrument Dok User	D-800 S/N00054845 version 3.24 D-8400 S/N09053144 version 2.14	CAL	H2S	200PPM	PASS	PASS	PASS	
			CAL	CO	200PPM	PASS	PASS	PASS	
			CAL	O2	10V/O2	PASS	PASS	N/A	
			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	
2009-06-02 09:52	Instrument Dok User	D-800 S/N00000002 version 3.24 D-8400 S/N09053144 version 2.14	CAL	H2S	200PPM	PASS	PASS	PASS	
			CAL	CO	200PPM	PASS	PASS	PASS	
			CAL	O2	10V/O2	PASS	PASS	N/A	
			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	
2009-06-02 08:54	Instrument Dok User	D-800 S/N02054860 version 3.24 D-8400 S/N09053144 version 2.14	Bump	H2S	200PPM	PASS	PASS	PASS	
			Bump	CO	200PPM	PASS	PASS	PASS	
			Bump	O2	10V/O2	PASS	PASS	PASS	
			Bump	LEL	50LEL	PASS	PASS	PASS	
			Bump	LEL	Alarm	PASS	PASS	PASS	
			Bump	Visual	Alarm	PASS	PASS	PASS	
2009-06-02 09:04	Instrument Dok User	D-800 S/N07122146 version 3.24 D-8400 S/N09053144 version 2.14 LAR'S BOETTNER	CAL	H2S	200PPM	PASS	PASS	PASS	
			CAL	CO	200PPM	PASS	PASS	PASS	
			CAL	O2	10V/O2	PASS	PASS	N/A	
			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	
2009-06-02 09:17	Instrument Dok User	D-800 S/N03082699 version 3.23 D-8400 S/N09053144 version 2.14	CAL	H2S	200PPM	PASS	PASS	PASS	
			CAL	CO	200PPM	PASS	PASS	PASS	
			CAL	O2	10V/O2	PASS	PASS	N/A	
			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	
2009-06-02 09:25	Instrument Dok User	D-800 S/N03082699 version 3.23 D-8400 S/N09053144 version 2.14	Bump	H2S	200PPM	PASS	PASS	PASS	
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			Bump	O2	10V/O2	PASS	PASS	PASS	
			Bump	LEL	50LEL	PASS	PASS	PASS	
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			CAL	LEL	50LEL	PASS	PASS	PASS	
			CAL	LEL	Alarm	PASS	PASS	PASS	
			CAL	Visual	Alarm	PASS	PASS	PASS	

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## Atmospheric hazards are frequently invisible to human senses

- **You don't know whether it's safe until it's been tested!**

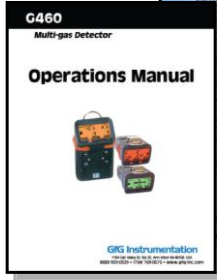
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**Questions?**



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