

**Test Preparation Study Guide  
For  
Underground Fire Boss Certification**

**FIRE BOSS**

*This guide was developed by the Utah Labor Commission.  
The CFR references throughout this guide are current as of 2014.*

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# CHAPTER ONE

## **MINE GASSES**

1. Methane
2. Carbon Monoxide
3. Carbon Dioxide
4. Hydrogen Sulphide
5. Hydrogen
6. Sulfur Dioxide
7. Nitrogen Dioxide
8. Nitrogen
9. Oxygen
10. Acetylene
11. Properties of Air
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# Methane



**Methane** is a colorless, odorless, flammable gas. It is lighter than air, having a specific gravity of 0.554 and is often found near the mine roof (ceiling of the mine opening). It is only slightly soluble in water. It burns readily in air, forming carbon dioxide and water vapour; the flame is pale, slightly luminous, and very hot. The boiling point of methane is -162.0° C (-259.6° F) and the melting point is -182.5° C (-296.5° F). Methane in general is very stable, but mixtures of methane and air are explosive. Explosions of such mixtures have been frequent in coal mines and collieries and have been the cause of many mine disasters. The most volatile explosion of methane and air mixture occurs when methane content is at 10 percent.

When mixed with air, methane is explosive in concentrations between approximately 5% and 15%. Liquid methane does not burn unless subjected to high pressure.

### ***Potential health effects***

Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. High concentrations of the gas in closed spaces, may reduce the oxygen percentage in air and cause suffocation. Asphyxia may result if the oxygen concentration is reduced to below 19.5% by displacement.

### ***Facts About Methane***

- Methane gas occurs naturally in all coal mines, trapped in pores within the coal bed. It is released as the coal is broken up during the mining process. The amount of methane liberated by the coal depends on the geologic age and type of coal and the depth of the coal deposit. Natural gas used in household furnaces is composed mostly of methane.
- Methane can be detected with hand-held or stationary instruments. Checks for methane are made by certified persons at regular intervals before and during the time while people are working underground.
- Federal safety standards mandate that, “when 1.0 percent or more methane is present in a working place or an intake air course, electrically powered equipment in the affected area shall be de-energized, and other mechanized equipment shall be shut off.”
- A flammable mixture of methane and air can be ignited by electric arcs and sparks, open flames or by the heat of friction between the cutting bits of mining equipment and the mine rock immediately above or below the coal.

## ***Coal Mines and Methane***

Methane emissions in working mines arise at two key stages:

(1) Methane is released as a direct result of the physical process of coal extraction. In many modern underground mines, the coal is extracted through longwall mining. Longwall mining, as with other sub-surface techniques, releases methane previously trapped within the coal seam into the air supply of the mine as layers of the coal face are removed, thus creating a potential safety hazard.

(2) Methane emissions arise from the collapse of the surrounding rock strata after a section of the coal seam has been mined and the artificial roof and wall supports are removed as mining progresses to another section. The debris resulting from the collapse is known as gob and also releases methane or 'gob gas' into the mine.

## **Carbon monoxide**

### **CO**

**Carbon Monoxide** is a colorless, odorless and tasteless gas, which is highly toxic to humans and animals. It is produced from the incomplete combustion or explosion of substances containing carbon such as coal, natural gas or gasoline. Large quantities of CO are generated during mine fires or explosions.

Carbon monoxide is slightly lighter than air. It is flammable and explosive in mixtures with air in concentrations between 12.5 and 74%. It is toxic because it blocks the ability of the hemoglobin in the blood to carry oxygen from the lungs to the muscles and other tissue in the human body.

### ***Coal Mines and Carbon Monoxide***

Carbon monoxide may be present in the afterdamp of a gas- or coal-dust explosion, or in the gases given off by a mine fire; also one of the gases produced by blasting. It is an important constituent of illuminating gas, supports combustion, and is very poisonous.

Carbon monoxide (sometimes referred to as "white damp") is the most dangerous gas to be dealt with in a mine. Unlike carbon dioxide, which as the levels increase the density makes it sink, carbon monoxide is lighter than air and subsequently more deadly because of it. It can be caused by explosions either from fire damp or coal dust (thus being an integral part of after damp). In addition to being toxic, it is also very flammable.

The NIOSH recommended exposure limit (REL) for CO is 35 ppm, measured as a time-weighted average (TWA) for up to a 10-hour workday during a 40-hour work week. The ceiling concentration (not to be exceeded during any part of the workday) is 200 ppm. CO in concentrations of 500 ppm or 0.05% can be fatal in 3 hours. Higher concentrations can lead to coma and death in minutes. Carbon monoxide is known as a “silent killer”.

Carbon monoxide can be detected by hand-held sensors. Stationary sensors may also be installed at strategic points in mine airways.

### ***Effects on Life***

Carbon monoxide is so dangerous to humans because it is so readily absorbed by the blood—even more than just oxygen. Making it worse, the body is slow to "give it up," making treatment that much more difficult. Also, because the body continues to absorb the gas (death comes at 80% saturation), even low levels can build up in the body causing death. It is at about 0.02% that one begins feeling the effects—in this case, "slight giddiness, headache and breathlessness" If the level gets as high as 0.2%, death will take place in one to two hours. The amount of time before a fatality (from there on up), is dependent not only on the percentage of carbon monoxide, but the amount of exertion by the person.

Because, unlike carbon dioxide, flames won't extinguish or die down in the presence of carbon monoxide, one of the chief tests was done by bringing small animals, usually birds (the proverbial "canary in a coal mine") and mice. They would succumb much sooner than a full grown man or even a boy.

### **Symptoms Associated With a Given Concentration of CO Over Time**

| <b>PPM CO</b> | <b>Time</b> | <b>Symptoms</b>  |
|---------------|-------------|--|
| 35            | 8 hours     | Maximum exposure allowed by OSHA in the workplace over an eight hour period.           |
| 200           | 2-3 hours   | Mild headache, fatigue, nausea and dizziness.  |
| 400           | 1-2 hours   | Serious headache-other symptoms intensify. Life threatening after 3 hours.             |
| 800           | 45 min      | Dizziness, nausea and convulsions. Unconscious within 2 hours. Death within 2-3 hours. |
| 1600          | 20 min      | Headache, dizziness and nausea. Death within 1 hour.                                   |
| 3200          | 5-10 min    | Headache, dizziness and nausea. Death within 1 hour.                                   |
| 6400          | 1-2 min     | Headache, dizziness and nausea. Death within 25-30 minutes.                            |
| 12,800        | 1-3 min     | Death  |



# Carbon Dioxide

## CO<sub>2</sub>

At room temperature, **carbon dioxide** takes the form of an odorless, colorless gas which is incombustible in normal conditions. Carbon dioxide can be forced into a solid form, in which case it is known as dry ice, and the gas is toxic to animals in high concentrations. People who inhale too much carbon dioxide essentially suffocate, ultimately falling into unconsciousness as their oxygen saturation level drops.

Carbon dioxide is a trace gas being only 0.038% of the atmosphere. It is produced through decomposition of organic materials as well as through respiration and combustion. It is also generated as a by-product of the combustion of fossil fuels or the burning of vegetable matter, among other chemical processes.

### ***Coal Mines and Carbon Dioxide***

Besides being a part of both after damp and black damp, as noted above, carbon dioxide levels increase due to human and (in some cases, particularly in the past) animal respiration. Other sources include burning of candles or torches (less common since electricity came to mining), explosions, chemical reactions with certain rocks/minerals, even the decay of timber. One of the key tasks of a mine ventilation system is to get rid of carbon dioxide (hardly the most deadly, but the one most apt to build up in the day to day operation of a mine).

While not combustible or poisonous, by itself, levels of 18% can kill, 25% quickly. If it is combined with a corresponding drop in the percentage of oxygen, those numbers can drop to 9% and 10%, respectively. Levels as low as 3% can make breathing more difficult, symptoms worsening as the percentage rises.

### ***Effects on Life***

While carbon dioxide does contribute to maintaining human health by maintaining the pH balance of blood, it can lead to suffocation when the concentration is too high.

CO<sub>2</sub> is toxic in higher concentrations: 1% (10,000 ppm) will make some people feel drowsy. When inhaled at concentrations much higher than usual atmospheric levels, it can produce a sour taste in the mouth and a stinging sensation in the nose and throat. Concentrations of 7% to 10% cause dizziness, headache, visual and hearing dysfunction, and unconsciousness within a few minutes to an hour.

# Hydrogen Sulfide

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

**Hydrogen sulfide** is a colorless, highly toxic and flammable gas. Being heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. It smells like rotten eggs and is sometimes called hydrosulfuric acid, stink gas or sewer gas. Although very pungent at first, it quickly deadens the sense of smell, so potential victims may be unaware of its presence until it is too late.

- 0.0047 ppm is the recognition threshold, the concentration at which 50% of humans can detect the characteristic odor of hydrogen sulfide
- Less than 10 ppm has an exposure limit of 8 hours per day.
- 10–20 ppm is the borderline concentration for eye irritation.
- 50–100 ppm leads to eye damage.
- At 150–250 ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger,
- 320–530 ppm leads to pulmonary edema with the possibility of death.
- 530–1000 ppm causes strong stimulation of the central nervous system and rapid breathing, leading to loss of breathing;
  - 800 ppm is the lethal concentration for 50% of humans for 5 minutes exposure(LC50).
- Concentrations over 1000 ppm cause immediate collapse with loss of breathing, even after inhalation of a single breath.

### Health Effects of Hydrogen Sulfide

H<sub>2</sub>S is classed as a **chemical asphyxiant**, similar to carbon monoxide and cyanide gases. It inhibits cellular respiration and uptake of oxygen, causing biochemical suffocation. Typical exposure symptoms include:

|                            |              |   |
|----------------------------|--------------|---|
| <b>L<br/>O<br/>W</b>       | 0 - 10 ppm   | Irritation of the eyes, nose and throat   |
| <b>M<br/>E<br/>D</b>       | 10 - 50 ppm  | Headache<br>Dizziness<br>Nausea and vomiting<br>Coughing and breathing difficulty   |
| <b>H<br/>I<br/>G<br/>H</b> | 50 - 200 ppm | Severe respiratory tract irritation<br>Eye irritation / acute conjunctivitis<br>Shock<br>Convulsions<br>Coma<br>Death in severe cases |

Prolonged exposures at lower levels can lead to bronchitis, pneumonia, migraine headaches, pulmonary edema, and loss of motor coordination.

Should a co-worker ever be overcome by H<sub>2</sub>S gas, do not attempt a rescue until you are properly protected yourself. The rescuer can very easily get caught out by venturing into a confined space without adequate protection. Remember that at levels above 200 ppm, collapse, coma and death due to respiratory failure can occur within seconds after only a few inhalations so you can be overcome yourself very quickly. Such incidents are sadly all too common and only serve to make the rescue effort twice as difficult.

### ***Coal Mines and Hydrogen Sulfide***

Hydrogen Sulfide, also known as "stink damp," the gas is caused by the decomposition of iron pyrites in a mine due to the dampness or presence of water. While considerably more deadly than carbon monoxide (and inflammable), amounts of this gas are usually only trace. Another thing in favor of the miners is that the gas has a foul, disagreeable odor (like rotten eggs) which serves as a usually adequate warning.

Like carbon dioxide, it is heavier than air and sinks. Animals could also be used to test for it by placing them near the floor of the mine (1% could cause death rather quickly and as little as 0.07%, over time, could also kill) but the smell and relative nonabundance of the gas make it less of a concern than the others.

While proper ventilation and methods to test for gases have come a long way since they actually used animals to test, the danger of gas buildup in a coal mine is a constant and important concern. Awareness of the potential problem and knowledge of the safety procedures are an important part of keeping men alive who spend so much of their lives digging underground for coal.

# Hydrogen

## H<sub>2</sub>

**Hydrogen** is the lightest element. It is by far the most abundant element in the universe and makes up about about 90% of the universe by weight. Hydrogen as water (H<sub>2</sub>O) is absolutely essential to life and it is present in all organic compounds. Hydrogen is the lightest gas. Hydrogen gas was used in lighter-than-air balloons for transport but is far too dangerous because of the fire risk. It burns in air to form only water as waste product and if hydrogen could be made on sufficient scale from other than fossil fuels then there might be a possibility of a hydrogen economy.

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Table: basic information about and classifications of hydrogen.

---

|   |   |
|---|---|
| <a href="#">Name</a> : Hydrogen               | <a href="#">Group in periodic table</a> : 1       |
| <a href="#">Symbol</a> : H                    | <a href="#">Group name</a> : (none)               |
| <a href="#">Atomic number</a> : 1             | <a href="#">Period in periodic table</a> : 1      |
| <a href="#">Atomic weight</a> : 1.00794 (7)   | <a href="#">Block in periodic table</a> : s-block |
| <a href="#">Standard state</a> : gas at 298 K | <a href="#">Color</a> : colorless                 |
| <a href="#">CAS Registry ID</a> : 1333-74-0   | <a href="#">Classification</a> : Non-metallic     |

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### ***Properties/Combustion***

Hydrogen gas is highly flammable and will burn in air at a very wide range of concentrations between 4% and 75% by volume. The enthalpy of combustion for hydrogen is  $-286$  kJ/mol:  
 $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\text{l}) + 572 \text{ kJ (286 kJ/mol)}$

Hydrogen gas forms explosive mixtures with air in the concentration range 4-74% (volume per cent of hydrogen in air) and with chlorine in the range 5-95%. The mixtures spontaneously detonate by spark, heat or sunlight. The hydrogen autoignition temperature, the temperature of spontaneous ignition in air, is  $500$  °C ( $932$  °F). Pure hydrogen-oxygen flames emit ultraviolet light and are nearly invisible to the naked eye. The detection of a burning hydrogen leak may require a flame detector; such leaks can be very dangerous. The destruction of the Hindenburg airship was an infamous example of hydrogen combustion; the cause is debated, but the visible flames were the result of combustible materials in the ship's skin. Because hydrogen is buoyant in air, hydrogen flames tend to ascend rapidly and cause less damage than hydrocarbon fires.

H<sub>2</sub> reacts with every oxidizing element. Hydrogen can react spontaneously and violently at room temperature with chlorine and fluorine to form the corresponding hydrogen halides, hydrogen chloride and hydrogen fluoride, which are also potentially dangerous acids.

## ***Safety and precautions***

Hydrogen poses a number of hazards to human safety, from potential detonations and fires when mixed with air to being an asphyxiant in its pure, oxygen-free form. In addition, liquid hydrogen is a cryogen and presents dangers (such as frostbite) associated with very cold liquids. Hydrogen dissolves in many metals, and, in addition to leaking out, may have adverse effects on them, such as hydrogen embrittlement, leading to cracks and explosions. Hydrogen gas leaking into external air may spontaneously ignite. Moreover, hydrogen fire, while being extremely hot, is almost invisible, and thus can lead to accidental burns.

Even interpreting the hydrogen data (including safety data) is confounded by a number of phenomena. Many physical and chemical properties of hydrogen depend on the parahydrogen/orthohydrogen ratio (it often takes days or weeks at a given temperature to reach the equilibrium ratio, for which the data is usually given). Hydrogen detonation parameters, such as critical detonation pressure and temperature, strongly depend on the container geometry.

## **Sulfur Dioxide**

### **SO<sub>2</sub>**

**Sulfur dioxide** (also **sulphur dioxide**) is a heavy, colorless, poisonous gas with a pungent odor, familiar as the smell of a just-struck match. It is a liquid when under pressure, and it dissolves in water very easily. Since coal and petroleum often contain sulfur compounds, their combustion generates sulfur dioxide. Further oxidation of SO<sub>2</sub>, usually in the presence of a catalyst such as NO<sub>2</sub>, forms H<sub>2</sub>SO<sub>4</sub>, and thus acid rain. Large quantities of sulfur dioxide are formed in the combustion of sulfur-containing fuels.

### **Effects on Life**

Sulfur dioxide is toxic in large amounts and can be life threatening. Exposure to 100 ppm is considered immediately dangerous to human life and health. Burning of the nose and throat, breathing difficulties, and severe airway obstructions occurred in miners who breathed Sulfur Dioxide released as a result of exposure. Sulfur dioxide blocks nerve signals from the pulmonary stretch receptors (PSR's). Inhaling sulfur dioxide has been associated with increased respiratory symptoms and disease and premature death.

**Sources:** Combustion of fuel containing sulfur -- mostly coal and oil. Also produced during metal smelting and other industrial processes.

# Nitrogen Dioxide

## NO<sub>2</sub>

**Nitrogen Dioxide** is a reddish-orange brown, gas with a characteristic sharp, biting odor and it is toxic. It is produced when fossil fuels (like gasoline or diesel) are burned. It dissolves in water with reaction to give a mixture of nitric acid and nitrous acid.

### Exposure to Nitrogen dioxide

People are exposed to NO<sub>2</sub> by breathing in the gas from the air. The levels of NO<sub>2</sub> are usually higher outdoors than indoors. The operation of gas or diesel engines in enclosed areas can result in a build up of dangerous levels of NO<sub>2</sub> in the air.

When energy sources burn fuel incompletely, there is the risk of NO<sub>2</sub> being produced. Gases produced by electric arc welding may also contain dangerous levels of nitrogen dioxide. Traces of NO<sub>2</sub> can be found in tobacco smoke.

### *Effect on Life*

Nitrogen dioxide is toxic by inhalation, but this could be avoided as the material is acrid and easily detected by our sense of smell.

Low concentrations (4 ppm) will anesthetize the nose, thus creating a potential for overexposure. Breathing low levels of nitrogen dioxide can cause a slight cough, mild fatigue, and nausea. Eye, nose, and throat irritation are also common symptoms.

High concentrations of NO<sub>2</sub> can cause severe coughing, choking, headache, nausea, abdominal pain, and shortness of breath. If the exposure is severe, symptoms may continue after the exposure has ended, causing difficulty breathing for weeks.

Long-term exposure to NO<sub>2</sub> at concentrations above 40– 100 µg/m<sup>3</sup> causes adverse health effects.

Nitrogen dioxide is a pulmonary irritant affecting primarily the upper respiratory system. Individuals with asthma, respiratory disorders and lung diseases are more sensitive to the effects of NO<sub>2</sub>. Healthy individuals exposed to concentrations of NO<sub>2</sub> from 0.7 to 5.0 ppm for 10-15 minutes have developed abnormalities in pulmonary airway resistance. At higher concentrations it can irritate the lungs, cause bronchitis and pneumonia and lower resistance to respiratory infections.

Health problems caused by nitrogen dioxide can either be acute, which occur immediately or within a few days of exposure, or they can be chronic, which are long-term health effects that might not show up for many years

# Nitrogen

## N<sub>2</sub>

**Nitrogen** makes up the major portion of the earth's atmosphere, accounting for 78.08% of the air by volume. Nitrogen gas is a colorless, odorless, tasteless, nontoxic and almost totally inert gas. It is nonflammable and it will not support combustion. Nitrogen gas is slightly lighter than air and slightly soluble in water.

Nitrogen condenses at its boiling point, -195.8° C (-320.4° F), turning into a colorless liquid that is lighter than water. It will freeze at -210 °C; (-346 °F.)

### Uses of Nitrogen

It is commonly thought of and used as an inert gas; but it is not truly inert. It forms nitric oxide and nitrogen dioxide with oxygen, ammonia with hydrogen, and nitrogen sulfide with sulfur. It is used to shield potentially reactive materials from contact with oxygen

Liquid nitrogen is valued for coldness as well as inertness. When liquid nitrogen is vaporized and warmed to ambient temperature, it absorbs a large quantity of heat. The inert properties of nitrogen make it a good blanketing gas in many applications. Nitrogen blanketing is used to protect flammable or explosive solids and liquids from contact with air. When working with liquid nitrogen, proper ventilation is very important.

Nitrogen is principally shipped and used in either gaseous or liquid form. When appropriately insulated from ambient heat, liquid nitrogen can be stored and transported, for example in vacuum flasks. Depending on the size and design, the holding time of vacuum flasks ranges from a few hours to a few weeks.

### *Effect on Life*

When inhaled at high partial pressures nitrogen begins to act as an anesthetic agent. It can cause nitrogen narcosis, a temporary semi-anesthetized state of mental impairment similar to that caused by nitrous oxide.

Direct skin contact with liquid nitrogen will eventually cause severe frostbite. This may happen almost instantly on contact, depending on the form of liquid nitrogen.

As liquid nitrogen evaporates it will reduce the oxygen concentration in the air and might act as an asphyxiant, especially in confined spaces. Nitrogen may produce asphyxia without any sensation or prior warning.

Vessels containing liquid nitrogen can condense oxygen from air. The liquid in such a vessel becomes increasingly enriched in oxygen as the nitrogen evaporates, and can cause violent oxidation of organic material.

# Oxygen

## O<sub>2</sub>

**Oxygen** is a colorless odorless tasteless gas. Atmospheric oxygen is of vital importance for all aerobic organisms. It is used in high-temperature flames and in breathing apparatus. Oxygen occurs in the free state as a gas, and makes up approximately 21% of the air we breathe.

### ***Properties***

- A colorless gas, without smell or taste,
- Is slightly heavier than air,
- Is sparingly soluble in water,
- Is difficult to liquefy, boiling point -183 °C, and the liquid is pale blue in color and is appreciably magnetic. At still lower temperatures, light-blue solid oxygen is obtained, which has a melting point of -218.4 °C

### ***Uses***

Oxygen is essential for life and it takes part in processes of combustion, its biological functions in respiration make it important.

Oxygen is sparingly soluble in water, but the small quantity of dissolved oxygen in is essential to the life of fish.

Oxygen gas is used with hydrogen or coal gas in blowpipes and with acetylene in the oxy-acetylene torch for welding and cutting metals.

Liquid oxygen mixed with powdered charcoal has been used as an explosive.

### **Combustion and other hazards**

Highly concentrated sources of oxygen promote rapid combustion. Fire and explosion hazards exist when concentrated oxidants and fuels are brought into close proximity; however, an ignition event, such as heat or a spark, is needed to trigger combustion.

Concentrated O<sub>2</sub> will allow combustion to proceed rapidly and energetically. Steel pipes and storage vessels used to store and transmit both gaseous and liquid oxygen will act as a fuel; and therefore the design and manufacture of O<sub>2</sub> systems requires special training to ensure that ignition sources are minimized.

Liquid oxygen spills, if allowed to soak into organic matter, such as wood, petrochemicals, and asphalt can cause these materials to detonate unpredictably on subsequent mechanical impact. As with other cryogenic liquids, on contact with the human body it can cause burns to the skin and the eyes.



# Acetylene

## C<sub>2</sub>H<sub>2</sub>

Acetylene Gas also called *ethyne*. – is a hydrocarbon consisting of two carbon atoms and two hydrogen atoms. It is a colorless, highly flammable, explosive gas with a garlic-like odor.

Acetylene has the highest flame temperature of any common hydrocarbon because of its triple-bond structure H-C≡C-H. Combustion with oxygen achieves a flame temperature of 5580° F (3087° C), releasing 1470 BTUs per cubic foot. Its high flame temperature allows it to be used in a variety of metal working applications like cutting, welding, brazing, and soldering.

### ***Safety and handling***

When acetylene is liquefied, compressed, heated, or mixed with air, it becomes highly explosive. As a result special precautions are required during its production and handling.

Acetylene is not especially toxic but when generated from calcium carbide it can contain toxic impurities such as traces of phosphine and arsine. It is also highly flammable (hence its use in welding). Its singular hazard is associated with its intrinsic instability; samples of concentrated or pure acetylene will explosively decompose. Acetylene can explode with extreme violence if the pressure of the gas exceeds about 200 kPa (29 psi) as a gas or when in liquid or solid form.

It is therefore shipped and stored dissolved in acetone or dimethylformamide (DMF), contained in a metal cylinder with a porous filling, which renders it safe to transport and use, given proper handling.

## **MSHA – Safety Hazard Information Special Hazards of Acetylene**

Acetylene is the most common gas used for fueling cutting torches in both general industry and the mining industry. When mixed with pure oxygen in a cutting torch assembly, an acetylene flame can theoretically reach over 5700°F. Users of this type of equipment are generally familiar with the fire hazards associated hot flames and the production of hot slag. However, many users may not be aware of the unique characteristics of acetylene itself that create special hazards compared to other fuel gases.

Chemical Composition: An acetylene molecule is composed of two carbon atoms and two hydrogen atoms. The two carbon atoms are held together by what is known as a triple carbon bond. This bond is useful in that it stores substantial energy that can be released as heat during combustion. However, the triple carbon bond is unstable, making acetylene gas very sensitive to conditions such as excess pressure, excess temperature, static electricity, or mechanical shock.

Storage: Because of acetylene's unstable nature, it must be stored under special conditions. This is accomplished by dissolving the acetylene in liquid acetone. The liquid acetone is then stored in the acetylene cylinder, which in turn, is filled with a porous (sponge-like) cementitious material.

- NEVER ATTEMPT TO STORE OR INJECT ACETYLENE GAS INTO ANY TYPE OF VESSEL, TANK, OR ENCLOSURE. IMPROPERLY STORED ACETYLENE GAS IS UNSTABLE.
- ACETYLENE GAS REGULATORS SHOULD NOT EXCEED A SETTING OF 15 P.S.I.G.
- FLAME ARRESTORS AND CHECK VALVES SHOULD BE INSTALLED AT BOTH THE TORCH BASE HOSE CONNECTIONS AND AT THE REGULATOR HOSE CONNECTIONS.
- ACETYLENE CYLINDERS SHOULD BE PROPERLY SECURED AT ALL TIMES. MOVEMENT OF CYLINDERS SHOULD BE DONE WITH CARE. CYLINDERS SHOULD BE PROTECTED FROM FLAME OR HEAT.

When exposed to excess temperature, pressure, or mechanical shock, pure or less than pure acetylene gas can undergo a violent, explosive decomposition reaction. Additionally, if this reaction, or an ignition of acetylene occurs within the torch base or supply hose, it can propagate back into the storage cylinder causing it to explode violently.

Flammable range: Acetylene has a very wide range of flammability. The lower flammable limit (LFL) is typically listed as 2.5% and the upper flammable limit (UFL) is listed as 81%. Although acetylene will not undergo combustion at concentrations above the UFL, it can undergo an explosive decomposition reaction, even at concentrations of 100%.

- NEVER USE ACETYLENE OR ITS EQUIPMENT IN ANY WAY NOT CONSISTANT WITH RECOGNIZED GOOD PRACTICE.
- ALWAYS MAINTAIN ACETYLENE CUTTING EQUIPMENT IN PROPER WORKING CONDITION TO PREVENT INADVERTANT LEAKAGE OF ACETYLENE OR OXYGEN INTO THE SURROUNDING WORK ENVIRONMENT.
- WHILE STORAGE IN A HORIZONTAL POSITION DOES NOT MAKE THE ACETYLENE LESS STABLE OR SAFE, IT DOES INCREASE THE LIKELIHOOD OF SOLVENT LOSS, WHICH WILL RESULT IN A LOWER FLAME QUALITY WHEN THE CYLINDER IS USED. THEREFORE IT IS ALWAYS PREFERABLE TO STORE AN ACETYLENE CYLINDER IN AN UPRIGHT POSITION.

Acetylene gas is ignitable over a wide range of concentrations.

Ease of ignition: Acetylene is a very easy gas to ignite. In fact, the energy from a static spark capable of igniting acetylene is lower than for any other fuel gas except hydrogen. The ignition energy of acetylene in air is approximately seventeen times lower than that of methane. The static charge developed by walking across a carpet floor on a dry day can be 1700 times greater than that needed to ignite acetylene. When mixed with pure oxygen, the ignition energy of acetylene is almost 100 times lower than it is in air.

- NEVER DISCHARGE UNBURNED ACETYLENE GAS FROM A TORCH EXCEPT FOR THE NORMAL PROCESS OF LIGHTING THE TORCH.
- NEVER DISCHARGE UNBURNED ACETYLENE GAS FROM A TORCH INTO ANY TYPE OF CONTAINER OR VESSEL.

When unburned acetylene gas is discharged from a torch, static electricity can be generated at the torch tip. If the tip comes in contact with a ground path, a static spark capable of igniting the acetylene can occur.

Rate of combustion reaction: Because of its simple chemical make up and sensitive triple bond, acetylene burns at a very fast rate. This very fast burning rate can accelerate the rate at which pressure is generated in an explosion beyond what would occur for other fuels. This, in turn, can make acetylene explosions more violent than for other fuels.

- NEVER DISCHARGE UNBURNED ACETYLENE GAS INTO ANY TYPE OF CONTAINER, VESSEL, ENCLOSURE, OR PIPE (SUCH AS A "POTATO GUN") WITH THE INTENT OF IGNITING THE GAS TO "DEMONSTRATE" THE HAZARDS OF ACETYLENE, OR TO PROPEL AN OBJECT FROM AN ENCLOSURE OR TUBE.

Because of the very fast reaction rate of burning acetylene, it is not generally possible to design an enclosure to safely vent the explosive pressures. Furthermore, because of the ease of ignition of acetylene, premature ignition is very possible.

# AIR

**Air** is a mixture of gases and aerosols that composes the atmosphere surrounding Earth. The primary gases of air include nitrogen (78%) and oxygen (21%). Trace gases and aerosols make up the remaining 1% of air. The trace gases include the noble gases argon, neon, helium, krypton and xenon; hydrogen; and the greenhouse gases. The aerosols are solid or liquid particles having diameters in the region of 0.001 to 10 microns (millionth of a metre), and include dust, soot, sea salt crystals, spores, bacteria, viruses and a plethora of other microscopic particles, which may be natural or man-made.

Besides "air," which is made up of primarily/approximately 78% nitrogen and 21% oxygen, there are four main gases that concern workers in a coal mine. They are carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), methane (CH<sub>4</sub>), and hydrogen sulfide (H<sub>2</sub>S). The levels and combinations of these gases along with the level of oxygen or "air" determine the danger and what they are known as.

## ***What gases make up air?***

**A:** Nitrogen - 78.09 %  
Oxygen - 20.95%  
Argon - .93%  
Carbon Dioxide - .03%.  
Neon - .0018%  
Helium - .0005%  
Krypton - .0001%  
Hydrogen - .0005%  
Xenon - .000008%  
Ozone - .000002%  
Radon - Traces

# COAL

Coal is a combustible rock formed from the remains of decayed vegetation. It is the only rock containing significant amounts of elemental carbon. The composition of coal varies between 60% and 95% carbon. Coal also contains hydrogen and oxygen, with small concentrations of nitrogen, chlorine, sulfur, and several metals. Coals are classified by the amount of volatile material they contain, that is, by how much of the mass is vaporized when the coal is heated to about 900°C in the absence of air. Coal that contains more than 15% volatile material is called bituminous coal. Substances released from bituminous coal when it is distilled, in addition to methane, include water, carbon dioxide, ammonia, benzene, toluene, naphthalene, and anthracene. The non-volatile component of coal, which remains after distillation, is coke.

## Types of Coal

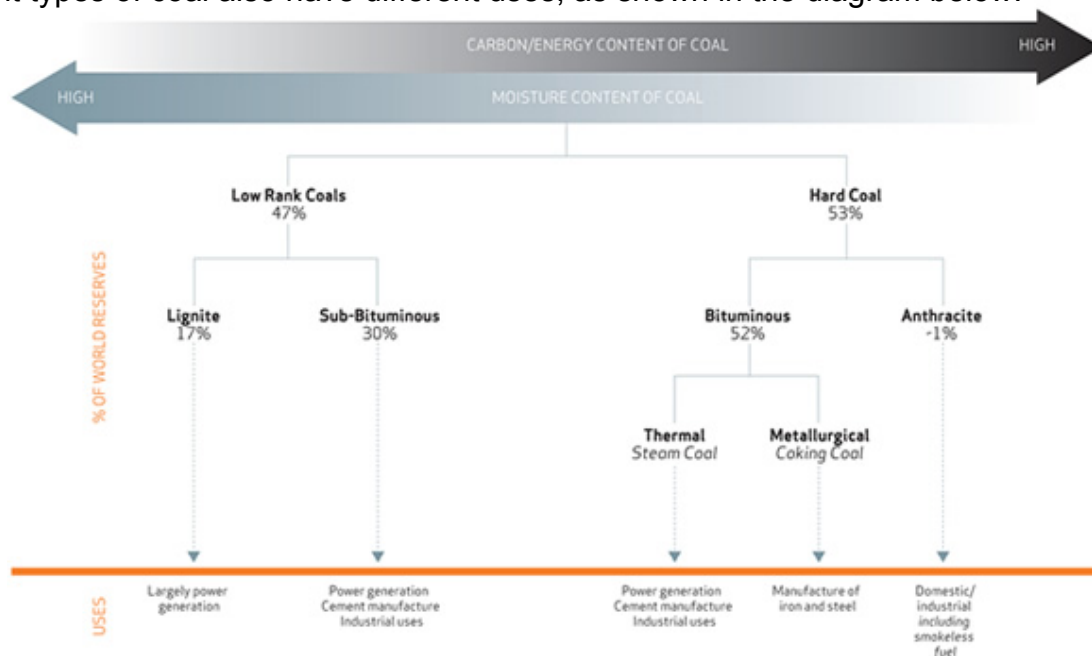
Initially the peat is converted into lignite or 'brown coal' - these are coal-types with low organic maturity. In comparison to other coals, lignite is quite soft and its color can range from dark black to various shades of brown.

Over many more millions of years, the continuing effects of temperature and pressure produces further change in the lignite, progressively increasing its organic maturity and transforming it into the range known as 'sub-bituminous' coals.

Further chemical and physical changes occur until these coals became harder and blacker, forming the 'bituminous' or 'hard coals'. Under the right conditions, the progressive increase in the organic maturity can continue, finally forming anthracite.

In addition to carbon, coals contain hydrogen, oxygen, nitrogen and varying amounts of sulphur. High-rank coals are high in carbon and therefore heat value, but low in hydrogen and oxygen. Low-rank coals are low in carbon but high in hydrogen and oxygen content.

Different types of coal also have different uses, as shown in the diagram below.



## PROPERTIES OF MINE GASES

| NAME OF GAS      | CHEMICAL SYMBOL               | SPECIFIC GRAVITY | COM-BUSTIBLE | EFFECT ON LIFE                  | SOURCE OR CAUSE WHERE FOUND  | EXPLOSIVE RANGE PERCENT BY VOLUME | COMMON NAME          | HOW DETECTED                              | COLOR-LESS   | ODOR-LESS                  | TASTE-LESS                   |
|------------------|-------------------------------|------------------|--------------|---------------------------------|--|-----------------------------------|----------------------|---|--------------|----------------------------|------------------------------|
| Air              |                               | 1.000            | Supports     | Supports                        | Atmosphere   | None                              |                      |   |              |                            |                              |
| Oxygen           | O <sub>2</sub>                | 1.105            | Supports     | Supports                        | 21% of atmosphere  | None                              |                      | O <sub>2</sub> detector                   | X            | X                          | X                            |
| Methane          | CH <sub>4</sub>               | .555             | Yes          | Inert                           | Coal & rock strata carbonaceous Shale, rotting mine timbers                  | 5.0% - 15.0%                      | Marsh gas, fire damp | Methanometer                              | X            | X                          | X                            |
| Carbon Dioxide   | CO <sub>2</sub>               | 1.529            | No           | Poisonous in high concentration | Oxide of coal, blasting, mine fires, timber decay, diesel engines, breathing | None                              | Black damp           | Colorimetric analysis                     | X            | X                          | If high, slightly acid taste |
| Carbon Monoxide  | CO                            | .967             | Yes          | Poisonous                       | Incomplete combustion, mine fires, explosions, blasting, diesel engines      | 12.5% - 74.0%                     | White damp           | CO detector                               | X            | X                          | X                            |
| Nitrogen         | N <sub>2</sub>                | .967             | No           | Inert                           | About 4/5 of atmosphere  | None                              |                      | Analysis                                  | X            | X                          | X                            |
| Hydrogen Sulfide | H <sub>2</sub> S              | 1.191            | Yes          | Poisonous                       | Explosions, mine fires, blasting   | 4.3% - 45.0%                      |                      | Hydrogen sulfide detector acetate of lead | X            | Sulfur odor                | X                            |
| Nitrogen Dioxide | NO <sub>2</sub>               | 1.503            | No           | Poisonous                       | Blasting, burning explosives, Burning nitrates, diesel exhaust               | None                              |                      | Analysis                                  | Brownish red | If high, sharp sweet order |                              |
| Sulfur Dioxide   | SO <sub>2</sub>               | 2.263            | No           | Poisonous                       | By burning Pyrites, some diesel fuels  | None                              |                      | Odor, Colorimetric analysis               | X            | Sulfur Odor                | Acidic taste                 |
| Hydrogen         | H <sub>2</sub>                | .070             | Yes          | Inert                           | Charging batteries, mine fires, explosions, strong acids on metal            | 4.1% - 74.0%                      |                      | Analysis                                  | X            | X                          | X                            |
| Acetylene        | C <sub>2</sub> H <sub>2</sub> | .907             | Yes          | Slightly poisonous              | Formed when methane is burned, welding                                       | 2.5% - 80.0%                      |                      | Odor                                      | X            | Garlic odor                | X                            |

## OXYGEN DEFICIENCY

### OXYGEN PRESENT    EFFECT

|     |   |
|-----|---|
| 21% | Breathing easiest   |
| 17% | Breathing faster and deeper                                     |
| 15% | Dizziness, buzzing noise, rapid pulse, headache, blurred vision |
| 9%  | May faint or become unconscious                                 |
| 6%  | Movement convulsive, breathing stops, shortly after heart stops |



# Title 30

## Code of Federal Regulation

### 30 CFR § 75.150

#### Tests for methane and for oxygen deficiency; qualified person.

(a) The provisions of Subpart D--Ventilation of this part and [§75.1106](#) require that tests for methane and for oxygen deficiency be made by a qualified person. A person is a qualified person for this purpose if he is a certified person under [§75.100](#).

(b) Pending issuance of Federal standards, a person will be considered a qualified person for testing for methane and for oxygen deficiency:

- (1) If he has been qualified for this purpose by the State in which the coal mine is located; or
- (2) The Secretary may qualify persons for this purpose in a coal mine in which persons are not qualified for this purpose by the State upon an application and a satisfactory showing by the operator of the coal mine that each such person has been trained and designated by the operator to test for methane and oxygen deficiency and has made such tests for a period of 6 months immediately preceding the application. Applications for Secretarial qualification should be submitted to the Health and Safety Activity, Mine Safety and Health Administration, Certification and Qualification Center, P.O. Box 25367, Denver Federal Center, Denver, Colo. 80225.

### 30 CFR § 75.321

#### Air quality.

(a) The air in areas where persons work or travel, except as specified in paragraph (a)(2) of this section, shall contain at least 19.5 percent oxygen and not more than 0.5 percent carbon dioxide, and the volume and velocity of the air current in these areas shall be sufficient to dilute, render harmless, and carry away flammable, explosive, noxious, and harmful gases, dusts, smoke, and fumes.

(2) The air in areas of bleeder entries and worked-out areas where persons work or travel shall contain at least 19.5 percent oxygen, and carbon dioxide levels shall not exceed 0.5 percent time weighted average and 3.0 percent short term exposure limit.

(b) Notwithstanding the provisions of [§75.322](#), for the purpose of preventing explosions from gases other than methane, the following gases shall not be permitted to accumulate in excess of the concentrations listed below:

- (1) Carbon monoxide (CO)--2.5 percent
- (2) Hydrogen (H<sub>2</sub>)--.80 percent
- (3) Hydrogen sulfide (H<sub>2</sub>S)--.80 percent
- (4) Acetylene (C<sub>2</sub>H<sub>2</sub>)--.40 percent
- (5) Propane (C<sub>3</sub>H<sub>8</sub>)--.40 percent
- (6) MAPP (methyl-acetylene-propylene-propodiene)--.30 percent

### 30 CFR § 75.323

#### Actions for excessive methane.

(a) *Location of tests.* Tests for methane concentrations under this section shall be made at least 12 inches from the roof, face, ribs, and floor.

(b) *Working places and intake air courses.*

(1) When 1.0 percent or more methane is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area where mechanized mining equipment is being installed or removed--

(i) Except intrinsically safe atmospheric monitoring systems (AMS), electrically powered equipment in the affected area shall be deenergized, and other mechanized equipment shall be shut off;

(ii) Changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane to less than 1.0 percent; and

(iii) No other work shall be permitted in the affected area until the methane concentration is less than 1.0 percent.

(2) When 1.5 percent or more methane is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area where mechanized mining equipment is being installed or removed--

(i) Everyone except those persons referred to in §104(c) of the Act shall be withdrawn from the affected area; and

(ii) Except for intrinsically safe AMS, electrically powered equipment in the affected area shall be disconnected at the power source.

(c) *Return air split.* (1) When 1.0 percent or more methane is present in a return air split between the last working place on a working section and where that split of air meets another split of air, or the location at which the split is used to ventilate seals or worked-out areas changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane in the return air to less than 1.0 percent.

(2) When 1.5 percent or more methane is present in a return air split between the last working place on a working section and where that split of air meets another split of air, or the location where the split is used to ventilate seals or worked-out areas--

(i) Everyone except those persons referred to in §104(c) of the Act shall be withdrawn from the affected area;

(ii) Other than intrinsically safe AMS, equipment in the affected area shall be deenergized, electric power shall be disconnected at the power source, and other mechanized equipment shall be shut off; and

(iii) No other work shall be permitted in the affected area until the methane concentration in the return air is less than 1.0 percent.

(d) *Return air split alternative.* (1) The provisions of this paragraph apply if--

(i) The quantity of air in the split ventilating the active workings is at least 27,000 cubic feet per minute in the last open crosscut or the quantity specified in the approved ventilation plan, whichever is greater;

(ii) The methane content of the air in the split is continuously monitored during mining operations by an AMS that gives a visual and audible signal on the working section when the methane in the return air reaches 1.5 percent, and the methane content is monitored as specified in [§75.351](#); and

(iii) Rock dust is continuously applied with a mechanical duster to the return air course during coal production at a location in the air course immediately outby the most inby monitoring point.

(2) When 1.5 percent or more methane is present in a return air split between a point in the



return opposite the section loading point and where that split of air meets another split of air or where the split of air is used to ventilate seals or worked-out areas--

(i) Changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane in the return air below 1.5 percent;

(ii) Everyone except those persons referred to in §104(c) of the Act shall be withdrawn from the affected area;

(iii) Except for intrinsically safe AMS, equipment in the affected area shall be deenergized, electric power shall be disconnected at the power source, and other mechanized equipment shall be shut off; and

(iv) No other work shall be permitted in the affected area until the methane concentration in the return air is less than 1.5 percent.

(e) *Bleeders and other return air courses.* The concentration of methane in a bleeder split of air immediately before the air in the split joins another split of air, or in a return air course other than as described in paragraphs (c) and (d) of this section, shall not exceed 2.0 percent.

### **30 CFR § 75.342 Methane monitors.**

(a)(1) MSHA approved methane monitors shall be installed on all face cutting machines, continuous miners, longwall face equipment, loading machines, and other mechanized equipment used to extract or load coal within the working place.

(2) The sensing device for methane monitors on longwall shearing machines shall be installed at the return air end of the longwall face. An additional sensing device also shall be installed on the longwall shearing machine, downwind and as close to the cutting head as practicable. An alternative location or locations for the sensing device required on the longwall shearing machine may be approved in the ventilation plan.

(3) The sensing devices of methane monitors shall be installed as close to the working face as practicable.

(4) Methane monitors shall be maintained in permissible and proper operating condition and shall be calibrated with a known air-methane mixture at least once every 31 days. To assure that methane monitors are properly maintained and calibrated, the operator shall:

(i) Use persons properly trained in the maintenance, calibration, and permissibility of methane monitors to calibrate and maintain the devices.

(ii) Maintain a record of all calibration tests of methane monitors. Records shall be maintained in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.

(iii) Retain the record of calibration tests for 1 year from the date of the test. Records shall be retained at a surface location at the mine and made available for inspection by authorized representatives of the Secretary and the representative of miners.

(b)(1) When the methane concentration at any methane monitor reaches 1.0 percent the monitor shall give a warning signal.

(2) The warning signal device of the methane monitor shall be visible to a person who can deenergize electric equipment or shut down diesel-powered equipment on which the monitor is mounted.

(c) The methane monitor shall automatically deenergize electric equipment or shut down diesel-powered equipment on which it is mounted when--

(1) The methane concentration at any methane monitor reaches 2.0 percent; or

(2) The monitor is not operating properly.

## **MINES GASES**

### **Questions for Review**

Q: What gases make up the air we breathe?

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Q: What are the sources of methane in coal mines?

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Q: What other gas must be present in order for methane to explode (when CH<sub>4</sub> content is between 5% - 15%)

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Q: What is the lowest level of Oxygen that will support life?

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Q: Why are small quantities of Carbon Monoxide injurious?

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Q: How is Carbon Dioxide formed in a coal mine?

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Q: What four gases are required (by CFR Part 75) to be monitored?

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Q: What element in air is essential for life?

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Q: What is the explosive range for Hydrogen Sulfide?

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Q: What is the most violent explosive point for methane?

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Q: What are some of the uses of Nitrogen?

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Q: Is Sulfur Dioxide combustible?

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Q: Is Hydrogen explosive?

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Q: What are some of the effects of breathing in Hydrogen Sulfide?

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Q: What effect does Carbon Dioxide have upon life?

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Q: At what level would someone begin to feel the effects of Carbon Monoxide exposure?

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Q: Where would Hydrogen Sulfide tend to accumulate in a coal mine?

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Q: What are some of the hazards posed to humans by Hydrogen?

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Q: What are some of the effects of inhaling Sulfur Dioxide?

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Q: How can you detect Nitrogen Dioxide?

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