Unified Mine Rescue Team Contest Training Module Study Guide

Module 2 – Mine Gases

Gas Detection (pages 2-3)

Gas detection is an important part of any rescue or recovery operation. Your team will make frequent tests for gases as it advances beyond the Fresh Air Base. For your own safety, you'll want to know what harmful gases are present, how much oxygen is in the atmosphere, and whether or not gas levels are within the explosive range.

Knowing what gases are present and in what concentrations provide you with important clues as to what has happened in the mine. Test results can also give you an idea about existing conditions.

For example, if you get carbon monoxide (CO) readings, there's probably a fire. The amount of carbon monoxide indicates something about the extent of that fire.

Gas Detector Requirements (pages 2-3)

Regulations require mine rescue stations to have four gas detectors appropriate for each type of gas that may be encountered at the mines served. Gas detectors must measure concentrations of methane from 0.0 percent to 100 percent of volume, oxygen from 0.0 percent to at least 20 percent of volume, and carbon monoxide from 0.0 parts per million to at least 9,999 parts per million (**30 CFR Parts 49.6(a)(6)** and **49.16(a)(6)).**

Diffusion of Gases (pages 2-5)

The volume of a gas changes in response to any change in atmospheric pressure or temperature. For example:

- An increase in pressure causes a gas to contract.
- A decrease in pressure causes a gas to expand.
- An increase in temperature causes a gas to expand.
- A decrease in temperature causes a gas to contract.

Atmospheric Pressure and its Effects on Rate of Diffusion (pages 2-6)

Pressure exerted on a gas is usually atmospheric pressure. Atmospheric pressure is measured on a barometer. A rise in the barometric reading indicates an increase in pressure. A drop in barometric reading indicates a decrease in pressure. The atmospheric pressure varies within a mine, just as it does on the surface.

Atmospheric pressure affects the diffusion rate of a gas. For example, if the barometer rises, indicating increased pressure, gas responds by contracting. A gas that's squeezed into a smaller area like this is more concentrated, so it diffuses more slowly.

It’s much easier for concentrations of explosive gases to build up when the barometric pressure is high. On the other hand, when barometric pressure falls, the pressure on the gas is reduced. The gas responds by expanding. Once the gas expands, it is less concentrated, so it diffuses more quickly.

Temperature and its Effects on Rate of Diffusion (pages 2-6)

It’s important to understand how temperature affects the rate of diffusion of a gas. High temperatures (or heat) cause gases to expand, so they diffuse more quickly. Consequently, heat from a fire in the mine will cause gases to expand and be dispersed more easily. Lower temperatures work the opposite way: Gases respond to cold by contracting and by diffusing more slowly.

Specific Gravity or Relative Weight (pages 2-6 and 2-7)

Specific gravity is the weight of a gas compared to an equal volume of normal air under the same temperature and pressure. (This is also referred to as “relative weight.”) The specific gravity of normal air is 1.0. The weight of air acts as a reference point from which we measure the relative weight of other gases. For example, a gas that is heavier than air has a specific gravity higher than 1.0. A gas that is lighter than air will have a specific gravity less than 1.0.

If you know the specific gravity of a gas, you will know where it will be located in the mine and where you should test for it. Gases issuing into still air without mixing tend to stratify according to the gas’s specific gravity. Light gases or mixtures tend to stratify against the roof and heavy gases or mixtures tend to stratify along the floor.

Methane, for example, has a specific gravity of 0.5545. This is lighter than normal air. Knowing this, you can predict that methane will rise and collect in greater concentrations near the top or roof of a mine. This is why you test for methane near the top.

Sulfur dioxide has a specific gravity of 2.2638. This is much heavier than normal air. Knowing this, you can predict that sulfur dioxide will collect in greater concentrations near the bottom or in low areas of a mine. This is why you test for sulfur dioxide in low areas of the mine.

If the weight of a gas you’re testing for is lighter than normal air, you’ll know to test for it within 12 inches of the mine roof. That’s because lighter gases tend to rise, so you can expect to find them in greater concentrations in high areas of the mine.

Besides helping you determine where to test for a gas, specific gravity also indicates how quickly the gas will diffuse and how easily it can be dispersed by ventilation. In still air, the ordinary process of diffusion is a very slow process.

However, under usual mine conditions, ventilating air currents and convection currents produced by temperature differences cause a rapid mechanical mixing of gases with air.

Once the gases are mixed, they will not separate or stratify again.

Light gases, such as methane or hydrogen, diffuse rapidly and are fairly easy to disperse. Heavier gases such as sulfur dioxide and carbon dioxide do not diffuse rapidly, so they're more difficult to disperse.
It's much easier to remove a concentration of a light gas like methane by ventilation than it is to remove the same concentration of a heavier gas like carbon dioxide.

Specific gravity is not the only factor that determines how quickly a gas will diffuse or disperse. Temperature and pressure also affect it. An increase in temperature makes a gas diffuse more rapidly. A decrease in temperature slows down the rate of diffusion.
Atmospheric pressure works just the opposite: An increase in pressure slows down the rate of diffusion. A decrease in pressure speeds it up.

Explosive Range and Flammability (pages 2-7 and 2-8)

A gas that will burn is said to be "flammable." Any flammable gas can explode under certain conditions. In order for a flammable gas to explode, there must be enough of the gas in the air, enough oxygen, and a source of ignition.

The range of concentrations within which a gas will explode is known as its "explosive range." Figures representing the higher and lower limits of the explosive range are expressed in percentages.

The amount of oxygen that must be present for an explosion to occur is also expressed as a percentage. When the necessary oxygen concentration approaches that found in normal air, the level is expressed simply as "normal air."

The explosive range of methane, for example, is 5 to 15 percent in the presence of at least 12.1 percent oxygen.

Solubility (pages 2-8)

Solubility is the ability of a gas to be dissolved in water. Some gases found in mines are soluble and can be released from water. Sulfur dioxide and hydrogen sulfide, for example, are water-soluble gases. Both may be released from water.

Solubility is an important factor to consider during recovery operations. When a mine is sealed off for any length of time, water can collect in it. This water may have occurred naturally, or it may have been introduced during firefighting.

Whatever the case, pools of water can release water-soluble gases into the air when they are stirred up. Pumping water from such pools, or walking through them, can release large amounts of soluble gases which would not otherwise be found in the mine atmosphere.

Color/Odor/Taste (pages 2-8)

Color, odor, and taste are physical properties that can help you identify a gas, especially during barefaced exploration. Hydrogen sulfide, for example, has a distinctive “rotten egg” odor.

Some gases may taste bitter or acid; others sweet. The odor of blasting powder fumes, together with a reddish-brown color, indicates there are oxides of nitrogen present.

Of course, you can’t rely on only your senses to positively identify a gas. Only detectors and chemical analysis can do that. Many hazardous gases, such as carbon monoxide, have no odor, color, or taste. Keep these properties in mind as we discuss each gas you may encounter in the mine. One or more of these properties may be your first clue that a particular gas is present.

Health Hazards

Toxic Gases (pages 2-8 and 2-9)

Some gases found in mines are toxic (poisonous). This can refer either to what happens when you breathe the gas, or what happens when the gas comes into contact with exposed areas of your body.

The degree to which a toxic gas will affect you depends on three factors:

(1) how concentrated the gas is,
(2) how toxic the gas is, and
(3) how long you’re exposed to the gas.

For example, the TLV for carbon monoxide (CO) is relatively low—50 PPM (or .005 percent). This means that the most CO you can be exposed to over **an 8-hour daily period without harmful effects is 1/200 of one percent.** That isn’t much. The TLV for carbon dioxide (CO_2) is higher—5,000 PPM (.500 percent). You can tolerate concentrations of up to ½ of 1 percent CO_2 over an 8-hour daily period without harmful effects.

Some toxic gases are harmful to inhale. A self-contained breathing apparatus (SCBA) will protect you from such gases, as long as your face-to-facepiece seal is tight. Other toxic gases harm the skin or can be absorbed by the skin. An SCBA won’t protect you from such gases. If you wear your SCBA in petroleum-based fumes for prolonged or successive periods, the fumes can eventually permeate its rubber parts so that the apparatus no longer provides you with adequate protection. Your team may be forced to leave an area where such gases are detected.

Asphyxiating Gases (pages 2-9)

"Asphyxiate" means to suffocate or choke. Asphyxiating gases cause suffocation. They do this by displacing oxygen in the air, thus producing an oxygen-deficient atmosphere. Since your self-contained breathing apparatus supplies you with oxygen, it will protect you against asphyxiating gases.

Review Questions (pages 2-10)

1. How do temperature and pressure affect a gas, and how do these factors affect mine rescue?

2. What is specific gravity?

3. What can you determine if you know the specific gravity of a particular gas?

4. What is the explosive range of a gas and why is it important for rescue team members to know the explosive range of gases they encounter?

5. What is a toxic gas?
6. How can you protect yourself from toxic gases?

7. How does an asphyxiating gas produce an oxygen-deficient atmosphere? Answer: It displaces oxygen.

8. How do you protect yourself in an oxygen-deficient atmosphere?

9. Why is it important for you to know about the solubility of certain gases in water?

10. Why should you know about the characteristic color, odor, and taste of gases you may encounter?

ANSWER SHEET (pages 2-10)

1. **Answer:** Temperature increases cause expansion. Temperature-decreases cause contraction. Pressure-increases cause contraction. Pressure-decreases cause expansion. Implication: These factors affect the diffusion rate of gases in the mine.

2. **Answer:** The specific gravity (or relative weight) of a gas is its weight in relation to an equal amount of normal air under the same temperature and pressure.

3. **Answer:** Specific gravity determines where the gas will stratify in still air in the mine (whether it will rise or fall). It also determines how easily a gas can be diffused or flushed out of the mine by ventilation.

4. **Answer:** The explosive range of a gas is the concentrations within which a flammable gas can explode when there is a specific amount of oxygen present. It's important for you to know the explosive ranges of gases you encounter and the amount of oxygen necessary for an explosion so you will immediately know when you encounter a potentially explosive atmosphere.

5. **Answer:** A gas that is capable of causing damage to living tissues, impairment of the central nervous system, severe illness or, in extreme cases, death when it is ingested, inhaled, or absorbed by the skin or eyes.

6. **Answer:** Wearing a self-contained breathing apparatus (SCBA) will protect you from many of them. However, an SCBA does not provide you with protection against gases that attack the skin or enter the body through the skin. Neither will it provide protection if you wear it for prolonged or successive periods in petroleum-based fumes, because such fumes may permeate the rubber. In the presence of such gases, your team may be forced to leave the area of the mine where they're located.

7. **Answer:** It displaces oxygen.

8. **Answer:** Wear an SCBA, which supplies you with oxygen.

9. **Answer:** Gases dissolved in water can be liberated in large quantities when mine rescue teams disturb the water by walking through it, or by beginning pumping operations.

10. **Answer:** The characteristic color and, if the team is barefaced, odor or taste of a gas may be the first clue a rescue team has that the gas is present in the mine atmosphere.

Normal Air (pages 2-11)

The air we breathe is actually a mixture of gases. Clean, dry air at sea level is made up of 78 percent nitrogen and 21 percent oxygen. The remaining one percent is made up of argon, carbon dioxide, and small traces of other gases. Other gases in air are: neon, helium, krypton, xenon, hydrogen, methane, nitrous oxide, and ozone.

Even internal combustion engines and battery-charging stations can be sources of contamination because they can produce hazardous fumes. Normally, these contaminants are carried away by the mine's ventilation system. But during a disaster situation, the mine's ventilation system may be partially or totally disrupted.

Fires and explosions can disrupt ventilation by damaging ventilation controls. Falls and rock bursts can disrupt ventilation by obstructing the flow of air. In addition, the disaster itself may provide additional sources of contamination.

Fires and explosions, for example, often produce dangerous gases. Inundations may release water-soluble gases.

Oxygen (O_2) (pages 2-12)

Specific Gravity. 1.1054

Explosive Range and Flammability. Oxygen is not an explosive gas, but it does support combustion.

Health Hazards. Oxygen found in normal air is nontoxic. In fact, it is essential for life. It is harmful to breathe air that is low in oxygen, and breathing extremely oxygen-deficient air can kill you.

There are five main causes of oxygen deficiency in the mine: (1) insufficient or improper ventilation which fails to bring enough oxygen to the work area, (2) displacement of the air's oxygen by other gases, (3) a fire or explosion that consumes oxygen, (4) the absorption of oxygen by coal, particularly at freshly cut faces, and (5) consumption of oxygen by workers.

Carbon Dioxide (CO_2) (pages 2-13)

Specific Gravity. 1.5291

Explosive Range and Flammability. Carbon dioxide will neither burn nor explode.

Health Hazards. Normal air contains about 0.04 percent carbon dioxide. When present in high concentrations (2 percent or higher), carbon dioxide causes you to breathe deeper and faster. Breathing air containing 5 percent carbon dioxide increases respiration 300 percent, causing difficult breathing. Breathing air containing 10 percent carbon dioxide causes violent panting and can lead to death.

Solubility. Carbon dioxide is soluble in water.

Color/Odor/Taste. Carbon dioxide is colorless and odorless. High concentrations may produce an acid taste.

Cause or Origin. Carbon dioxide is a normal component of air and is a product of complete combustion (burning). Oxidation and the decay of timbers also produce carbon dioxide. Carbon dioxide is also a by-product of the respiration (breathing) process. Fires, explosions, and blasting operations produce CO_2. In some mines, it is liberated from the rock strata.

Methane (CH_4) (pages 2-14)

Specific Gravity. 0.5545

Explosive Range and Flammability. Methane is flammable. Its explosive range is 5 to 15 percent when there is at least 12.1 percent oxygen. Methane is most explosive, however, in the 9.5 to 10 percent range.

Methane's explosive range is not an absolute measure of safety. There are several other important factors to take into consideration. For example, the presence of other combustible gases with wider explosive ranges or lower ignition points than methane may result in a more highly explosive mixture.

Coal dust in the air also lowers methane's explosive limits. A mixture containing as little as 1 ½ to 2 percent methane, together with coal dust, may be explosive.

Because moisture tends to keep dust levels down, dust will be more of a problem underground in the winter months when the mine air is less humid.

Solubility. Slightly soluble in water.

Color/Odor/Taste. Colorless, odorless, tasteless.

Cause or Origin. Methane is the most common flammable gas found in coal mines. It is a normal component of coal, originating from the decomposition of vegetable matter during its formation.

Methane can be liberated in large quantities from feeders and blowers or from clay veins in coal mines. It's also often liberated from virgin (uncut) coal and released from freshly broken coal faces.

Carbon Monoxide (CO) (pages 2-15 and 16)

Specific Gravity. 0.9672

Explosive Range and Flammability. Carbon monoxide is explosive and flammable. Its explosive range in normal air is 12.5 to 74.2 percent.

Health Hazards. Carbon monoxide is highly toxic even in very low concentrations. Exposure to as little as .15 to .20 percent CO is extremely dangerous. Carbon monoxide is so toxic because it combines easily with your red blood cells (hemoglobin) —the cells that normally carry oxygen to your body's tissues. Once the cells have taken up CO, they no longer have the capacity to carry oxygen.

It doesn't take much CO to interfere with your blood's oxygen-carrying capacity because the gas combines with hemoglobin 200 to 300 times more readily than oxygen.

The first symptom of carbon monoxide poisoning is a slight tightening across your forehead and possibly a headache. Carbon monoxide poisoning is cumulative over time. As you continue to be exposed to it, the poisoning effects build up accordingly. As little as 500 PPM (0.05 percent) can kill you in three hours. If you're exposed to a high CO concentration, you may experience very few symptoms before losing consciousness.

Solubility. Carbon monoxide is slightly soluble in water.

Cause or Origin. Carbon monoxide is a product of the incomplete combustion of any carbon material. It is produced by mine fires and explosions of gas.

Nitrogen (N_2) (pages 2-16)

Explosive Range and Flammability. Nitrogen is not an explosive gas and it will not burn.

Health Hazards. Nitrogen is nontoxic. However, in above-normal concentrations, it acts as an asphyxiant, because it lowers the oxygen content of the air.

Cause or Origin. Normal air contains approximately 78 percent nitrogen, making nitrogen the largest component of normal air. Underground, nitrogen levels may increase as coal faces adsorb oxygen. Gas blowers and feeders may give off nitrogen, and nitrogen is also released from coal during mining.

Another source of nitrogen in underground mines is the detonation of explosives.

Mine Gases and Their Properties

GAS	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLUBILITY	COLOR/ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Normal Air	-	1.0	-	-	-	-	-	-
Oxygen	O_2	1.1054	Supports combustion n	Moderate	-	Respiratory/cardiovascular in oxygen deficient atmosphere	8 - 10%	All areas of opening
Carbon Dioxide	CO_2	1.5291	-	Soluble	Acidic taste high concentrations	Respiratory/ cardiovascular in high concentrations	40,000 ppm	Low areas near floor
Methane	CH_4	0.5545	5 - 15%	Slight	-	-	-	High areas near roof
Carbon Monoxide	CO	0.9672	12.5 - 74.2%	Slight	-	Highly toxic to cardiovascular system even in low concentrations	1,200 ppm	Near center of openings
Nitrogen	N_2	0.9674	-	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Near face areas
Nitrogen Dioxide	NO_2	1.5894	-	Very slight	Reddish brown color- high concentrations, odor/taste of blasting powder	Highly toxic to respiratory system even in low concentrations	20 ppm	Low areas near floor
Hydrogen	H_2	0.0695	4 - 74.2%	-	-	Asphyxiant in higher concentrations due to oxygen displacement	-	High areas- especially near battery charge stations
Hydrogen Sulfide	H_2S	1.1906	4.3 - 45.5%	Soluble	Rotten egg odor/ slightly sweet taste	Highly poisonous to respiratory system and eyes even in low concentrations	100 ppm	Low areas- especially near water accumulation
Sulfur Dioxide	SO_2	2.2638	-	High	Sulfur odor/acidic taste	Highly toxic to respiratory system and eyes even in very low concentrations	100 ppm	Low areas near floor
Ethane	C_2H_6	1.0493	3 - 12.5%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
GAS	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLUBILITY	COLOR/ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Propane	C_3H_8	1.5625	2.12 - 9.35%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
Butane	C_4H_{10}	2.0100	1.86 - 8.41%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
Acetylene	C_2H_2	0.9107	2.5 - 80%	Very slight	Slight garlic odor	Asphyxiant in higher concentrations due to oxygen displacement	-	All areas after methane explosion
Radon	Rn	7.526	-	High	-	Continuous exposure linked to lung cancer	-	Most prevalent in uranium mines

Gas Detection Chart

GAS	DETECTION METHODS	WHEN TO TEST
Oxygen (O_2)	Oxygen indicator. Chemical analysis.	During any team exploration.
Nitrogen (N_2)	Chemical analysis.	When an oxygen deficient atmosphere is suspected. In mines where nitrogen issues from rock strata. In inactive areas where ventilation has been inadequate.
Carbon Dioxide (CO_2)	Carbon dioxide detector. Multi-gas detector. Chemical analysis.	After a fire or explosion. When entering abandoned areas. When reopening sealed areas.
Carbon Monoxide (CO)	Carbon monoxide detector. Multi-gas detector. Chemical analysis.	During any team exploration, especially when fire is suspected.
Nitrogen Dioxide (NO_2)	Nitrogen dioxide detector. Multi-gas detector. Chemical analysis. Color.	After mine fires or explosions. When diesel equipment is used. After detonation of explosives.
Hydrogen (H_2)	Multi-gas detector. Chemical analysis.	After mine fire or explosion. Near battery-charging stations. When steam is produced by water, mist, or foam in fire-fighting.
Hydrogen Sulfide (H_2S)	Hydrogen sulfide detector. Multi-gas detector. Chemical analysis. Eye irritation.	In poorly ventilated areas. During unsealing operations. Following mine fires.
Sulfur Dioxide (SO_2)	Multi-gas detector. Chemical analysis. Odor, taste, and respiratory tract irritation.	When standing water is disturbed. After mine fires or explosions and when reopening sealed areas of the mine after mine fires.
Methane (CH_4)	Methane detector. Chemical analysis.	During any team exploration. When normal ventilation is disrupted. When entering abandoned workings.
Heavy Hydrocarbons Ethane (C_2H_6) Propane (C_4H_{10}) Butane (C_3H_8)	Multi-gas detector. Chemical analysis.	Following fires or explosions when methane is present. Following accidental entry into adjacent oil or gas well casings.
Acetylene (C_2H_2)	Multi-gas detector. Chemical analysis. Odor.	Following a methane explosion in air which is low in oxygen.
Radon (Rd)	Survey meter.	When normal ventilation is disrupted and during unsealing operations.

Smoke, Rock-Strata Gases, and the Damps

Smoke

Smoke is a result of combustion. It consists of tiny particles of solid and liquid matter suspended in the air. The particles in smoke are usually soot or carbon, and tar-like substances such as hydrocarbons.

Although smoke may irritate your lungs when you inhale it, it is not normally considered to be an asphyxiant. However, smoke usually contains carbon monoxide and other toxic or asphyxiating gases produced by fires. This is why it is so dangerous to inhale smoke.

Also, if there is a sufficient amount of hydrocarbons in the smoke, the hydrocarbons can make the smoke explosive.

Besides the dangers involved in inhaling smoke and its potential for explosion, smoke is also hazardous in another important way: The presence of smoke limits your visibility. This single factor adds an extra element of difficulty to any rescue or recovery operation.

Rock-Strata Gases (pages 2-25)

Rock-strata gases occur in some metal mining districts in the United States, particularly in Colorado and Nevada. Commonly called rock gas, it is assumed to be largely nitrogen and carbon dioxide, and is released from the rock strata under the influence of atmospheric pressures.

Because rock gas is largely nitrogen and carbon dioxide, the effect of rock gas is to produce an oxygen-deficient atmosphere. This can cause a person to suffocate if breathing protection is not worn.

The Damps (pages 2-25)

"Damps" are the names early miners gave to mixtures of gases. Many of these terms are still in use today. These names often describe what causes the mixtures or how they affect miners

The damps most commonly found in mines are:

Whitedamp. Whitedamp is a mixture of carbon monoxide and air which results from a mine fire. It gets the name "whitedamp" from the fact that it is found in high concentrations in black powder smoke, which is white. The carbon monoxide in this mixture makes it toxic.

Stinkdamp. This is a mixture of hydrogen sulfide and air. Stinkdamp gets its name from the characteristic "rotten egg" odor of hydrogen sulfide. It is highly toxic and in certain concentrations it can be explosive.

Afterdamp. This is a mixture of carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen. It is called "afterdamp" because it's usually found after a mine fire or explosion. Afterdamp is toxic to breathe, and it may also be oxygen-deficient.
Carbon monoxide is the most poisonous of the gases in afterdamp.

Blackdamp. Blackdamp gets its name from the fact that this mixture caused miners' lights to go out. It is actually a mixture of carbon dioxide, nitrogen, and air. Blackdamp is produced by methane fires and explosions, so it also probably contains carbon monoxide. This mixture is oxygen-deficient so it makes breathing difficult, and can cause suffocation.

Firedamp. This is a mixture of methane and air that will burn or explode when ignited. The "fire" in firedamp comes from the fact that the mixture is flammable.

Review Questions (pages 2-27)

1. What are the five main causes of oxygen deficiency in the mine?

2. What are the explosive gases that may occur in the mine or mines you may be called to work in?

3. Name the gases that can be detected by color, odor, or taste, and explain these identifying features.

4. Of the gases we've talked about, which ones are toxic if you inhale them?

5. What are the five major damps? Explain what each mixture contains and why it's dangerous.

ANSWER SHEET (pages 2-28)

1. Answer:

1) insufficient or improper ventilation which fails to bring enough oxygen to the work area,
2) displacement of the air's oxygen by other gases,
3) a fire or explosion that consumes oxygen,
4) the absorption of oxygen by coal, particularly at freshly cut faces, and
5) consumption of oxygen by workers.

2. Answer:

1) Carbon monoxide 12.5 to 74.2%
2) Hydrogen 4.0 to 74.2% even with as little as 5% oxygen present
3) Hydrogen sulfide 4.3 to 45.5%
4) Methane 5 to 15% in at least 12.1% oxygen
5) Ethane 3.0 to 12.5%
6) Propane 2.12 to 9.35%
7) Butane 1.86 to 8.41%
8) Acetylene 2.5 to 80%

3. Answer:

1) Carbon dioxide—acid taste in high concentrations.
2) Nitrogen dioxide—reddish brown in higher concentrations, odor and taste of blasting powder fumes.
3) Hydrogen sulfide—rotten egg odor (however, continued exposure deadens your sense of smell), slight sweetish taste.
4) Sulfur dioxide—sulfur odor, acid taste.
5) Propane and butane—"gassy" odor in certain concentrations.
6) Acetylene—slight garlic odor.

4. Answer:

Carbon monoxide, oxides of nitrogen, hydrogen sulfide, sulfur dioxide, and acetylene.

5. Answer:

1) Whitedamp—carbon monoxide and air. Toxic.
2) Stinkdamp—hydrogen sulfide and air. Toxic, and may be explosive.
3) Afterdamp—carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen. Toxic, explosive, and can be oxygen-deficient.
4) Blackdamp—carbon dioxide, nitrogen, and air. Oxygen-deficient. Can cause suffocation.
5) Firedamp—methane (5 to 15%) and air. Can explode.

Mine Gases General Review

(Pages 2-49 thru 2-51)

Choose the correct answer to each of the following questions:

1. Normal air contains approximately what percent oxygen?
   a. 15%
   b. 21%
   c. 31%
   d. 79%

2. The explosive range of a methane/air mixture (normally 5-15%) will change if:
   a. certain other combustible gases are present.
   b. coal dust is suspended in the atmosphere.
   c. there is less than 12.1% oxygen in the atmosphere.
   d. all of the above.

3. Carbon monoxide is:
   a. a gas found in all mining operations
   b. a normal constituent of air
   c. detected during a mine fire or explosion
   d. a product of the breathing process

4. An elevated concentration of carbon dioxide in mine air can be harmful because:
   a. it is highly explosive
   b. it increases the breathing rate
   c. it is highly toxic in small concentrations
   d. all of the above

5. An elevated concentration of nitrogen in mine air can be harmful because:
   a. it can lower the oxygen content of the air
   b. it is highly explosive
   c. it is highly toxic
   d. all of the above

6. Oxides of nitrogen can occur in a mine atmosphere:
   a. when certain explosives are used
   b. when diesel-powered equipment is being used
   c. when electric equipment produces arcs or sparks
   d. all of the above

7. Accumulations of hydrogen in the mine atmosphere are dangerous because hydrogen:

   a. is highly toxic
   b. is highly soluble in water
   c. is highly explosive
   d. gives off a suffocating odor

8. Characteristics of hydrogen sulfide include:
   a. explosive
   b. highly toxic
   c. can be liberated from pools of stagnant water
   d. all of the above

9. Which of the following is not true of sulfur dioxide?
   a. it is explosive
   b. it is highly toxic
   c. it is highly soluble in water
   d. it can occur during mine fires

10. The most likely source of ethane, propane, or butane in a mine is:
    a. use of diesel equipment
    b. battery charging stations
    c. leakage from adjacent gas or oil wells
    d. all of the above

11. Acetylene would normally be found in a mine atmosphere where:
    a. diesel equipment is used
    b. methane has burned or exploded in air with a lowered oxygen content
    c. leakage has occurred from adjacent oil or gas wells
    d. battery charging stations are located

12. Match each damp with its components:

1. Firedamp	a. Carbon monoxide and air
2. Blackdamp	b. Hydrogen sulfide and air
3. Afterdamp	c. Carbon dioxide, nitrogen, and air
4. Whitedamp	d. Carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen
5. Stinkdamp	e. Methane and air

13. Mine rescue teams are required by Federal law to have available:
    a. one detecting device for every gas listed as dangerous by the U. S. Bureau of Mines
    b. one detecting device for each gas normally encountered in the mine(s) the team serves
    c. four detecting devices for each gas normally encountered in the mine(s) the team serves
    d. one detecting device for each team member

14. Atmospheric pressure and temperature are important factors because they:
    a. affect the rate of diffusion of a gas by ventilation
    b. can cause false readings on gas detection instruments
    c. lower oxygen content in the mine
    d. all of the above

15. Two gases that are highly soluble in water are:
    a. methane and acetylene
    b. hydrogen sulfide and hydrogen
    c. nitrogen and sulfur dioxide
    d. hydrogen sulfide and sulfur dioxide

16. A gas that is normally found near the roof or in high places in the mine is said to have a low:
    a. level of toxicity
    b. level of explosivity
    c. specific gravity
    d. level of solubility

17. The amount of coal dust suspended in the mine atmosphere is most important because:
    a. it can alter the explosive range of methane.
    b. it can affect the specific gravity of oxygen.
    c. hydrogen is liberated from the coal dust.
    d. coal dust lowers the oxygen content in the mine atmosphere.

18. A nontoxic gas can still be dangerous because it can:
    a. displace oxygen
    b. burn
    c. explode
    d. all of the above

19. The type of coal mine where the greatest amount of methane would be likely to be found would be a:
    a. drift mine with tight and compact adjoining strata
    b. drift mine with loose or broken adjoining strata
    c. shaft mine with tight and compact adjoining strata
    d. shaft mine with loose or broken adjoining strata

20. Gases that are neither toxic nor explosive:
    a. are not found in mine atmospheres
    b. are not dangerous
    c. can be dangerous because they can displace oxygen
    d. cannot be detected with today’s detection instruments

GENERAL REVIEW ANSWER KEY (IG XX pages 2-52)

1. **b**
2. **d**
3. **c**
4. **b**
5. **a**
6. **d**
7. **c**
8. **d**
9. **a**
10. **c**
11. **b**
12.
    1) **e**
    2) **c**
    3) **d**
    4) **a**
13. **c**
14. **a**
15. **d**
16. **c**
17. **a**
18. **d**
19. **c**
20. **c**

Module 3 – Ventilation

Airflow (pages 3-4)

The purpose of mine ventilation is to provide a volume of air sufficient to disperse and remove harmful gases, dust, smoke, and fumes, and to provide adequate oxygen.

When a mine is ventilated, air from the surface enters the mine at the main intake (or intakes) and is directed or "coursed" through the mine by a system of ventilation controls. These controls force the air to move in certain directions and at certain velocities so that it reaches all sections of the mine.

All the return air from the working sections is then channeled to the main return and eventually exits the mine.

To obtain the 'flow' of air through the mine there must be a difference in air pressure between the intake and return airways.

The basic principle underlying mine ventilation is that air always moves from high pressure regions to low pressure regions. Therefore, in order to get the air to flow from the intake to the return, the return air must be at a lower pressure than the intake

Mine Fans

Mine fans are used to create this pressure differential by changing the air pressure at specified points in the mine.

The greater the pressure difference the fan creates, the faster the flow of air. This method of using a fan to create the pressure differential is known as mechanical ventilation.

The mine fan(s) can create this pressure differential either by blowing air into the mine or exhausting air from the mine.

An exhaust fan pulls old air out of the exhaust airway. This pulling causes a pressure differential which, in turn, pulls fresh air into the mine's intake.

Blowing fans are used mostly in mines having little overburden, because these mines may have surface cracks, a blowing fan is used so that any air that leaks through the crack will leak away from the mine, not into the mine.

In most cases, one main fan is used to ventilate the entire mine or a particular section of the mine; however, in large mines with vast underground workings, several main fans may be used.

These fans may be exhaust, blowing, or a combination of the two (push-pull). Teams need to be familiar with the ventilation plan for the mine."

To help ensure your team's safety while working underground, the main fan(s) should be monitored or guarded by an authorized individual to make sure that it operates continuously. If the fan goes down while you're underground, and hazardous conditions ensue, you will be withdrawn from the mine.

Also, this monitor or guard will help ensure that no alterations in the operation of the fan(s) will be made without orders from the Command Center.

Ventilation Maps (pages 3-5)

As mine rescue team members, you should know how to read a mine map that shows ventilation. This is basic knowledge for any team member, especially the map person. The team's map person is responsible for marking down information on the map as the team explores and assesses ventilation.

At the team's briefing before going underground, you will be given an up-to-date ventilation map of the area to be explored. You should study this map and get familiar with where you are going and what you should expect to see underground.

If other teams have already explored part of the mine, the map will show what has been found and done on previous explorations.

Map Symbols (pages 3-5)

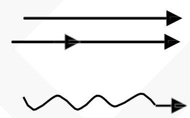
Also, you should get familiar with that particular map's symbols since maps can differ from one mine to the next. It's a good idea for the map person to fix a legend of each map symbol to the bottom of the map or mapboard, as well as the scale to which the map is drawn.

Intake and Return Airway Symbols (pages 3-6)

NOTE: There are a few ways to indicate the direction of *intake* and *return* (or exhaust) airflow on a ventilation map. The following symbols are commonly used:

Direction of Intake Airflow Direction of Return

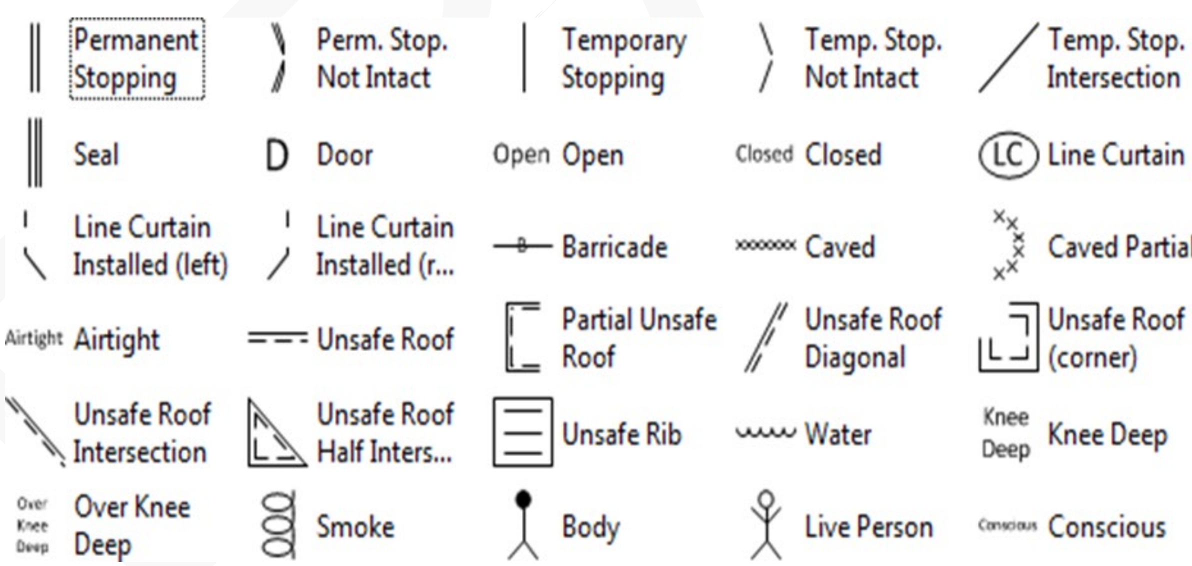
Airflow Direction of Low-Velocity Airflow



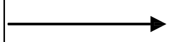
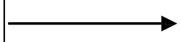
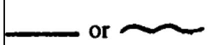
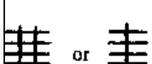
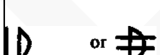
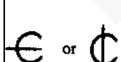
Sometimes, color-coded lines or arrows are used to indicate intake and return airways (for example, blue or green arrows for intake and, and red arrows for return air).

Mapping Symbols

Some of the commonly-used symbols on mine maps are shown in the table below:



Other Mapping Symbols (pages 3-7)

	**Direction of Intake Airflow**
	**Direction of Return Airflow**
	**Direction of Low-Velocity Airflow**
	**Main Fan**
	**Auxiliary Fan and Tubing**
	**Temporary Stopping**
	**Permanent Stopping**
	**Line Brattice**
	**Overcast (if used)**
	**Undercast (if used)**
R	**Regulator**
	**Belt Regulator**
	**Box Check**
	**Belt Conveyor with Belthead and Tailpiece**
D	**Mine Door**
	**Track**
	**Man Door**
	**Check Curtain or Run-through Curtain (if used)**

Ventilation Controls (pages3-8)

Stoppings/Bulkheads (pages3-8)

Stoppings are used in crosscuts to direct air through the mine. They keep intake air in one entry separate from return air in the next entry so that the intake air doesn't short- circuit into the return before it reaches the working faces.

Permanent Stoppings/Bulkheads (pages3-8)

Permanent stoppings/Bulkheads are built of concrete blocks, metal panels, or other incombustible materials. They are sealed tightly against the roof, floor, and ribs of a mine passage so that no air can leak through. Porous stoppings such as concrete block stoppings are usually plastered on the high-pressure side to reduce air leakage.

Sometimes permanent stoppings/Bulkheads have a man door (or drop door) in them to allow miners to pass through the crosscut from one entry to another. Man doors are not meant to be ventilation controls, but if a man door is propped open, it can affect airflow and may cause intake air to short-circuit into the return.

Temporary Stoppings/Bulkheads (pages3-9)

Temporary stoppings /Bulkheads are used in active working of the mine to temporarily advance and direct the flow of air until a permanent stopping which is stronger and more airtight can be built.

Temporary stoppings /Bulkheads are usually built of canvas, brattice cloth, or plastic. Sometimes, however, they are built with a frame of wood.

In mine rescue work, temporary stoppings/Bulkheads are used to advance ventilation as the exploration or mine recovery work progresses.

There are specially designed temporary stoppings/Bulkheads for use in mine rescue work which are fast and easy to install. One of these is an inflatable, rubberized type. Another is a self-sealing stopping commonly referred to as a "parachute stopping."

Also, urethane foam, available in pressurized containers, is sometimes used by rescue teams for sealing the edges of a temporary stopping to make it more airtight

Line Brattice (pages3-9 and 3-10)

Line brattice is brattice cloth or plastic that is hung to channel intake air from the last open crosscut to the working face. It is extended as the mining progresses to keep the air flowing to the face.

Line brattice is hung from the roof to the floor, extending from the end of a check curtain to within ten feet of the working face. It can be hung from a rough lumber frame, from timber posts, or from special fasteners. It can also be secured to the roof with spads.

Line brattice is especially useful for rescue teams to use when they need to sweep out or ventilate a room or area of the mine or when they need to split an air current as they are advancing ventilation.

Auxiliary Fans and Tubing (pages3-10)

In mines where drilling or blasting is done and large amounts of dust are produced, auxiliary ventilation systems are often used to control and direct airflow to or from the mining area. These auxiliary systems usually consist of a small, portable fan and tubing, sometimes referred to as a vent bag or a fanline. Sometimes, auxiliary fans are used without any tubing to direct air into a raise

In mines where continuous mining machines cut large quantities of coal and produce large amounts of dust, auxiliary ventilation systems are often used to control and direct air flow to or from the face. These auxiliary systems consist of an auxiliary fan and tubing.

The auxiliary fan can be used to either exhaust or blow the air. The tubing, which is usually suspended from timbers or roof bolts (if approved), carries the air to or away from the working face. This tubing can be either rigid (for exhausting systems) or collapsible (for blowing systems).

An auxiliary ventilation system allows the continuous miner to operate without being obstructed by line brattice which would normally be required to ventilate the working face. The tubing is easily moved closer to the working face making it convenient to extend ventilation to the face as the mining advances.

Regulators (pages3-12)

Regulators are used in mine ventilation to regulate airflow to meeting the individual needs of each air split. There are many different kinds of regulators that can be used in the mine:

- Section regulators used in returns are often sliding doors or windows built into permanent stoppings near the mouth of a section.
- Teams should mark a visible reference point to return the sliding door back to the original set-point of the regulator in case passage of men or materials required movement.
- Opening or closing the door or window adjusts the air flow to a section. If one of these regulator doors has to be opened to allow miners to pass through, it must always be closed to the position in which it was found.
- Another type of regulator can be made by knocking blocks out of a permanent stopping. The air flow can be adjusted by removing blocks or replacing blocks.
- Taking down one corner of a check curtain can make another type of regulator. The opening at the corner lowers the air's resistance and allows more air to flow. The airflow can be adjusted by lowering the corner to make a larger opening, or tacking it up to make a smaller opening.
- Another type of regulator can be made by hanging a check curtain so that it does not reach the floor of the mine. This again would lower the air's resistance and allow more air to flow. This type of regulator can also be adjusted to change the airflow.
- A pipe overcast can also serve as a regulator.

Review Questions (pages3-14)

1. Define and discuss the purpose or function of the following:
   - Stoppings/<u>Bulkheads</u>
   - Line Brattice
   - Regulators
   - Auxiliary Fans and Tubing

2. Provide the symbol for each of the following ventilation terms: (If the symbols used at the team's mine differ from the ones provided here, be sure to use the team's symbols).
   a. Temporary stopping/<u>Bulkheads</u>
   b. Permanent stopping/<u>Bulkheads</u>
   c. Line brattice
   d. Overcast (if used)
   e. Undercast (if used)
   f. Regulator
   g. Mine door
   h. Box check
   i. Belt Regulator
   j. Main fan
   k. Auxiliary fan and tubing
   l. Track
   m. Conveyor belt with belthead and tailpiece
   n. Man door
   o. Check curtain or run-through check (if used)

Answers: (pages3-15)

1. **Stoppings** /Bulkheads – Stoppings/Bulkheads are used to direct air through the mine. They keep intake air in one entry separate from return air in the next entry so that the intake air doesn't short-circuit into the return before it reaches the working faces.

   Line Brattice – Line brattice is used to channel intake air from the last open crosscut to the working face.

   Regulators – Regulators are devices which, by their adjustment, can regulate airflow to meet the individual needs of each air split.

   Auxiliary Fans and Tubing – Auxiliary fans and tubing are used to provide sufficient airflow to face areas during mining operations.

2. **Answers:**

   a. Temporary stopping/Bulkheads

    or 

   b. Permanent stopping/Bulkheads

   c. Line brattice

   d. Overcast (if used)

   e. Undercast (if used)

   f. Regulator

g. Mine door

h. Box check

O

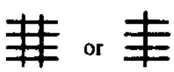
i. Belt regulator

R | |

j. Main fan

k. Auxiliary fan and tubing

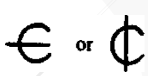
l. Track



m. Conveyor belt with belthead and tailpiece

n. Man door

o. Check Curtain



Assessing Ventilation

During a mine emergency, it is very important to determine as quickly as possible what the condition of the ventilation system is. This includes knowing the condition of the ventilation controls and knowing the direction and velocity of the underground airflow.

Reporting Condition of Existing Ventilation (pages3-17)

As the team advances through the mine during exploration, all the ventilation controls should be checked, especially those in the affected part of the mine. When you come to a regulator or door, its position should be noted on the map by the map person and it should be reported to the Command Center.

The officials at the Command Center need to receive accurate information from the team regarding the ventilation controls and air lines. They need to be kept well- informed about conditions underground so that they can make the appropriate decision as to what changes to make in the ventilation.

The Command Center should be told the **type** of damage you find and the **extent** of the damage. For example, if a stopping/Bulkheads or other type of structure has been blown out by explosive forces, you should note the direction in which it appears to have blown. Even if stoppings/Bulkheads are not destroyed, indications of blocks having been moved should be reported.

The most positive indicator of the origin of an explosion is the direction in which blocks have moved in or from stoppings/Bulkheads across entries near intersections. The movement of blocks from stoppings/Bulkheads in crosscuts seldom indicates the origin of an explosion.

The Command Center considers several factors before it orders a change in ventilation—most importantly, it has to consider how the alterations will affect ventilation into an unexplored area. The rule-of-thumb when altering ventilation is not to change the ventilation into an unexplored area.

The wrong alterations could cause changes in the air at the Fresh Air Base, push deadly gases or smoke into areas where survivors are located, force explosive gases back over fire areas or hot spots and cause an explosion, or redirect and feed air to a fire.

NOTE: Mine rescue teams should NEVER alter ventilation without direct orders from the Command Center.

Measuring Airflow (pages3-18)

There are times when a team will be asked to determine the direction and velocity of airflow in a certain section of the mine. Knowing the velocity is important because the quantity of airflow can be calculated from it.

Being able to determine the direction and velocity of airflow enables the team to check both whether the ventilation system is functioning as a whole and whether it is functioning as it should in a given area.

When a team takes the air direction and velocity measurements, it will report those findings to the Command Center. The officials at the Command Center will calculate the figures and compare them with the normal readings obtained previously at the mine.

The two instruments commonly used to measure air movement are the anemometer and the smoke tube. The smoke tube is used mainly to determine what direction very slow-moving air is moving, and at what velocity. The anemometer is used to measure medium- and high-velocity air movement.

Sometime the high velocities encountered are those flowing in ducts or tubing where measurements by an anemometer are difficult. For such measurements the most practical instruments are a Pitot tube or Magnehelic, which can be inserted through a small hole in the duct or tubing.

Anemometer (pages3-18 and 19)

An anemometer is a small sort of windmill with a mechanical counter for recording the number of revolutions caused by the moving air current. It is used to measure air velocities of over 120 feet per minute. There are two types of anemometers:

1) A medium-velocity (or "regular") anemometer for measuring velocities from 120 to 2,000 feet per minute; and

2) A high-velocity anemometer for measuring velocities from 2,000 to 10,000 feet per minute.

The anemometer actually measures **linear feet of travel** and requires timing—usually one minute—to determine **velocity** in feet per minute. Then the **area** of the airway (where the reading is taken) is computed in square feet. The **area** is then multiplied by the **velocity** to obtain the quantity of the air current in cubic feet per minute.

A commonly-used method of measuring the velocity in an airway is to traverse the airway so that you get an accurate measurement of the average velocity in the airway. This procedure is as follows:

1. Stand with your back to one rib and hold the anemometer in a vertical position out in front of you at full arm's length. The anemometer should be positioned so that the air current will enter the back of it (that is, the side without the dials). Your free arm should be kept close to your body.
2. Turn the anemometer on and walk slowly to the opposite rib, pacing yourself to get a one minute reading. Be sure to keep the anemometer out in front of you (to decrease resistance as much as possible). The anemometer should be raised and lowered as you walk to the opposite rib so that the average velocity of the air is measured.
3. At the end of one minute, turn off the anemometer and read the dials. This reading will have to be corrected by using the manufacturer's table of corrections for the various velocity readings.
4. Determine the cross-sectional area of the entry by multiplying the width times the height.
5. Report the velocity and area measurements to the Command Center. The Command Center will calculate the quantity of airflow in cubic feet per minute by multiplying the area (ft.$^{2)}$ by the corrected velocity (ft. /min.).

NOTE: If the anemometer reading is taken for **less than a minute**, the velocity reading will have to be **converted** to feet per minute.

Smoke Tube (pages3-19)

The smoke tube is used to show the direction and velocity of slow-moving air (below 120 feet per minute). The smoke tube is a device that emits a smoke cloud which floats along with the air current to show the direction of the airflow and the approximate velocity of the airflow.

The smoke tube contains a smoke-generating chemical. To use it, break off both ends of the glass tube and then squeeze the aspirator bulb to force air into the tube. A white cloud of smoke will come out of the tube and travel with the air current in the passage. This will show you the direction in which the air is flowing (in cases where the direction cannot otherwise be determined).

If you are not wearing breathing protection when working with the smoke tube, you should be careful not to come in contact with the smoke. It is extremely irritating and can cause choking.

There are two methods of measuring the velocity with a smoke tube. With one method, the reading is taken only at the center of the airway. This method **is not** very accurate, as it gives only an approximate reading and a high reading because the center of an airway has the fastest moving air.

The **more accurate** method of determining the air velocity is to take readings at quarter points within the airway.

1. Measure off a distance in a relatively straight and uniform airway. Twenty-five feet is usually a suitable distance for this measurement. (This distance should be determined by how well the smoke cloud holds together and how well it can be seen.)

2. Station one person with the smoke tube at the upwind point of the measured distance, and station one person with a stopwatch at the downwind point.

3. The person with the smoke tube then releases a smoke cloud utilizing an aspirator bulb at each quarter point within the airway. The person with the stopwatch then must time each cloud from the moment it is released until it reaches the downwind point or line at the prescribed distance. The measurements are taken separately, that is, the first smoke cloud is timed, then the second, and so forth

   Each velocity measurement in a quadrant should be repeated several times to determine an accurate average. Abnormal high and low measurements should be discarded, and the remainder averaged. A correction will then have to be made to the averaged figure, because the air travel at the quarter points will average about 10 percent high.

   NOTE: To make this correction, either multiply the averaged figure by **0.10** and subtract this number from the averaged figure, or multiply the averaged figure by **0.9.**

4. Determine the average area of the entry along the measured distance by multiplying the width times the height.

5. Report the velocity and area measurements to the Command Center. The Command Center can then calculate the quantity of airflow in cubic feet per minute.

   Use this formula: Quantity (ft.^{3} /min.) = Area (ft.^{2}) x Velocity (ft. /min.)
   NOTE: Velocity is always measured in feet per minute (ft./min.) for mine application.

To do the next calculation, you first have to convert the smoke tube reading into feet per minute.

For example, let's say that 25 feet is the measured distance and it averages 23 seconds for the smoke cloud to reach the downwind point.

You need to find the decimal equivalent of 23 seconds to find what fraction of a minute it is:

$$\frac{23 \text{ seconds}}{60 \text{ seconds}} = .38 \text{ minute}$$

So you would have:

- 25 feet of travel divided by, .38 minute. This equals 65.7 ft. /min.
- Now plug 65.7 into the formula: Q (ft.3) = A(ft.2) x V(ft./min.)
- Quantity = Area (let's use 200) x 65.7
- Quantity of airflow = 13,140 ft.3/min.

Review questions (pages3-21)

1. What are the reasons why mine rescue teams should not alter ventilation without authorization from the Command Center?

2. Under what conditions would a team use a smoke tube to determine air velocities?

3. Under what conditions would an anemometer be used to determine air velocities?

ANSWER SHEET (pages3-22)

1. **Answer:**
   - Altering the ventilation could force deadly gases into areas where survivors might be located.
   - It could force explosive gases over fire areas or hot spots and cause an explosion.
   - It could supply additional oxygen to a fire area and "feed" the fire.
   - It could also result in ventilation changes that would alter the air at the Fresh Air Base.

2. **Answer**: The smoke tube is used to determine the direction and velocity of slow- moving air, below 120 feet per minute.

3. **Answer**: The medium-velocity (or "regular") anemometer is used to determine air velocities from 120 to 2,000 feet per minute. A high-velocity anemometer is used to determine air velocities from 2,000 to 10,000 feet per minute.

Building Ventilation Controls (pages 3-23)

NEVER make alterations or do any construction without the approval of the Command Center.

Constructing Temporary Stoppings/Bulkheads (pages3-23)

When installing a temporary stopping /Bulkheads in a crosscut, the stopping/Bulkheads should be erected a sufficient distance into the crosscut (at least 4 to 6 feet) to permit enough room for a permanent stopping/Bulkheads to be built later.

The site for the temporary stopping/Bulkheads should ideally have good roof and ribs, and little or no debris on the floor in order to obtain a good seal around the stopping/Barricades. You should be sure to test the roof and, if necessary, bar down any loose material from the roof.

A post should be set at each rib and, depending on the width of the crosscut, more posts can be set between the ribs. Boards should be nailed to the top and bottom of the posts to which the brattice or plastic can be attached, or loose material can be shoveled onto the bottom surplus of brattice or plastic to seal the bottom of the stopping.

NOTE: Non-sparking tools, nails, or spads **must be used in mine atmospheres of above 1% methane** to reduce the chance of a spark that could cause an ignition. Also, non-sparking shovels should be used to fill in around temporary stoppings in such atmospheres.

If they are available, “pogo sticks,” which are spring-loaded expandable metal rods much like a pole lamp, can be used instead of posts to erect temporary stoppings. These permit stoppings to be built much faster, since posts do not need to be cut and fitted. They could also be used along with posts in wide crosscuts to reduce the number of posts that would normally be needed.

If the mine has had an explosion, the team may encounter a great deal of debris, damage to stoppings/Bulkheads, and hazardous roof and rib conditions. In order to restore ventilation under these conditions, teams might find it necessary to improvise and “control” the ventilation as much as possible.

Destroyed or damaged stoppings/Bulkheads in crosscuts that are filled with debris or have large pieces of equipment or mine cars in them can be sealed so that ventilation can be moved ahead.

In these cases, the team can hang brattice or plastic from the roof and cut the brattice to fit around the piece of equipment or obstruction. Loose material can then be shoveled onto the excess brattice at the bottom and onto the equipment to effect as tight a seal a possible.

When miners are trapped and the rescue team is advancing ventilation to them, the work must be done as quickly as possible. Through teamwork and practice, and with the proper materials, a mine rescue team can erect adequate temporary stoppings quickly and efficiently.

Constructing Permanent Stoppings/Bulkheads (pages3-24)

As soon as possible after ventilation has been restored to the mine, permanent stoppings/Bulkheads should be built to replace any temporary stoppings/Bulkheads. Under normal circumstances these permanent stoppings/bulkheads would be constructed outby the advancing Fresh Air Base, so they could be built by barefaced work crews rather than mine rescue teams.

There are instances, however, such as in sealing a fire area, where the mine rescue team, under oxygen, would be required to build a permanent stopping /bulkhead

Air Locks (pages3-24 and 25)

An air lock consists of two doors or two stoppings/bulkheads with flaps or doors in them which are in close proximity to each other in the same passageway. The purpose of an air lock is to separate two different atmospheres while still permitting miners to enter and exit without mixing the atmospheres. In order to maintain the air lock, one door of the air lock must be kept closed while the other door is open.

In mine rescue work, air locks are normally put up to establish a Fresh Air Base and enable teams to move forward into questionable air without contaminating the air at the Fresh Air Base.

Air locks are also used any time a team is required to break open a stopping/bulkheads or open a door when the conditions on the other side of that stopping or door are not definitely known.

Air locks are also required prior to opening any barricade or door in irrespirable atmospheres behind which survivors may be located.

When erecting an air lock, the team should build the two stoppings/bulkheads as close together as possible, yet with enough space to allow room for the team and their equipment to fit between

Line Brattice (pages3-25)

Mine rescue teams may, at times, find it necessary to use line brattice to sweep noxious or explosive gases from a face area or to split an air current as they are advancing ventilation. The line brattice can be installed by erecting posts or supports with boards along the roof to which the brattice can be attached. Or the brattice can simply be attached to the roof with spads, or held up with pogo sticks, if available.

If the brattice needs to hang only for a short time, the team can simply hold up the brattice, extending it into the area to be ventilated. In these situations, each team member should hold up a section of the line brattice and try to get it as close to the roof as possible

Review questions (pages 3-25)

1. Why would a team need to be able to build temporary stoppings quickly and effectively?

2. How would a team build a temporary stopping in a crosscut that has equipment in it?

ANSWER SHEET (pages 3-26)

1. **Answer:** Re-ventilation is essential for the advancement of the Fresh Air Base and the flushing out of dangerous gases. In particular, when miners are trapped, it is very important to be able to advance the Fresh Air Base quickly in order to rescue the miners.

2. **Answer:** The brattice should be cut to fit around and over the equipment, and the seal secured with loose material from the floor, shoveled onto the excess brattice along the floor and on the equipment.

General Review

Mine Ventilation

Choose the correct answer to each of the following questions.

1. A smoke tube is a device used to:
   a. Determine oxygen content of the mine atmosphere.
   b. Determine direction and velocity of airflow.
   c. Detect carbon monoxide.
   d. Detect leaks in temporary stoppings.

2. The traverse method is used when:
   a. Taking a reading with a smoke tube.
   b. Taking a reading with an anemometer.
   c. Erecting a temporary stopping.
   d. None of the above.

3. Mine rescue teams should alter existing ventilation:
   a. Only when directed to do so by the Command Center.
   b. When the team captain decides to do so.
   c. When they encounter high concentrations of methane.
   d. When they encounter smoke.

4. Mine rescue teams erecting temporary stoppings/Bulkheads in atmosphere with elevated methane readings should:
   a. Use only inflatable seals.
   b. Leave a corner of the stopping /Bulkheads open for the methane to exit.
   c. Use non-sparking tools, nails, and spads.
   d. Mine rescue teams should never enter such atmosphere.

5. During mine rescue team explorations, the main fan:
   a. Should be kept running.
   b. Should be continually monitored.
   c. Both of the above.
   d. None of the above.

6. Air locks are used by mine rescue teams:
   a. To establish a Fresh Air Base.
   b. When opening a door or knocking out a stopping/Bulkheads behind which conditions are not definitely known.
   c. Before opening a barricade in bad air behind which trapped miners may be located.
   d. All of the above.

7. Two instruments commonly used to measure velocity of airflow in a mine are:
   a. Smoke tube.
   b. Smoke tube and CO detector.
   c. Anemometer.
   d. Smoke tube and anemometer.

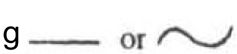
8. Temporary stoppings/Bulkheads built in a passageway should be placed at least 4 to 6 feet into the passageway in order that:
   a. Sufficient space is available to construct a permanent stopping/Bulkheads
   b. It will be protected from further explosions.
   c. It will not be affected by fire if a fire should spread to that crosscut.
   d. All of the above.

9. “Pogo sticks” are devices that are used:
   a. To test the roof and rib.
   b. To measure air velocity.
   c. To determine the direction of airflow.
   d. As supports on which brattice cloth can be hung.

10. Match the term with its correct symbol:

    Note: These are not standard symbols. If your mine uses different symbols, be sure to substitute your own here.

(1) Temporary stopping/Bulkheads
(2) Line brattice
(3) Overcast
(4) Main fan
(5) Man door
(6) Permanent stopping /Bulkheads
(7) Regulator
(8) Mine Door
(9) Box Check
(10) Check Curtain

a. 
b. 
c. 
d. 
e. 
f. 
g 

h. 
i.
j. 
k

GENERAL REVIEW ANSWER SHEET (pages3-59)

1. b
2. b
3. a
4. c
5. c
6. d
7. d
8. a
9. d
10. Answers:

    (1) g

    (2) k

    (3) a

    (4) c

    (5) j

    (6) i

    (7) f

    (8) h

    (9) d

    (10) e

Module 4
Exploration

"Exploration" is the term we use to describe the process of assessing conditions underground and locating miners (or clues to their whereabouts) during a rescue or recovery operation.

Examination of Mine Openings (pages 4-6)

Before anyone goes underground (if it is safe to do so), it's important to examine the mine openings to determine the safest route for entering the mine. Tests should be made for the presence of gases, and someone should make ventilation checks. Whenever possible, it's best to enter the mine by way of the safest intake airway.

In a shaft mine, check the cage to make sure it's operating properly. To test an automatic elevator, run it up and down the shaft manually several times.

Tests should also be made for the presence of gases, smoke, or water in the shaft. If a mine has had an explosion, the cage, signaling devices, and head-frame may be damaged.

Many times following fires, explosions or inundations, large sections of the mine outby where the event took place are relatively undamaged. These conditions make it possible to make an initial exploration barefaced. The mine rescue team conducts explorations using this technique with their breathing apparatuses on their back, ready to function. Putting on the apparatus prior to exploration allows the team to put on their face pieces quickly and get under oxygen if conditions make it necessary

Barefaced exploration should be conducted only when the ventilation system is operating properly and frequent gas tests indicate sufficient oxygen and no buildup of carbon monoxide, methane or other dangerous gases. As with regular exploration, a backup team with apparatus should be stationed on the surface.

The purpose of such exploration is to establish the extent of damage and to quickly progress in good air to the point where the initial Fresh Air Base will be established. Not being under oxygen, a barefaced crew will probably be able to advance and determine current conditions quickly. They may be able to cover moderate to large distances when conditions are good.

During barefaced exploration, the crew uses radios and/or the mine's communication system to report their progress and findings to the surface. Once the exploring team goes a certain distance into the mine, Command Center will send a backup team underground to follow in case the exploring team experiences any problems. The underground backup team should remain a predetermined distance behind the advancing team and a third team should remain outside the mine to act as surface backup.

Barefaced exploration should stop at any point where disruptions in ventilation are found, or when gas tests indicate the presence of any carbon monoxide or other noxious gases, elevated readings of explosive gases, elevated methane readings, or oxygen deficiency. A barefaced crew should also stop exploration when they encounter smoke or damage.

A Fresh Air Base is usually established at the point where conditions no longer permit barefaced exploration. Because the area has already been explored, rescue team members and backup personnel are then free to travel to and from the Fresh Air Base without apparatus. Teams equipped with apparatus continue exploration from the Fresh Air Base."

The Fresh Air Base (pages4-7)

The Fresh Air Base (FAB) is the base of operations from which rescue and recovery work advances into irrespirable atmospheres. This is where apparatus crews begin their exploration of the affected area.

The Fresh Air Base also functions as a base of communications for the operation linking the team, the Command Center, and all support personnel.

Establishing a Fresh Air Base (pages4-7 and 8)

Usually, the operation's initial Fresh Air Base will be established somewhere underground, and then advanced as the exploration proceeds. But if underground damage is extensive, it may be necessary to establish the initial Fresh Air Base on the surface.

Whether you put it underground or on the surface, the Fresh Air Base should be located as close as possible to the affected area of the mine, but situated where it's assured a supply of fresh air. Communications from the Fresh Air Base to the surface should be secure.

When the Fresh Air Base is set up underground, an air lock must be built to isolate the Fresh Air Base from the unexplored area beyond it. The air lock allows the team to enter and exit the unexplored area without contaminating the air at the Fresh Air Base.

NOTE: Refer to the list of requirements for a Fresh Air Base on **Visual 1.**

Here are some specific factors to consider when you select a site for a Fresh Air Base:

- Be sure the Fresh Air Base is located where it's assured positive ventilation and fresh air.
- If the Fresh Air Base is underground, it should be located where it's assured a fresh air travelway to the surface. This travelway will be used to safely move people and supplies to and from the Fresh Air Base. **If possible, there should also be transportation available.**
- The site should be situated where it can be linked to the Command Center by means of a communication system.
- There should also be a communication system to link the team and the Fresh Air Base.

These factors are probably the most important that help determine where to establish a Fresh Air Base, but there are also some other elements to take into consideration. For example, the area should be free of oil and grease. It should also be well rock dusted

The Fresh Air Base should be large enough to accommodate all the people who will be using it and allow enough space for them to work efficiently. It's also desirable to have a roof that's high enough for everyone to stand under, and a level floor.

It is often recommended that all possible electrical conductors (track, pipe, wires, etc.) be severed so that the affected area beyond the Fresh Air Base is isolated from any possible stray or direct current.

The Fresh Air Base is normally outfitted with supplies and other equipment to be used during the operation. For example, a typical Fresh Air Base will probably be equipped with gas testing devices, equipment for detecting oxygen deficiency, and perhaps firefighting equipment.

There may also be first aid supplies and oxygen therapy equipment at the Fresh Air Base, as well as tools and replacement parts for self-contained breathing apparatus and a map of the affected area.

If possible, the Fresh Air Base should be supplied with benches, canvas, or brattice cloth on which the backup team can set their apparatus or other supplies.

The Fresh Air Base Coordinator (pages4-9)

Stationed at the Fresh Air Base, there will be a person who is responsible for establishing and maintaining orderly operations. This is the “Fresh Air Base Coordinator.” The Fresh Air Base Coordinator plays a key role in ensuring that the entire operation runs smoothly and efficiently.

Because the Fresh Air Base Coordinator’s job is so important, it is absolutely essential that everyone at the Fresh Air Base respect the Coordinator’s authority and do whatever they can do to help out. It’s also critical that only those people necessary to the operation are permitted at the Fresh Air Base.

NOTE: Refer to **Visual 2** as you discuss the Coordinator’s responsibilities.

The primary responsibilities of Fresh Air Base Coordinator **include the following:**

- Monitor communications with the active rescue teams, perform maintenance on the communications as necessary, and ensure there is an established link between the working teams and the Command Center.
- All Fresh Air Base communication should either be hard wired or provided with its own separate, encrypted system.
- The FAB Coordinator should not become a message relay point, unless there is a failure in the communications system.
- Follow the team’s progress on the mine map and mark findings on the map as the team reports them.
- Coordinate and oversee the activities of all personnel who are at the Fresh Air Base.

These primary responsibilities include a great number of duties that may be delegated to other personnel, but it’s still the Fresh Air Base Coordinator’s responsibility to make sure these duties are carried out.

The Coordinator’s duties typically include checking and logging the time and name or number of the team(s) going inby the Fresh Air Base or returning to surface, checking the condition of the backup team for their readiness as well as checking and logging equipment/materials.

If a lifeline is used, it’s usually the Fresh Air Base Coordinator’s responsibility to make sure someone is stationed at the Fresh Air Base to monitor it. Additionally, the Fresh Air Base Coordinator should also make sure no unauthorized personnel or equipment are permitted to go inby the Fresh Air Base.

An incoming Fresh Air Base Coordinator who is relieving another Coordinator, must be briefed on all the necessary up-to-date information to ensure that the changeover goes smoothly. It’s also the incoming Fresh Air Base Coordinator’s duty to check communications between the Fresh Air Base and the Command Center to make sure the system is operating properly.

The Coordinator should reports his or her arrival at the Fresh Air Base and ensure the Command Center logs the arrival time.

Sometimes, “runners” are stationed at the Fresh Air Base to carry messages from the Fresh Air Base to the Command Center in the event of a communication breakdown. The runners may also be responsible for other tasks, such as taking gas samples to the surface or monitoring the lifeline.”

Advancing the Fresh Air Base (pages4-10)

The Fresh Air Base is usually advanced closer to the affected area of the mine as soon as the areas inby the base are explored and re-ventilated. This ensures that the apparatus crews will begin their explorations as close as possible to the affected area of the mine.

To advance the Fresh Air Base, the team will have to build a new air lock at the site of the new Fresh Air Base and put up any additional temporary stoppings in parallel entries that are needed to seal off the area at that point so that fresh air can be advanced.

Also, the team will have to repair any damaged ventilation controls in the area between the old Fresh Air Base and the new one. However, be sure to leave open the last stopping outby the new Fresh Air Base that goes to the return. If the stopping is intact, open it. This ensures that the area can be properly flushed out and ventilated

Next, return to the old Fresh Air Base and remove or open that air lock and any stoppings in parallel entries. This permits air to enter inby the old Fresh Air Base and flush the area up to the new Fresh Air Base.

Before everyone is moved up to the new Fresh Air Base, the area between the old and the new one should be explored by a mine rescue team or by a crew of company, state and Federal officials. Using gas testing devices, check all dead ends, intersections, and high places in the area to make sure it’s adequately ventilated.

Once the entire area is explored, all appropriate checks have been made, and the area is declared safe, the team and other designated personnel can then advance the Fresh Air Base.

Review questions:

1. What is a Fresh Air Base (FAB)?
2. What are some of the requirements for a FAB?
3. What are the three main duties of the FAB Coordinator?
4. How do you advance a FAB?

ANSWER SHEET

1. **Answer:**
   The Fresh Air Base is the underground base of operations and starting point for rescue and recovery work into irrespirable atmospheres.

2. **Answer:**
   - The Fresh Air Base must be situated where it's assured of positive ventilation, supply of fresh air, and a travelway to the surface for people and equipment.
   - It must also have communications systems linking it to the Command Center and to the mine rescue team.
   - It is also best if the area is well rock-dusted and free of oil and grease.
   - A level floor and a roof high enough for everyone to stand are also desirable.

3. **Answer:** The Fresh Air Base Coordinator:
   - handles communications with the team and the Command Center,
   - maps the team's progress and findings,
   - and coordinates and oversees the activities of all designated personnel at the Fresh Air Base.

4. **Answer:** To advance the Fresh Air Base,
   - construct a new air lock and any stoppings/bulkheads in parallel entries that are needed, repair ventilation controls to the point where the new Fresh Air Base is located, and provide an opening to the return.
   - Then return to the old Fresh Air Base and remove that air lock and any stoppings/bulkheads in parallel entries in order to ventilate the new area.
   - Prior to moving everyone up to the new Fresh Air Base, a mine rescue team or designated crew will need to perform gas tests in all dead ends, intersections, and high places of the newly ventilated area.

Apparatus Teams (pages4-12)

Once the Fresh Air Base is established, apparatus teams will be sent inby to explore the affected area. This exploration may require only one or two trips inby, or it may continue through many team rotations. How many trips will be needed to complete the exploration (and how long it will take) will depend on the extent of the area involved and the conditions within the affected area.

Team's Role in Exploration (pages4-12 and 13)

During exploration, the team travels in potentially hazardous atmospheres. Roof/back and rib conditions will be uncertain—and perhaps hazardous.

As the team progresses through the mine, team members make gas tests and assess conditions. The team also searches for clues as to where survivors may be located, and locates fires. All these findings are mapped and reported to the Fresh Air Base as the team proceeds.

As you explore, keep in mind that your first priority is team safety. The rescue of survivors comes second. Your third priority is the recovery of the mine. During exploration, teams will work according to a rotation schedule. One team, for example, will be scheduled to work inby.

A second team will be stationed at the Fresh Air Base as the "backup team," and a third team, known as the "standby team," will be ready and waiting on the surface. Other teams may be scheduled to rest.
Because rescue work is strenuous and demanding, it's important for team members to be well rested. It's also recommended that you don't eat within one hour of the time you'll be wearing your apparatus, and you shouldn't drink alcoholic beverages for at least 12 to 18 hours before you get under oxygen.

Lack of sleep, a recent meal, or alcoholic beverages can cause you to be sluggish and impair your judgment and reflexes. It's also a good idea to **limit** intake of stimulants such as coffee, colas, etc., because these substances increase heart and respiration rates.

Team Equipment

Rescue team members use some of the same basic equipment that any underground miner uses. For example, each member will be outfitted with a hard hat, cap lamp, steel-toe shoes or boots, and a metal ID tag.

For rescue work, you will also wear a metal ring on your mine belt so you can hook onto a lifeline or linkline, and it is common practice for everyone to wear a watch. Of course, each team member will also wear a Self-Contained Breathing Apparatus (SCBA).

Equipment Required by Law (pages4-13 and 14)

- **Metal and Nonmetal:** 30 CFR Section 49.6 - Equipment and maintenance requirements
- **Coal:** 30 CFR Section 49.16 – Equipment and maintenance requirements

The regulations state:

(a) Each mine rescue station shall be provided with at least the following equipment. Mine rescue stations serving underground anthracite coal mines, which have no electrical equipment at the face or working section, shall have at least the amount of equipment appropriate for the number of mine rescue team members.

(1) Twelve self-contained breathing apparatus, each with a minimum of 4 hours capacity (approved by MSHA and NIOSH under 42 CFR part 84, subpart H), and any necessary equipment for testing such breathing apparatus.

(2) A portable supply of liquid air, liquid oxygen, pressurized oxygen, or oxygen generating chemicals, and carbon dioxide absorbent chemicals, as applicable to the supplied breathing apparatus and sufficient to sustain each team for 8 hours while using the breathing apparatus during rescue operations.

(3) Two extra, fully-charged oxygen bottles for every six self- contained breathing apparatus.

(4) One oxygen pump or a cascading system, compatible with the supplied breathing apparatus.

(5) Twelve permissible cap lamps and a charging rack.

(6) Four gas detectors appropriate for each type of gas that may be encountered at the mines served. Gas detectors must measure concentrations of methane from 0.0 percent to 100 percent of volume, oxygen from 0.0 percent to at least 20 percent of volume, and carbon monoxide from 0.0 parts per million to at least 9,999 parts per million.

(7) [Reserved].

(8) One portable mine rescue communication system (approved under part 23 of this title) or a sound-powered communication system.

(i) The wires or cable to the communication system shall be of sufficient tensile strength to be used as a manual communication system.

(ii) These communication systems shall be at least 1,000 feet in length.

(9) Necessary spare parts and tools for repairing the breathing apparatus and communication system.

(b) Mine rescue apparatus and equipment shall be maintained in a manner that will ensure readiness for immediate use.

(1) A person trained in the use and care of breathing apparatus shall inspect and test the apparatus at intervals not exceeding 30 days and shall certify by signature and date that the inspections and tests were done.

(2) When the inspection indicates that a corrective action is necessary, the corrective action shall be made and the person shall record the corrective action taken.

(3) The certification and the record of corrective action shall be maintained at the mine rescue station for a period of 1 year and made available on request to an authorized representative of the Secretary.

Team Briefing Sessions (pages4-16)

Before your team goes underground, they must attend a briefing session. This usually takes place at the Command Center and is usually conducted by a briefing officer and a briefing committee. The briefing committee is generally composed of company and Federal officials and, where applicable, state and union representatives.

Personnel from the Command Center are responsible for conducting briefing sessions, and they determine who should be included in the sessions. It is suggested that the team captain, map man, and, possibly, the team's trainer be included.

At the briefing, the team needs to be informed about what has happened in the mine and what conditions currently exist. The briefing officer will give the captain the team's assignment. This assignment specifies what areas your team will explore.

The briefing officer will also issue your team an up-to-date mine map and give you a time limit within which you should be able to complete your work and return to the Fresh Air Base.

The exchange of information between the Command Center and the mine rescue teams carrying out the assignments is extremely important to the successful completion of the assignment. However, it must be emphasized that the Command Center makes the final decisions regarding all aspects involved in the operation.

The safety of the team is dependent upon accurate, up-to-date information regarding conditions in the mine. The team should ask questions concerning items about which they are unsure, and they need to express to Command Center personnel **any** concerns they have with their assignments. Be sure you have answers to the following questions:

- Is the evacuation complete?
- Are any miners missing, if so, how many, and what are their possible locations?
- What is known about the cause of the disaster?
- Is your team the first one to explore?
- Have State and Federal officials been notified?
- Are guards stationed at all mine entrances?
- Is the ventilation system operating? Is it an intake or exhaust system?
- Are attendants posted at the surface ventilation controls?
- Have air samples been taken? If so, what are the results?
- Will there be a backup team ready at the Fresh Air Base, and reserve teams on the surface?
- What are the team's objectives and what is their time limit?
- What conditions are known to exist underground (roof conditions, water, gas, etc.)?
- Is the mine's communication system operating?

- Is it being monitored?
- What other types of communications equipment will team members be required to use during rescue/recovery operations?
- Have team members been trained on the set-up and operation of real-time communications/tracking systems to be used during mine rescue and recovery work?
- Is power to the affected area on or off?
- Is there battery-powered or diesel equipment or a charging station in the affected area?
- What type of equipment is in the area? Where is it located?
- Where are compressed air and/or water lines located?
- Are they in operation? Are valves known to be open or closed?
- What type of firefighting equipment is located underground? Where is it?
- What tools and supplies are available underground? Where are they?
- In the area to be explored are there storage areas for oil or oxygen, acetylene tanks, or explosives?

  NOTE: The team should be aware that battery-powered or diesel equipment may still be running **even though power to the area has been cut off**

Preparing for Exploration

Team Captain's Responsibilities (pages 4-17 and 18)

Before your team proceeds to the Fresh Air Base, it is the captain's responsibility to make sure the team, its equipment, and its apparatus are ready to go. The captain should:

- Check each team member's physical condition, to make sure he or she is physically fit to wear the apparatus and to perform rescue work.
- Team members must be clean-shaven before entering the mine with an apparatus. **NOTE:** Failure of a member to be clean-shaven will result in that member not being allowed underground or serve as a surface backup during the event.
- Ensure that all apparatus have been tested, checked (including confirmation that the CO2 Scrubber is properly filled according to OEM recommendations), and are operating properly.
- Make sure the team has all necessary tools and equipment (including the captain's own supplies, such as notebook, pencil, chalk, etc.):

  - Check battery levels for radios, gas detectors, communications systems.
  - Determine which team member(s) will check radio signal strength and monitor the communication system's connection to Fresh Air Base and the Command Center.
  - Make sure the team members understand the briefing instructions and what their individual jobs will be.

  Before the team travels inby the Fresh Air Base, it's the captain's responsibility to make sure the team is prepared. The captain should:

  - Make sure the gas-testing equipment, the communication equipment, signaling equipment, and stokes basket or stretcher have been checked by the designated people.
  - If not the first team to explore, get up-to-date information from the last team (or from the Fresh Air Base Coordinator) about how far the last team advanced and what they found.
  - Make sure your team's map person gets an updated map from the last team's map person or from the Fresh Air Base Coordinator.
  - Check battery levels for radios, detectors, and communications systems.
  - Synchronize watches with the Fresh Air Base Coordinator.
  - Discuss with the Fresh Air Base Coordinator the type of communication system that will be used.

Donning the Apparatus and Getting Under Oxygen (pages 4-18)

Once all preparations and last-minute checks have been made, each team member is ready to put on their apparatus and get under oxygen.

Once all preparations and last-minute checks have been made, including a check to assure all team members have CO2 scrubbing absorbent in the breathing apparatus, each team member is ready to put on their apparatus and get under oxygen.

Just before the team begins to travel inby the Fresh Air Base, the team captain should be sure to write down the time of departure. The captain may also have the map person to jot down the time on the map for later reference.

Review questions:

1. What equipment is a mine rescue team required to have?

2. What type of information is normally covered in a team briefing and/or what questions should team members ask?

Answers

1. **Answer:**
   In addition to the normal underground mining gear (i.e., hardhat, cap lamp, safety shoes, metal ID, and perhaps a watch), the team members wear breathing apparatus, and the team must have two detecting devices (or multi-gas detector) for each gas they may encounter, and a communication system.

2. **Answer:**

- Evacuation report—missing miners and possible locations?
- What may have caused the disaster?
- Are they the first team to go underground?
- Have State and Federal authorities been notified?
- Is property guarded?
- What is state of ventilation system (fans) and gas conditions at returns?
- Is backup team available?
- What are team's objectives and time limit?
- What are known conditions?
- What is status of mine's communication system?
- Is power in mine on or off?
- What equipment is in the affected area? Is there diesel, battery-powered, equipment, or a charging station?
- What is the location and/or condition of air and water lines?
- What type of firefighting equipment is underground and where is it located?
- Where are tools and supplies located underground?
- Are there storage areas for oil, oxygen, acetylene tanks, or explosives in the area to be explored?
- Are there any other questions you can ask that could relate directly to the mine(s) your team(s) cover?

Exploration Methods and Procedures (pages4-21)

Every mine emergency is different, so each one presents its own problems. Although it's difficult to tell exactly what you'll be doing during any exploration, there are some accepted methods and procedures for carrying out basic exploration work.

These methods and procedures have developed over the years, as mine rescue teams have gained knowledge and experience from the many challenges that come with mine rescue and recovery work.

There are two primary methods of mine emergency exploration for which your team will need to practice and prepare:

1. "Rapid Exploration and"
2. "Advance, Tie Across and Behind"

Rapid Exploration (pages4-21)

NOTE: Rapid Exploration requires the use of radios and can be used **only** in areas **CLEAR OF SMOKE.**

This exploration method allows the mine rescue team to split up and explore multiple (adjacent) entries simultaneously, while maintaining in constant radio contact with their other team members, the Fresh Air Base, and the Command Center**.**

Using this method, it is common practice for the team members to travel one crosscut, then communicate information (via hand-held radio) to the Fresh Air Base **and** the Command Center simultaneously, if the system permits.

When permanent stoppings, equipment, or materials are found in crosscuts and causes a visual obstruction between two adjacent entries, **at least two** team members should travel together in these entries. These two team members will also need to maintain radio contact with the rest of the team.

When using this method to explore, **ALWAYS** maintain radio communication between the team members. If radio communication is interrupted for any reason, exploration **stops** until communication is reestablished.

NOTE: When a team encounters smoke, they MUST return to the communication/lifeline system (lifeline).

Advance, Tie Across and Behind (pages 4-23)

This more commonly-used method of exploration has been a standard procedure for many years whenever mine rescue teams encounter smoke. Using this method, the team travels closely together on a sound-powered communication/lifeline system (cable and cable reel), referred to as the “lifeline.”

Advancing and Tying In (pages 4-23)

Using this method, you “tie in” as you advance. “Tying In” is the process by which you systematically explore all crosscuts and adjacent entries as you advance so that you are never inby an unexplored area.

As you advance within the affected area, it’s recommended that you use the least obstructed travelway and stay on intake air whenever possible.

Until you’ve explored each entry and crosscut, you have no way of knowing what the conditions are in these areas. For example, there may be a fire located in an adjacent entry which could spread and cut off your escape.

By tying in, you are ensuring that there is never any unexplored area between you and the Fresh Air Base. Even though you know (or think you know) where survivors are located, or where a fire or explosion has originated, it’s absolutely essential for you to tie in as you advance.

As your team advances underground, the captain always takes the lead, followed by the other team members. It’s standard practice for the team captain to enter unexplored areas ahead of the rest of the team to check roof and rib conditions.

In most cases, the co-captain will be the No. 5 person. In this position, the co-captain can easily keep an eye on the other team members to make sure they’re proceeding without difficulty. The co-captain can then quickly halt the team if anyone appears to be having trouble.

NOTE: The Command Center must **ALWAYS** consider, first and foremost, the safety of mine rescue teams and all other personnel involved in the operation. In mine rescue and recovery work, conditions could change very quickly. A hasty or misguided decision could mean **disaster and the loss of life**. During exploration, your team’s safety **MUST ALWAYS** be the first priority.

Standard Exploration Procedures and Practices

Team Checks

Regardless of the method the team uses to explore, one standard procedure you'll use during exploration is the "team check." There are three main reasons for the team check:

1. To make sure each team member is fit and ready to continue.
2. To make sure each team member's apparatus is functioning properly.
3. To give the team a chance to rest.

Usually, the captain conducts the team checks by simply halting the team briefly, asking each team member how he or she feels, and checking each team member's apparatus.

It's recommended that these team checks be conducted every 15 to 20 minutes. However, under certain conditions, the team may not be able (or may not find it feasible) to stop this often. It is also recommended that you make your first stop for a team check just inby the Fresh Air Base.

This first team-stop inby the Fresh Air Base also allows you to check that all components of the Communication and Tracking Systems are functioning properly.

If the team has donned their apparatus, team captains note each team's member's gauge reading at each rest stop, and reports the lowest reading to the Fresh Air Base and the Command Center. The lowest reading may then be used as a reference point to determine when the team should return to the Fresh Air Base.

Rate of Travel (pages4-25)

The speed or rate at which you will travel underground is usually determined by the team captain. Your pace may change continually as you explore, reflecting changes in surrounding conditions that occur as the team advances. Your rate of travel will depend on a number of factors. Poor visibility, for example, will slow you down, as will an obstructed or inclined travelway. You also won't be able to move as quickly if the team is carrying something, such as heavy equipment or an injured person.

Traveling in Smoke (pages4-25)

Traveling in smoke always presents difficulties for a mine rescue team. The biggest problem is the fact that you can't see where you're going as easily.

The smoke may be light enough that it limits your visibility only slightly, like a light fog or mist. But smoke can also be so dense that it will completely obscure everything around you.

Smoke so dense that it conceals the roof, ribs, and other reference points you normally use to guide you from place to place can cause you to experience what's known as "spatial disorientation."

Traveling Through Ventilation Controls (pages 4-26)

As your team advances, you may find it necessary to determine conditions on the other side of doors, mandoors, or stoppings, or you may have to travel through them. This is normally done **only** on orders from the Command Center.

Before going through a ventilation control, the team should first try to determine what conditions exist on the other side of the door or stopping by feeling it for heat and looking for smoke.

Before you open and travel through any stopping inby which conditions are not **definitely** known, you should first erect a temporary stopping outby. Doing so provides an air lock which ensures that when the stopping is opened, you will not mix the atmospheres and alter the current status of the ventilation.

Traveling through Water (pages4-26)

When your team encounters water during exploration, the Command Center will usually decide how to deal with the problem. The captain can probe the water depth with a walking stick, if necessary.

If the water isn't too deep and you can get through it without endangering the team, you will probably just travel through it.

Marking Route of Travel (pages4-27)

As the team advances, your lifeline trails along behind you, marking your route through the mine. Your captain or co-captain may also mark the team's route with chalk or spray paint at key points.

Here's how it's done: As you proceed, the captain or co-captain marks an arrow along the rib at each intersection where your direction of travel changes. The head of this arrow points toward the Fresh Air Base.

As the team returns to the Fresh Air Base, the captain or co-captain draws an "X" through each arrow to show that the team has retreated.

There are two reasons for marking your route of travel: (1) It helps the team find its way back to the Fresh Air Base, and (2) if a backup team is sent in to look for you, it shows them which way you traveled.

Marking Areas Explored (pages4-27)

As you advance, the captain also marks areas explored by initialing and marking the date on faces, entries, crosscuts, impassable falls, barricades, stoppings, and at other points where conditions don't permit the team to advance.

All of these places should also be noted on your map. Marking areas as you explore provides a visual record of what your team did and found as they advanced.

Inspecting and Testing Roof/Back and Rib/Sides (pages4-28)

As you explore, the captain takes the lead, inspecting and testing the roof/back and rib/sides before the team advances into the area.

Visual Inspections (pages4-28)

Your team captain should constantly conduct visual inspections of the roof and ribs as you advance unless, of course, heavy smoke makes this impossible. Roof inspections should be made from rib to rib. At each face, the captain should inspect the face and ribs.

Roof/Back and Rib Tests (pages 4-28)

Roof/Back tests should be conducted when visual inspection indicates that the roof/back or rib may be unsafe or in areas where roof conditions are known to be bad, and at faces.

It may also be necessary to test in areas where smoke is so thick it doesn't permit visual inspection. Poor or unsafe conditions, such as falls of roof/back or ribs, also indicate the need to test.

In addition, the captain should make roof/back and rib tests when the team builds an air lock or stopping or erects a line curtain. Another time to test is before you extinguish a fire.

Testing for Gases (pages 4-29)

Monitoring the mine atmosphere for the presence of oxygen, methane, and carbon monoxide is another important element of team exploration.

Depending on the type of mine and the specific situation, you may have to test for other gases as well.

These tests should be made at each intersection you encounter, at the furthest point of travel into each crosscut, at each dead end, and at the face of each section you explore.

It's also necessary to conduct gas tests on the other side of doors or stoppings, or curtains prior to traveling through any of them, especially where conditions on the other side are not definitely known.

If you encounter smoke or potentially dangerous gas conditions, gas levels shall be frequently monitored as you advance.

Progress Reporting (pages4-29 and 30)

During exploration, information the team relays to the Fresh Air Base and Command Center is known as the "progress report." Progress reports keep Command Center and other personnel directing the operation up-to-date on what your team is doing, where you are, and what you've found.

Once the progress report is communicated to the Fresh Air Base and Command Center, This information may then be used as a basis for making further modifications to the rescue and recovery plan.

The progress report also helps keep track of your team so that if it becomes necessary to send a backup team in to find you, they'll know where to look. Include information such as the team's condition, the condition of each member's apparatus, the team's location, and their progress.

As you advance, report the condition of ventilation controls and auxiliary fans. If they are damaged, be specific as to what type of damage they've received and how extensive it is. Also, if doors or stoppings**/bulkheads** are blown out, be sure to report in what direction they have blown.

Report any other damage caused by fire, explosion, or other condition. If you encounter "coking" or coke streamers, report both their location and size. "Coking," as mentioned here, refers to a grey-black residue that is sometimes left behind when coal is burned in the absence of oxygen. Its presence indicates that the area has been subjected to extremely high temperatures.
A progress report should also include information about roof and rib conditions, gas conditions, or an encounter with smoke or water.

You'll need to report the location of tools, materials, and other equipment encountered as you progress. When you encounter any tools or equipment, you will need to report whether the power switch is on or off.

Report the condition of compressed air and water line valves (open or closed) and be sure to include the location of explosive magazines, storage areas for oil, oxygen, and acetylene cylinders.

Also, report the location and examine the contents of any dinner buckets you find, because these may offer important clues as to the whereabouts of survivors.

NOTE: Miners are taught that, if they become trapped in the mine, they should leave notes in their dinner buckets telling where they are. For this reason, the mine rescue team should search all dinner buckets they find during exploration.

If you locate survivors or bodies, report this immediately to the Fresh Air Base and the Command Center. In your progress report, be sure to include any other significant conditions, materials, or evidence the team encounters during exploration. When you report anything to the Fresh Air Base, be sure you clearly and correctly identify the location.

Mapping (pages30 and 31)

As the team advances, the map person records what the team encounters by marking the information on a mine map. At the same time, the Fresh Air Base Coordinator marks a mine map with your findings based on what you include in your progress report. The same information is relayed to the Command Center, where a third map is marked with the team's findings.

This "simultaneous mapping" provides the Fresh Air Base and the Command Center with a visual record of what is happening underground. Accurate, up-to-date mine maps are critical to a mine rescue operation.

Officials in charge on the surface use these maps as a basis for making decisions and providing the team with instructions.

Here is the type of information you should mark on the mine map as the team explores:

1. Bad roof
2. Water
3. Smoke
4. Gas readings
5. Valves on water and compressed air lines (open or closed)
6. Firefighting equipment
7. Other equipment and tools
8. Types and position of power equipment (on or off)
9. Storage areas for materials
10. Evidence of fire and/or explosion
11. Dinner buckets
12. Condition of ventilation controls
13. Survivors
14. Bodies
15. Any other significant conditions, materials, etc.

Before you actually explore a mine, take time to establish a uniform set of map symbols and learn to use them. Familiarize yourself with the scale of the map you will be using. Before you go underground, make sure you have an adequate mapboard to place under the map.

Communication

During mine emergency rescue and recovery operations, effective communication is vital. It is extremely important that teams develop effective skills and methods of communicating among themselves, other teams, the Fresh Air Base, and the Command Center.

The backup team members should be included in **all** communications and briefing(s) for the active team(s); this keeps the backup team informed and fully aware of everything that is found and reported by the active team members.

Communication with the Fresh Air Base and Command Center (pages4-32)

As the team advances, it's essential to stay in close contact with the Fresh Air Base and the Command Center to report your team's progress and to receive further instructions.

At a minimum, teams generally use either sound or battery-powered communication equipment. One team member, usually the No. 5 person, wears the equipment, and is responsible for sending information to the Fresh Air Base and relaying instructions from the Fresh Air Base to the team.

Using the Lifeline Cable to Communicate (Signaling) (pages4-33)

In the event that your team's communication system fails, you can still communicate some with the Fresh Air Base by tugging or pulling on the communication/lifeline system cable. The system's cable must meet requirements set forth in **30 CFR Section 49.16 and 30 CFR Part 49.6**

At the Fresh Air Base, there should be an attendant who is in charge of unwinding your communication line as you travel. This person, usually known as a lifeline attendant, also monitors the line to make sure it's not getting snagged or caught.

NOTE: Teams are usually instructed to return to the Fresh Air Base **immediately if their communication system fails.** On the return trip, or if the team is unable to return immediately, they may still need to make use of lifeline signals.

If the team loses voice contact with the Fresh Air Base, it will be the attendant's job to receive and send signals to and from the team by means of the lifeline

One pull or tug:	Stop
Two:	Advance
Three:	Retreat
Four:	Emergency or Distress

Review questions: (pages4-34)

1. What team signals do you use during exploration?

2. List four factors that affect a team's rate of travel.

3. How does a team mark its route of travel on advance and retreat?

4. List some findings that should be marked on a mine map.

Review Answers: (pages4-35)

1. **Answer:** One—stop, two—advance, three—retreat, four—emergency
2. **Answer:** Falls and obstructions, water, smoke, fatigue, amount/weight of equipment carried, degree of slope
3. **Answer:** As you advance, the captain or co-captain draws or paints an arrow along the rib at all intersections where your direction of travel changes. (The head of the arrow points toward the Fresh Air Base.) On retreat, the captain or co-captain puts an "X" through each arrow.
4. **Answer:** Dinner buckets, bad roof, water, smoke, storage areas, gas readings, valves on air and water lines, firefighting equipment, equipment and tools, power machinery, condition of ventilation controls, survivors, bodies, other significant conditions and materials.

Returning to the Fresh Air Base (pages4-36)

It's very important for the team to pace its work so that it can return to the Fresh Air Base on time. Also, you must be sure to allow an ample supply of oxygen for the return trip to the Fresh Air Base plus an extra "margin of safety" in case anything unforeseen occurs.

Be sure to take into account the fact that you'll be more tired when returning to the Fresh Air Base, so the return trip will usually take longer than the advance. You'll probably need to take longer and more frequent rest stops on the return trip. If you're carrying a survivor, this will tend to make the trip even slower.

The time a team spends underground is usually limited to two hours or less. The exact amount of time is determined both by the underground conditions and the type of apparatus being used. The distance you can advance also depends on underground conditions. However, it is often recommended that you limit your advance to 1,000 feet.

Under certain circumstances, even when you are working well within the time limits originally set, your captain may order the team to return immediately to the Fresh Air Base, if, for example, a team member's apparatus malfunctions.

You may also be ordered to return immediately if you encounter gas conditions that present an imminent explosion hazard, a fire that you can't extinguish, or excessive water. Your captain may also order you to return to the Fresh Air Base if you encounter bad roof that's impossible to detour and too hazardous to secure.

There are certain other conditions that won't necessarily require retreat but will hinder your team's progress. For example, encountering water in passageways will slow you. Dense smoke is also a hindrance. Climbing a steep incline or ladder or crawling for a distance will slow you also.

Debriefing (pages4-37)

When you return to the Fresh Air Base, your team captain will confer with the Fresh Air Base Coordinator and the captain of the incoming team to exchange information about what the team saw and found.

The information that your team captain should transfer to the backup team includes such things as the traveling conditions your team encountered, how far you traveled, what gases you encountered, and roof and rib conditions.

When you arrive on the surface, your team will attend a debriefing session. Like the briefing session, the debriefing session is set aside for information gathering. This time, however, your team **provides** the information.

You inform the debriefing official or committee of what you did, saw, and found during exploration.

The debriefing session is a very important aspect of your team's exploration. Often, significant details that appeared to be unimportant while you were underground or were simply overlooked in your progress reports come out during this debriefing session and turn out to be important factors to the operation.

Review questions: (pages4-38)

1. Under what conditions/situations might your team captain order your team to return to fresh air immediately?
2. What information is usually transferred from the outgoing team to the backup team at the Fresh Air Base?
3. Why is the debriefing session important?

ANSWER SHEET (pages4-39)

1. **Answer:** Malfunctioning apparatus, hazardous roof that cannot be secured, presence of gases that produce an imminent explosion hazard, fire that cannot be extinguished, excessive water.

2. **Answer:** Markings on mine maps, damages, distance traveled, gas conditions, roof and rib conditions, stoppings constructed, equipment or supplies left in the area, and any other important information.

3. **Answer:** It provides the surface officials with more detailed information, ensures all important findings are mentioned, provides time to check team's map against master map, and instructs team as to what they should or should not say to media representatives and others.

General Review Exploration

Choose the correct answer to each of the following questions.

1. Prior to rescue team exploration, the first step to take after a disaster is to:
   a. Examine all mine openings.
   b. Establish a Fresh Air Base.
   c. Proceed as far as possible into the mine without apparatus.
   d. None of the above.

2. The purpose of rescue team exploration is to:
   a. Determine conditions underground.
   b. Locate missing miners.
   c. Locate clues or indications of missing miners' locations.
   d. All of the above.

3. If at all possible, entry into the mine should be made on:
   a. A return airway.
   b. An intake airway.
   c. The main haulageway.
   d. The belt entry.

4. Barefaced exploration should be attempted only when:
   a. No breathing apparatus is available.
   b. Miners are trapped in the mine.
   c. A backup mine rescue team with apparatus is immediately available.
   d. A Fresh Air Base is established.

5. In advancing a Fresh Air Base, after you put up the new air lock, the team should:
   a. Come out of the mine.
   b. Perform gas tests in all dead ends and high places between the old and new Fresh Air Base to ensure that all gases have been flushed from the area.
   c. Proceed inby the new Fresh Air Base to explore and let other workers check for any gases outby the new Fresh Air Base.
   d. Shut off and remove your apparatus since you are in fresh air and will no longer need it.

6. When exploring in heavy smoke, it is recommended that the team:
   a. Use a linkline to hook all team members together.
   b. Follow along the rail to aid their progress.
   c. Keep in contact with the side to aid their progress.
   d. All of the above.

7. Prior to a mine rescue team passing through a door or stopping/bulkhead behind which conditions are not definitely known, they should:
   a. Ask the Fresh Air Base to send in the backup team.
   b. Erect an air lock to prevent the mixing of atmospheres.
   c. Open the door or stopping/bulkhead, and wait at least 10 minutes so that any harmful gases are diffused.
   d. Never enter such areas.

8. Gas readings should be taken:
   a. At all intersections.
   b. At any dead end or face area.
   c. At the furthest point of travel in any entry or heading.
   d. All of the above.

9. The captain should mark the date and his or her initials:
   a. Each time the team stops for a rest.
   b. Every 50 feet.
   c. Every 200 feet.
   d. On all explored areas (faces, entries, crosscuts, impassable falls, barricades, stoppings, etc.)

10. Dinner buckets encountered during exploration are important because:
    a. They can contain food and/or water for the rescue team.
    b. They may contain notes that would indicate the whereabouts of survivors.
    c. They indicate where miners ate their dinner.
    d. None of the above.

11. If a team member experiences problems with his or her apparatus inby the Fresh Air Base, the team member should:

    a. Be immediately sent back to the Fresh Air Base.
    b. Be sent back to the Fresh Air Base with another team member.
    c. Switch to the apparatus that was carried on the stretcher or stokes basket.
    d. With the entire team, return immediately to the Fresh Air Base.

12. Debriefings are held to:

    a. Inform news reporters of developments.
    b. Inform family members of developments.
    c. Review the rescue team's findings after they have returned from underground.
    d. All of the above.

General review answers: (pages4-63)

1. a
2. d
3. b
4. c
5. b
6. d
7. b
8. d
9. d
10. b
11. d
12. c

Module 5

Fires, Firefighting, and Explosions

Fighting a mine fire may be one of the most frequent duties that you perform as a rescue team. Fires in underground mines are particularly hazardous not onlybecause they produce toxic gases and heat, but also because they produce smoke, pose an explosion hazard, and create oxygen-deficient atmospheres.

Fires (pages5-6)

Most fires are the result of a chemical reaction between a fuel and the oxygen in the air. Material such as wood, coal, methane, gas, oil, grease, and many plastics will burn when ignited in the presence of air.

Fighting a fire with water removes the heat. Smothering the fire with noncombustible material such as rock dust, removes the oxygen. Sealing off the fire area is another way of removing oxygen. Loading out hot materials from the fire area removes the fuel.

Another way to extinguish a fire is by stopping the chemical reaction between the fuel and the oxygen. Dry chemical extinguishers operate on this principle. They function to chemically inhibit the oxidation of the fuel.

Exactly how a fire will be fought is usually determined by the materials that are burning and the conditions in the fire area. Consequently, a large part of your job will be to explore the mine and assess the condition of the fire so the Command Center can decide how to go about fighting the fire.

Classification of Fires

For firefighting purposes you should know the type of fire you are fighting.
The National Fire Protection Association classifies fires into the following five classes:

Class A fires involve ordinary combustible materials such as wood, coal, plastics, paper, and cloth. They are best extinguished by cooling with water or by blanketing with certain dry chemicals.

Think of **Class A** fires as those that leave **A**shes.

Class B fires involve flammable or combustible liquids such as gasoline, diesel fuel, kerosene, and grease. Typical Class B fires can occur where flammable liquids are spilled or leak out of mechanical equipment. They are best extinguished by excluding air or by special chemicals that affect the burning re-actions.

Think of **Class B** fires as those that involve contents that will **B**oil.

Class C fires are electrical fires. Typical electrical fires include electric motors, trolley wire, battery equipment, battery-charging stations, transformers, and circuit breakers. They are best extinguished by non-conducting agents such as car-bon dioxide and certain dry chemicals. If the power has been cut off to the burning equipment, the fire can be treated as a Class A or B fire.

Think of **Class C** fires as those that involve **C**urrent.

Class D fires involve combustible metals such as magnesium, titanium, zirconium, sodium, and potassium. Special techniques and extinguishers have been developed to put out these fires. Normal extinguishers generally **should not be used** on a Class D fire since they could make the fire worse. **NOTE:** Class D fires are not frequently found in coal mines.

Class K fires involve combustible cooking media such as oils and grease commonly found in commercial kitchens. These are best extinguished by a special wet chemical extinguishing agent.

Firefighting Equipment (pages5-7)

Mines usually have a number of different types of equipment available for firefighting:

- Dry chemical extinguishers
- Rock dust
- Water
- High expansion foam

Dry Chemical Extinguishers (pages5-7)

Dry chemical extinguishers put out fires by stopping the chemical reaction between the fuel and oxygen (which produces the flame). The dry chemical agents work to inactivate the intermediate products of the flame reaction, resulting in a decreased combustion rate (rate of heat evolution) and thus extinguishing the fire.

There are basically two types of dry chemical extinguishers: hand-held extinguishers and larger wheeled extinguishers. Hand-held extinguishers range in size from about 2 to 55 pounds.

Wheeled extinguishers can weigh from 75 to 350 pounds. These extinguishers consist of a large nitrogen cylinder, a dry chemical chamber, and a hose with an operating valve at the nozzle.

It is generally recommended that mine rescue teams use multi-purpose dry chemical extinguishers, which contain monoammonium phosphate, because they are effective on

Class A, B, or C fires. Consequently, having monoammonium phosphate extinguishers eliminates the team's need for a separate extinguisher for each class of fire that may be encountered underground.

Hand-Held Extinguishers (pages5-8)

Before using any type of hand-held extinguisher you should be sure to check the label on the side of the extinguisher. Be sure to use the right extinguisher for the fire you will be fighting. Using the wrong type of extinguisher could result in spreading a fire rather than extinguishing one. **NOTE:** Be sure to follow manufacturers recommended procedures when energizing a cartridge type fire extinguisher.

The extinguisher's label should provide information regarding the proper distance from the fire where the extinguisher will be most effective at fighting the fire. Most small dry chemical extinguishers are effective 5 to 8 feet from the fire. Larger units have ranges of 5 to 20 feet from the fire.

By using an extinguisher that is effective for only 5 to 8 feet while standing 10 to 15 feet away from the fire will not put out the fire. It may waste both valuable time and the contents of the extinguisher.

How to Use Wheeled Extinguishers (pages5-9)

To operate the wheeled extinguisher, you must first open the valve on the nitrogen cylinder. This forces the dry chemical through the hose to the nozzle. You then control the discharge from the hose by adjusting the nozzle operating valve.

The method for approaching the fire and putting it out is the same as the method used with the hand-held extinguisher. You should use a sweeping motion and direct the dry chemical stream to about 6 inches ahead of the flame edge.

Rock Dust (pages5-9 and 10)

Rock dust is a fire extinguisher material that is readily available in most areas of the mine. It is used to put out a fire by smothering it or by eliminating oxygen from the fire triangle. Rock dust can be used on Class A, B, or C fires.

Rock dust is most successfully used to fight a fire by applying it by hand to the fire or by shoveling it onto the fire.

Rock dusting machines are usually available in the mines; however, they should not be used when a fire is involved, because they generate air to disperse the rock dust. This air could then move over the fire area, thereby fanning the fire and increasing its intensity.

Water (pages5-10)

Water can also be used to put out fires. Water acts to cool the fire, removing heat from the fire triangle. Water is an effective extinguishing agent on Class A fires. In most mines, the water needed to fight underground fires can be provided by two sources: waterlines and fire cars.

Waterlines (pages5-10)

In working sections of the mine that produce over 300 tons per shift and that do not have portable firefighting equipment, waterlines are required.

Under Federal regulations, waterlines are required to extend to each section loading point and to be equipped with enough fire hose to reach each working face.

If you are going to fight a Class A fire, and a waterline is available, you can simply hook up the fire hose to the waterline.

Fire Cars (pages5-10)

Fire cars (or water cars or chemical cars) are available in some mines. These may be mounted on tires or flanged wheels and can be pushed or pulled to the fire area. The components of a fire car can vary from a water tank, pump, and hose to a more elaborate version that contains a wider selection of firefighting equipment such as water, large chemical extinguishers, hand tools, brattice cloth, and rock dust.

Fire Cars with Low Expansion Foam (pages5-10)

Some fire cars contain a foam agent that can be hooked up to the water hose along with a special foam nozzle to produce low expansion foam. The foam works to extinguish the fire by simultaneously smothering and cooling it.

Low expansion foam is very wet and heavy. It does not move down an entry as high expansion foam would. Low expansion foam can only be used when you’re close enough to a fire to force the foam directly onto the fire.

Techniques of Applying Water to Fires (pages5-11)

The best way to fight a fire with water is to aim the water stream directly at the burning material. You should use a side-to-side sweeping motion to wet the entire burning surface. Where possible, you should break apart and soak any deep-seated fires and stand by to extinguish any remaining embers.

Several different kinds of water nozzles are available for the hose. Some produce a solid stream of water, some produce a fog spray, and others are adjustable, much like a garden hose nozzle, to produce a solid stream or a spray. Solid stream nozzles are best to use when it is necessary to project the water a long distance to the fire. For shorter distances, a fog spray is better to use on a fire because it usually will extinguish a fire more quickly than a solid stream.

High Expansion Foam (pages5-11)

High expansion foam is used mainly to contain and control fire by removing two legs of the fire triangle—oxygen and heat. The tremendous volume of the foam acts to smother and cool the fire at the same time. Foam is useful only in fighting Class A or B fires. Because the foam is light and resilient it can travel long distances to a fire without breaking down.

Consequently, it is very effective and used most commonly in controlling stubborn localized fires that cannot be approached at a close range because there is too much heat or smoke or the fire is spreading too rapidly. When using foam, firefighters can be quite a distance from the actual fire. Five hundred feet is a common distance, although there have been successes in the past where foam was used from more than 1,500 feet away from the fire.

High expansion foam is normally used just to control a fire. Once conditions permit, teams are usually sent in to fight the fire more directly. It is generally recommended that teams do not travel through foam-filled areas. Before entering such an area teams should clear the foam as much as possible. One way of doing this is to use a solid stream of water to knock the foam down and clear the area.

Foam Generators (pages5-12)

The high expansion foam is made by mixing water, air, and a foam concentrate or detergent in a foam generator. Foam generators are portable and come in different sizes with different foam-producing capacities. The smaller models may be hand-carried by two people or wheeled into position. Larger models may be mounted on rubber tires or may be transported on a track-mounted mine car.

There are water-driven models of foam generators and electric- or diesel-powered models. In the water-driven models, the foam is produced as the water/detergent mixture is pushed by water pressure through nylon netting or a screen. With the other models, a blower fan is used to produce the bubbles and push them out.

How to Use a Foam Generator (pages 5-12 and 13)

There are a couple different methods of using foam to fight a fire. With one method, the foam generator is positioned outby the fire, and plastic tubing is attached to the foam outlet.

The plastic tubing is designed to unroll as the foam passes through it, leading the foam directly to the fire area. Another method is to first create a confined area so that the foam can be pumped onto the fire to completely fill or plug the fire area. This is done by building a stopping with an opening in it for the foam generator to fit into.

The foam generator is then set up at the opening and braced or fastened down if possible. Once it is set up, the generator can be started and foam will begin filling the area. Sometimes plastic tubing is attached to the foam generator to direct the foam to the fire area.

In some situations, a team can use the generator in stages, moving it closer to the fire as the fire is brought under control. Before you travel through a foam-filled area, you should knock down the foam with water to clear a path for you to safely walk along.

Review questions (pages 5-13)

1. What are the characteristics of the five classes of fires and what extinguishing agents should be used when fighting each of them?

2. What are the pieces of equipment normally available to fight underground fires at the team's mine?

Answers: pages (5-13)

Question 1:

1. **Class A** fires are those that involve ordinary combustible materials such as wood, plastics, paper, and cloth. They are best extinguished by cooling with water or by blanketing with certain dry chemicals.
2. **Class B** fires are those that involve flammable or combustible liquids such as gasoline, diesel fuel, kerosene, and grease. They are best extinguished by excluding air or by special chemicals that affect the burning reactions.
3. **Class C** fires are electrical fires. They are extinguished by non-conducting extinguishing agents such as carbon dioxide and certain dry chemicals.
4. **Class D** fires are those that involve combustible metals such as magnesium, titanium, zirconium, sodium, and potassium. They are extinguished by special extinguishing agents designed for such applications.
5. **Class K** fires involve combustible cooking media such as oils and grease commonly found in commercial kitchens. These are best extinguished by a special wet chemical extinguishing agent.

Question 2:

a. Hand-held extinguishers – type, location, how to operate the particular brand the team uses.

b. Wheeled extinguishers – type, location, how to operate

c. Water cars – location, type, how to operate

d. Fire cars – location, what equipment is on car, how to operate

e. Waterlines – hose location, how to operate

f. Foam machine – location, how to operate

g. Any other equipment the team uses

Before Going Underground (pages 5-14)

When a team goes into a mine to explore or fight a fire, it should be concerned with two main things—spreading of the fire and the possibility of an explosion. Before going underground, the team should make sure that the **main fan is running**, that **a guard is monitoring the operation of the fan**, and that **tests are being made at the main returns** for any gases that may be present in the mine.

It is important to monitor the levels of oxygen, carbon monoxide, and any explosive gases. Ventilation should always be continued through the mine during a fire in order to carry explosive gases and distillates away from the fire area and to direct the smoke, heat, and flames away from the team.

Before going underground, the team should also know about any possible **ignition sources** that may exist in the affected area, such as battery-operated or diesel equipment. Also, if there are any underground **storage areas for explosives, oil and grease, or oxygen or acetylene cylinders** in or near the affected area, you should know about them.

If there is **electrical power** to the affected area of the mine, it is usually recommended that it be cut off. Arcing from damaged cables is a possible ignition source for further fires or explosions. However, if the power is cut, the mine will lose power to any auxiliary fans or booster fans underground.

You will also lose power to any other electrically powered equipment, such as a pump in the area. Losing a pump could result in major flooding. These are all factors that the Command Center will have to take into consideration when deciding about cutting the power.

Most of this information should be available to the team at the time of your briefing. However, some of the very specific information about what is in or near the affected area and whether equipment has been left energized can only be determined by the exploration teams as they advance.

Locating Fires and Assessing Conditions (pages5-15 and 16)

Two of the main objectives of exploration work during a mine fire are locating the fire and assessing the conditions in and near the fire area. Once the conditions are known and reported to the Command Center, the officials there can then decide how the fire should be fought.

The Command Center will want to have as much information as possible about the fire: where it is, what's burning, how large it is, and what the conditions are near the fire area.

Before you enter the mine, there might already be some information about where the fire is located. The first report of a fire will often have been from miners working near the fire area. They may have reported seeing smoke and/or flames before evacuating the mine.

These reports will help you to pinpoint the location of the fire and may help to determine the magnitude of the fire. Carbon monoxide and/or smoke coming from the main fan or main return are obvious indications that a fire exists.

Lab analysis of air samples from the main fan or return will give an accurate analysis of the gases that are present and help provide information on what is burning. The amount of carbon monoxide found in the sample gives some indication of the magnitude of the fire.

There is some information, however, that can only be obtained by rescue teams during exploration of the mine. The teams can roughly pinpoint an un-located fire and assess its magnitude by reporting where and how heavy the smoke is and by feeling stoppings and doors for heat.

If you encounter a small fire while exploring the mine, you should be able to extinguish it immediately by using hand-held fire extinguishers, rock dust, or water from a waterline if it is nearby. Dealing with larger fires, however, will require more equipment and careful planning.

During your exploration of the mine, you must gather as much information as possible about the conditions in or near the fire area. As the information is gathered, report it to the Command Center as soon as possible in order to keep the officials up-to-date with what you have observed.

You must take gas readings in the returns near the fire area to determine if the mine atmosphere is potentially explosive. Also, some damage to ventilation controls should be expected during a fire in the mine so you'll have to be especially aware of their condition. Check the roof and rib conditions carefully in the fire area because heat from a fire can weaken them.

From all this information, the Command Center will have a fairly good indication of where and how large the fire is. Officials will then be able to decide how to go about controlling or extinguishing the fire—whether to fight it directly or indirectly by sealing the mine.

Direct Firefighting (pages 5-16)

Fighting a fire "directly" means that an extinguishing agent is put directly onto the fire to put it out. This usually means that firefighters will have to get relatively close to the fire in order to use fire extinguishers, water, rock dust, or foam on the fire.

When fighting a fire directly, you should always approach the fire and fight it from the intake air side, if possible. This will ensure that the smoke and heat will be directed away from you.

If the fire begins to back up against the intake air in search of oxygen, you can put up a “transverse” brattice from rib to rib leaving an open space at the top. This will cause increased air flow at the roof and should slow down the progress of smoke and flame into the intake air current.

The brattice should cover about one-half to two-thirds of the area from the floor to the back. You don’t want to run the brattice too high or it will cut off airflow over the fire which could result in an explosion.

If heat, smoke, and ventilating air currents permit, water is the most desirable and efficient means of fighting a fire, provided it is not an electrical fire. Of course, to fight a fire with water there must be a sufficient supply of water, sufficient water pressure, and available lengths of hose to reach the fire. In situations where it is impossible to approach the fire for direct firefighting, foam or water can be pushed over the fire area to slow down the fire sufficiently, allowing the team to get closer to the fire to fight it more directly.

Hazards of Direct Firefighting (pages5-16)

During direct firefighting, there are certain hazards to the team in which you should be aware. These hazards include electric shock and electrocution, toxic and asphyxiating gases, oxygen deficiency, explosive gases, and heat, smoke, and steam.

Electric Shock and Electrocution (pages5-17)

Electric shock and electrocution are hazards to firefighters using water, foam, or other conductive agents to fight a fire. For this reason, it is usually recommended that the power to the fire area be cut off regardless of the type of fire. This is done not only to eliminate the electrical hazard, but also to cut the power to any electrical components that may be involved in the fire.

Toxic and Asphyxiating Gases (pages5-17)

The extremely toxic gas, carbon monoxide, is produced by all fires because of the in- complete combustion of carbon materials during the burning process.

Carbon dioxide is also produced by fires, though it is a product of **complete** combustion. Carbon dioxide is an asphyxiate. Breathing large amounts of carbon dioxide causes rapid breathing and insufficient intake of oxygen. Too much of it in the blood- stream can cause unconsciousness and even death.

Other gases such as hydrogen sulfide are even more toxic than carbon monoxide. Some toxic gases are produced by burning rubber, neoprene, or polyvinyl chloride (PVC). These materials are frequently found in electrical cables, conveyor belts, or tires on machinery. Even small fires that involve burning rubber, neoprene, or PVC can be extremely toxic.

Because all of these gases can harm you, it is extremely important that you wear your breathing apparatus at all times when dealing with underground fires.

Oxygen Deficiency (pages5-17)

Because fire consumes such large quantities of oxygen, there is a hazard of oxygen deficient air in the mine—another reason for you to wear your breathing apparatus when dealing with mine fires.

Explosive Gases (pages5-18)

The buildup of explosive gases, such as methane and hydrogen, are very real hazards for teams during direct firefighting. That is why it is so important to maintain a sufficient and consistent flow of air over the fire area.

Methane is the most common explosive gas found in coal mines. Its explosive range is 5 to 15 percent when there is at least 12.1 percent oxygen present.

Hydrogen is also highly explosive in mine atmospheres. Its explosive range is 4.0 to 74.2 percent when there is at least 5 percent oxygen present. Hydrogen is produced by the incomplete combustion of carbon materials during fires. Additionally, hydrogen can be liberated when water or steam comes in contact with hot carbon materials. This situation occurs when water, water mist, or foam is used to fight fires.

Small hydrogen explosions, known as hydrogen "pops," are fairly common in fire-fighting. The bigger hazard with hydrogen is the possibility of it accumulating to a large enough extent to cause a violent explosion. Adequate ventilation over the fire area will help prevent the buildup of these and other explosive gases.

If the fan slows down or stops, teams should immediately leave the fire area. If the fan continues to run slowly or remains stopped, teams and other underground personnel should leave the mine entirely before the fan is restarted.

The fan should never be stopped or reversed while teams are underground. This could force unburned distillates from the fire to travel back over the fire area, thereby increasing the magnitude of the fire.

If any explosive concentrations of gas are detected in the return air of the fire, all teams and any other underground personnel should leave the mine immediately.

Heat, Smoke, and Steam (pages5-19)

Heat, smoke, and steam are other hazards to the team and will determine how close you can get to a fire and how long you can work. Working in a hot, smoky, or steamy atmosphere can be extremely uncomfortable.

Smoke not only limits your visibility but it also causes disorientation. Even the simple act of walking is more difficult because you will not be able to judge your position in relation to your surroundings as you normally do when moving. This lack of orientation may cause you to lose your sense of balance more frequently. Working in a hot and/or steamy atmosphere will tend to make you more exhausted than normal and cause additional stress on your system, especially if you're working hard.

Another hazard of heat is that it tends to weaken the roof in the fire area, especially in mines where head coal is left when the coal is mined. To protect yourself as much as possible from weak roof, you should test the roof near a fire area frequently and bar down any loose material.

Keep in mind during firefighting that smoke and steam will be less dense near the floor of the mine and worse near the roof of the mine. Adequate ventilation over the fire area should help to carry the smoke, heat, and steam away from the team.

However, if the fire begins to back up against the flow of intake air in search of oxygen, you can put up a transverse brattice from rib to rib, leaving an open space near the roof. This should slow down the progress of the smoke and flame into the intake air current.

Review Questions

1. Why should the fan should be kept running during underground firefighting.
2. What is a method of controlling the backup of a fire against the ventilating current (intake air) while fighting it directly.
3. Why are burning conveyor belts, cable insulation, and tires are particularly hazardous to firefighters.
4. What other hazards that the rescue team should consider when fighting a mine fire directly.

Review Answers: (pages 5-20)

1. Answer:
    - To ensure that explosive gases and distillates are carried away from the fire area. This lessens the chance for an explosion to occur.
    - To direct smoke, heat, and flames away from the team.
2. Answer:
    - A transverse brattice can be installed from rib to rib in the entry, with open space near the roof.
    - This brattice forces the ventilating air current to the upper portion of the passageway and thus slows down the progress of smoke and flame into the intake air current.
3. Answer:
    - These materials emit extremely toxic gases as they are decomposed by the fire.
    - Many of these gases are much more dangerous than carbon monoxide. Breathing apparatus should be worn when fighting this type of fire.
4. Answer:
    - Electrocution
    - Toxic and asphyxiating gases
    - Oxygen deficiency
    - Explosive gases
    - Heat, smoke, and steam

Sealing Underground (pages5-21 and 22)

The purpose of sealing a mine fire is to contain the fire to a specific area and to exclude oxygen from the fire and eventually smother it. Sealing can also be done to isolate the fire so that normal mining operations can be resumed in other areas of the mine. Sealing mine fires underground is a complex issue to which no one set of procedures will apply. There are many factors that determine the methods used and the eventual success of the sealing operation.

There are two types of seals: temporary and permanent. Temporary seals are often put up before permanent seals are erected in order to seal off a fire area as quickly as possible. Usually permanent seals are then constructed outby the temporary seals to seal off the fire area more effectively.

The officials at the Command Center will decide what types of seals to erect based on all the information they have concerning the fire. Some of the factors that the Command Center considers when planning to seal a fire are:

1. The **volatility of the coal seam**. High volatile coal seams burn much faster than low or medium volatile coal. Sealing a fire that involves high volatile coal is often necessary because fighting the fire directly is very difficult.

2. The **amount of methane liberated by the coal seam**. The potential for explosion increases as the methane count increases.

3. The **location of the fire and the area involved**. This determines the number of seals necessary and where they should be placed.

4. The **presence of head coal and composition of roof strata**. In mines where head coal is left, a fire will spread more rapidly. Certain roof strata is greatly weakened by fire and heat and may be too hazardous for the team to work under.

5. The **availability of construction materials and the means of transporting them to the sealing sites**. This factor affects the type of temporary or permanent seal that will be built. Oftentimes in urgent situations, seals, especially temporary seals, are built with materials that are readily available.

6. The **building sites for the seals**. These sites are determined by the location of the fire, how fast the fire is spreading, the ability to control ventilation in the fire area, the gas conditions present, and the volatility of the burning coal seam.

Fires involving high volatile coal are often sealed more than 1,000 feet away from the fire, while fires involving low volatile, non-gassy coal may be sealed relatively close to the fire.

One of the reasons why seals should be erected as far as possible from a high volatile coal fire (1,000 feet more) is to allow sufficient time for the mine rescue teams to leave the mine before an explosive mixture of gas is likely to form inby the seals.

Ventilation (pages5-25 and 26)

When building temporary seals, one of the most important things to consider is ventilation. **You should be careful to ensure that there are no abrupt changes in the ventilation over the fire area.** A steady flow of air must continuously move over the fire to carry explosive gases, distillates, heat, and smoke away from the fire.

When sealing a mine fire, the only way to keep the air flowing over the fire area is to leave one intake airway and one return airway unsealed while other airways are being sealed. Then, as a final step, the last intake and return can be sealed simultaneously. This will enable ventilation to continue over the fire area until both seals are completed.

Sometimes two teams are used to simultaneously seal the last intake and return. In cases like these, the teams should be in constant communication between themselves or with a coordinator in order to synchronize the simultaneous construction.

Usually, fires are sealed far enough away from the fire so that the heat and pressure in the sealed area do not affect the seals. In some cases, however, the only site available for sealing a fire is close to the fire area where the heat and smoke are very intense in the returns. As a result, the mine rescue teams will not be able to work in the returns for very long.

In such a situation, the fire area can be systematically sealed so as to protect the team as much as possible from the heat and smoke in the returns. Entries 2, 3, and 5 (on the visual) can be sealed first. Entry 4 will be the last intake entry to be sealed.

When Entries 2, 3, and 5 are sealed, the surplus intake air can be coursed by a brattice line to the returns, one at a time. The teams can then construct the framework for the return seals while working on the fresh air base

When the intake seal is finished, the pressure will be reduced in the returns and the brattice curtains can be immediately dropped by the rescue teams, spadded to the ribs and weighted at the bottom – all within a couple of minutes. The teams then immediately leave the mine.

If, for some reason, the seals do not hold because of the heat or pressure within the sealed area, the fire area will have to be resealed further away from the fire.

Explosions (pages 5-26)

If an explosion is likely to occur after the seals have been erected, arrangements should be made to close the last seals **after all personnel are out of the mine**. This can be done by leaving hinged doors (similar to drop doors) that will close automatically in one or more of the seals, usually the last intake seal to be erected.

These doors can be temporarily held open with a counterbalance in the form of a perforated bucket filled with water. The holes in the bucket should be made so that sufficient time will elapse before the water drains from the bucket.

This will allow time for personnel in the mine to reach the surface before the door or doors close to complete the seals.

When fires are being sealed in gassy or dusty mines, it is essential to apply a thick coating of rock dust to the ribs, roof/back, and floor of entries, crosscuts, etc., for several hundred feet outby the seal, and, if possible, inby the seal. Hence, in the event of an explosion around the fire, there will be less chance of propagating a coal-dust explosion.

Considerations for Permanent Seals (pages5-27)

Isolation

Just as when you seal an area with temporary seals, when you put up permanent seals, the area inby the seals must be isolated from the rest of the mine.

This means that all cables, lines, or track that were removed or severed for the temporary seal must also be removed or severed for the permanent seal.

Sometimes this work will already have been done for you at the time when the temporary seals were built, so you will not have to take care of it when you build the

Review questions: **(pages5-29)**

1. What are the reasons why a mine fire would be sealed rather than fought directly?
2. Why is recommended that the last intake and return seals be erected and closed simultaneously?
3. Why should all waterlines, power cables, and track leading into a sealed area should be severed or removed before sealing a fire area?

ANSWER SHEET (pages 5-30)

1. **Answer:**
    - Attempts to fight directly are ineffective
    - Insufficient materials to fight fire directly
    - Fire of too great a magnitude
    - Roof conditions are too dangerous
    - Buildup of explosive gases
    - Location of the fire
2. **Answer:** It lessens the possibility of explosive gases building up in the fire area.
3. **Answer:** This practice ensures that the sealed area is completely isolated from the other areas of the mine and possible ignition sources.

Causes and Effects

Explosions are very similar to fires in terms of what causes them. Just as with a fire, three elements must be present for an explosion to occur: fuel, oxygen, and heat (Ignition). The fuel for an explosion can be an explosive mixture of gas, or a sufficient concentration of coal dust, or a combination of both.

An explosion can only occur if all three elements are present at the same time. To avoid an explosion, the three elements of the fire triangle must be kept away from each other.

Explosions in coal mines are most often caused by the ignition of methane, coal dust, or a combination of the two. The source of ignition is commonly sparks, an electric arc, an open flame, or misuse of explosives.

Explosions can cause significant damage. Roof supports may be blown out, ventilation controls damaged or destroyed, machinery twisted and scattered, and numerous fires ignited. The other main problems associated with explosions are hazardous roof conditions and spreading fires.

Once an explosion has occurred, there is always the possibility of further explosions. Further explosions are possible because once the ventilation system is damaged from the first explosion, explosive gases can accumulate and be ignited either by fires that have developed or by some other ignition source, such as arcing from a damaged cable. Also, coal dust stirred up by the first explosion can propagate further explosions.

Before Going Underground (pages5-32)

The types of things that you should be concerned about are the same types of things we discussed when we talked about preparing to go into a mine to explore or to fight a fire:

1. The team should make sure that the main fan is running, that a guard is monitoring the operation of the fan, and that tests are being made at the main returns for any gases that may be present in the mine. Ventilation is necessary to prevent the buildup of explosive gases. Keeping the main fan running will ensure ventilation at least up to the point where underground controls have been damaged or destroyed. Testing for CO and explosive gases at the mine openings is essential so that a determination can be made by the Command Center whether the mine is safe to enter.

2. It is usually recommended that the power to the affected area of the mine be cut off. Arcing from damaged cables is a possible ignition source for further explosions or fires. However, cutting the power will affect any auxiliary ventilation and will affect the operation of any electrically-powered equipment such as a

pump. The Command Center will have to take these factors into consideration.

3. The team should also know about any possible ignition sources that may exist underground. This could include battery-operated or diesel equipment that may have been left running. Any fires that developed from an explosion are also possible ignition sources for further explosions.

4. If there are any underground storage areas for explosives, oil and grease, or oxygen or acetylene cylinders, you should know about them.

Indications of Explosion and Assessment of Conditions (pages5-32 and 33)

Reports of a suspected explosion along with elevated carbon monoxide readings at mine openings are indications that an explosion has occurred. However, sometimes the gases from an explosion will be ventilated out of the mine before the rescue teams arrive or the ventilation system may have been disrupted.

Officials will not know for sure until rescue teams go into the mine to explore and assess the conditions to see if an explosion really did occur. Sometimes what seems like an explosion is actually a major roof fall, or a rock bump or rock burst.

The first indications that an explosion has occurred in a mine may be reports from miners in nearby sections who felt a sudden movement of air, noticed smoke or dust in the air, or heard the sound of the explosion.

Another indication of an explosion may be a jump in the pressure recording chart for the main fan.

Teams may want to re-enter the mine immediately to determine the conditions. However, teams need to be patient and let the Command Center assess the situation to determine the risk of re-entry.

Because as stated previously, once an explosion has occurred, there is always the possibility of further explosions.

When rescue teams go into a mine to see if an explosion has occurred, some of the indications to look for include:

- The presence of afterdamp and toxic and explosive gases in the main returns
- Blown out stoppings and roof supports:
  - Stoppings that have been damaged or have blown out should be carefully examined. The direction in which a stopping has blown helps to indicate the direction of the force of the explosion.
  - Even if stoppings are not destroyed, indications of blocks having been moved should be noted, especially when the stoppings are across entries near

intersections (the movement of blocks from stoppings in crosscuts is seldom significant).

- Overturned equipment
- Evidence of “coking” and “coke streamers” and their size. **NOTE:** Coke is produced when coal is burned in the absence of oxygen.
  - Roof falls
  - Coal dust or soot on rock-dusted surfaces (this may be the first evidence of an explosion that occurred inby that point)
  - Film of dust on mine rail (for same reason)
  - Smoldering fires and scorched material

The initial role of the rescue team after an explosion is normally to explore and assess conditions. Once this is completed, the teams will begin the process of reestablishing ventilation and recovering the mine.

Review questions (pages5-34)

1. What are the necessary factors that must be present in order for an explosion to occur?

2. What are the chief concerns of a mine rescue team when exploring a mine following an explosion?

3. What types of evidence may the exploring team might encounter that would indicate an explosion has occurred in the mine?

ANSWER SHEET (pages5-35)

1. Answer:
- An accumulation of gas within its explosive range (fuel);
- Sufficient oxygen; and
- A source of ignition (heat).

2. Answer:
- Disrupted ventilation
- Possibility of further explosions
- Possibility of fires
- Damage to energized electrical systems that could be further ignition sources
- Accumulations of toxic and explosive gases
- Altered roof and rib conditions

3. Answer:
- Disrupted ventilation
- Presence of afterdamp and other toxic and explosive gases in return airways
- Blown out or damaged roof supports and/or stoppings
- Damage to machinery and equipment (cars off track, machinery out of place or overturned)
- Evidence of coking and coke streamers
- Roof falls
- Darkened rock dusted surfaces
- Dust on mine rail
- Presence of small fires or scorched material

General Review

Fires, Firefighting, and Explosions

1. Explosions in coal mines are most often caused by ignitions of:
   a. Carbon monoxide
   b. Hydrogen
   c. Methane
   d. Sulfur dioxide
2. The first indications that an explosion has occurred are often very similar to those of:
   a. An inundation of water
   b. A large roof fall
   c. A fan stoppages
   d. All of the above
3. A positive indication that a fire exists in a mine is:
   a. Carbon monoxide and/or smoke in the return airways
   b. Methane and carbon dioxide in the return airways
   c. Lowered oxygen content in the return airways
   a. A disruption in normal ventilation
4. Burning materials that give off extremely toxic gases in addition to carbon monoxide are:
   a. The coal seam itself
   b. Hydraulic fluids
   c. Neoprene and other synthetic rubber compounds
   d. All of the above
5. The preferred type of hand-held extinguisher for teams is a dry chemical type that contains:
   a. Sodium bicarbonate
   b. Potassium chloride
   c. Carbon tetrachloride
   d. Monoammonium phosphate
6. A monoammonium phosphate extinguisher is effective in fighting:
   a. Class A fires
   b. Class B fires
   c. Class C fires
   d. All of the above

7. Foam generators are effective in controlling mine fires in that they:
   a. Limit the amount of oxygen reaching the fire area
   b. Cool the burning materials
   c. Can be effective when set up long distances from the actual fire
   d. All of the above

8. Seals in high volatile coal seams are often placed:
   a. 10 feet from the fire area
   b. 100 feet from the fire area
   c. 1,000 feet or more from the fire area
   d. 10,000 feet or more from the fire area

9. Probably the best material to use for sealing a mine fire is:
   a. Brattice cloth
   b. Cement blocks
   c. Tile or bricks
   d. Tongue-and-groove lumber

10. Non-metallic tubes or pipes are inserted in temporary and permanent seals for the purpose of:
    a. Checking for smoke
    b. Bleeding off excess pressure from the sealed area
    c. Collecting air samples from the sealed area
    d. Ventilating the sealed area

General review answers: (pages5-56)

1. c
2. b
3. a
4. c
5. d
6. d
7. d
8. c
9. b
10. c

Module 6

Rescue of Survivors and Recovery of Bodies

Rescuing Survivors (pages 6-3 and 4)

Locating Survivors

Before going into a mine to search for missing miners, there are several questions to which you should have answers.

- How many miners are missing?
- What are the latest tracking locations for each missing miner?
- In what section or sections were they supposed to be working?
- Where are the escape routes in the mine?
- Where are the refuge alternatives or refuge chambers located?
- Where are miners likely to barricade?
- Are there any ventilation boreholes in the area where miners might go to obtain fresh air?

Survivors may be found in open passageways, perhaps along the escape routes, injured and unable to walk out of the mine. They may be trapped behind falls or other obstructions, or trapped under a piece of equipment or debris. They may be in a refuge alternative, refuge chamber, or they may have barricaded themselves in an area with fresh air.

When you search for survivors, it is important to both **look** and **listen** for clues. Miners who barricade themselves into an area will usually try to leave indications of where they are barricaded to aid rescuers in finding them. For instance, they might put a note in a dinner bucket or they might draw an arrow along the side or mark a rail to indicate in which direction rescuers should look.

On the outside of refuge alternative or barricade, the trapped miners will probably have written down how many people are inside the chamber or barricade, and the time and date that they went inside. Another clue to look for would be articles of clothing or possessions, such as the case or cover of a self-rescuer, dropped along the way.

While locating something like this would not indicate the direction in which the survivors were traveling, it would show that someone had been in that area. In some instances, teams may find fresh footprints (in the dust from an explosion or in rock dust in seldom traveled areas indicating the direction survivors had taken.

When **listening** for clues, you should be on the alert for any noise, such as voices or pounding on rails or pipes. When survivors are located, their location, identities (if possible, and condition should be reported immediately to the Command Center. The Command Center can then send in a backup team with any equipment that may be needed, such as stretchers or breathing apparatus. Also, when survivors are located, the location, time, and date should be marked on the team's map and on the rib where they were found.

Teams may find fresh footprints in the dust from an explosion or in rock dust in seldom- traveled areas indicating the direction survivors had taken.

Opening Refuge Chambers, Refuge Alternatives, or Barricades (pages 6-4 and 5)

When you have located a refuge alternative (RA, refuge chamber, or barricade try to determine as quickly as possible whether the miners inside are still alive and conscious. Do this by establishing verbal communication or by creating noises so that those inside can respond. If you don't get a response, don't assume the miners are dead; they could be unconscious.

If you **do** get a response, try to find out how many miners are inside and their condition. Then you will have a better idea of what medical supplies you may need when you reach them. Ask if they have used their self-rescuers, and how long they have been inside.

The safest procedure for getting survivors out is usually to advance fresh air to the barricade by the quickest means possible. Once the fresh air is advanced, the barricade can be opened. Sometimes, however, it may be necessary to rescue the survivors before fresh air can be advanced to them.

Refuge alternatives will have an integral airlock built in. For instance, fresh air cannot be advanced to the survivors if a fire is spreading and moving in their direction. In these cases, an air lock should be established outside the refuge chamber or barricade before it is opened.

The Command Center will determine whether to advance fresh air or build an air lock. The Command Center will make its decision based on all existing conditions in the area and whatever information is available on the condition of the survivors.

If it is decided to establish an air lock, the team will have to build a stopping with a flap in it as close as possible to the RA, refuge chamber, or barricade. You should try to keep the air lock small in order to minimize the amount of contaminated air that will enter the RA, refuge chamber or barricade once opened.

The air lock should be just large enough to allow all team members to move comfortably and to allow all their necessary equipment, such as a stretcher, to fit in.

Once the stopping is constructed, the barricade can be opened. An opening large enough to admit the team members and a stretcher should be made in the barricade and covered immediately with canvas to keep the air within it as safe as possible.

When anyone goes through the air lock, every effort should be made to admit as little outside air as possible.

Body Recovery (pages 6-11)

Locating the Dead and Marking the Area

When a team locates a body, the usual procedure is to report the location to the Command Center. You should also mark the body's location and position on the mine map and on the roof or rib close to the body.

It is suggested that a team member outline the body with chalk or paint on the floor, or at least mark where the head and feet are. If the floor is too muddy to mark, you should draw the position of the body on a piece of paper or on the mine map. If there is more than one body, usually an identifying number is given to each one. This number should also be marked on the map and on the roof and rib close to the body.

When a body is first located, every effort should be made not to disturb any possible evidence in the area. Evidence will be important later in ensuing investigations. Usually, the first team that discovers a body is not the team that actually does the body recovery work. The recovery of bodies may wait until fresh air is advanced or it may be decided to bring the bodies out immediately. Either way, a fresh team will probably be sent in to handle the work.

Review Questions (pages6-15)

1. What are the possible clues that would aid the mine rescue teams in locating survivors during a mine emergency?

2. If miners are missing after a fire or an explosion, what is the critical information that your team will need during the briefing?

3. What are the procedures a rescue team would employ to enter a refuge chamber or barricade behind which miners are located?

4. What are the usual procedure when a body is encountered during exploration?

ANSWER SHEET (pages6-16)

1. **Answers:**
   - Notes left in lunch buckets.
   - Arrows drawn on rib or rail.
   - Pounding sounds on a rail or pipe.
   - Self-rescuer covers or cases, or discarded self-rescuers Miner's personal items left or discarded.
   - Evidence of footprints in dust.

2. **Answers:**
   - Number of missing miners.
   - Section or sections where they were working.
   - Escape routes used from those section.
   - Likely places where miners would erect barricade.
   - Location of any ventilation boreholes where miners could obtain fresh air.

3. **Answers:**
   - Try to establish communication with the miners.
   - If possible, advance fresh air to the area; if it is NOT possible, erect an air lock before entering the refuge chamber or barricade.
   - When opening a barricade, use as small an opening as possible, and cover the opening with a flap to prevent contamination of the atmosphere.

4. **Answers:**
   - Report location of the body to the Command Center. Mark location and position of body on map.
   - Mark location in mine.
   - Attach identifying number to body bag.
   - Remove nothing from the body or surrounding area. Keep all personal belongings of the miner with the body.

Module 7

Mine Recovery

Re-ventilation Methods Used for Unsealing Fire Areas

There are two basic re-ventilation methods that can be used when unsealing a fire area: Progressive ventilation and direct ventilation.

Progressive Ventilation

Progressive ventilation is the re-ventilation of a sealed area in successive blocks by means of air locks. Direct ventilation is the re-ventilation of the entire sealed area at once.

Progressive ventilation was traditionally the most common method of unsealing a fire area in coal mines. The costs associated with the large number of teams needed for air locking has led to a trend of direct ventilation. The advantage of progressive ventilation is that gas conditions can be carefully controlled, and the operation can be halted at any point in which conditions become hazardous. The disadvantage of progressive ventilation is that it is a slow process.

Direct Ventilation

The other method for recovering a sealed fire area is by direct ventilation. With this method, the affected area is recovered and re-ventilated as a whole rather than by successive blocks. As a result, recovery is accomplished more quickly than with progressive ventilation, but gas conditions are less controlled.

NOTE: Before using direct ventilation, there should be conclusive evidence that the fire has been extinguished.

When direct ventilation is used to recover mines that have been sealed on the surface, the procedure is basically the same except an air lock is not used. Just as with underground unsealing, surface seals (one on the intake and one on the return) should be opened at about the same time. Then, when it is decided that it is safe, apparatus teams can explore and re-establish ventilation.

Preconditions for Opening a Sealed Fire Area

Although each situation is different, experience indicates that **no attempt** should be made to unseal a fire area **until**:

1. The oxygen content of the atmosphere in the sealed area is low enough to make it inert;
2. Carbon monoxide (gas that indicates combustion) has disappeared or nearly disappeared from the air behind the seal; and
3. The area behind the seals has been given enough time to cool so that air introduced during the unsealing operation will not rekindle the fire.

Achieving these goals may be difficult, and it may require a great deal of time.

Preparations for Opening a Sealed Fire Area

Opening a sealed fire area requires certain preparations:

1. Adjustments in ventilation should be made so that toxic and explosive gases released from the sealed area are directed into the main returns. NOTE: Someone should be monitoring gas levels at the main returns.
2. An observer should be at the main fan to ensure it is operating correctly. If the fan slows down or malfunctions, the teams working underground should be withdrawn immediately. NOTE: If the fan is electrically driven and exhausting, precautions should be taken so that explosive gases do not come in contact with the fan motor or any other electrical equipment used to operate the fan.
3. Checks should be made to ensure that all electrical power in the sealed area has been cut off. Also, power in the return airways near the sealed area should be locked out.
4. In bituminous coal mines, all entries and crosscuts leading to and from the sealed area should be heavily rock dusted. This should be done for a considerable distance outby the sealed area to be opened.
5. Withdraw all unnecessary people from the mine.

Dealing with Obstructed Passageways

During re-ventilation, if entries are obstructed by falls, debris, or equipment, it may be hard to travel through them to advance the ventilation.

In these cases, the team would normally try to bypass or circumvent those entries and come in behind the obstruction to erect the stoppings.

There have been situations in the past, however, where all entries have been obstructed by falls. In some instances, teams have re-ventilated as close as possible to the area and then used permissible machinery and tools to clear an entry. While this is being done, line brattice can be used to ventilate the area, in the same manner that a face area would be ventilated during normal production.

In other cases where falls were extensive, access was gained to the obstructed area by mining through the solid from the closest unobstructed entry.

In these cases, the teams have mined to within a few feet of breaking through the solid. At that point an air lock was put up, the power turned off, and all unnecessary personnel removed from the mine. Then a team with apparatus on went through the air lock and hand mined the last few feet.

These two procedures are described as examples of methods of recovery that have been used successfully in the past. Any decision to use such methods would normally rest with the officials in charge of the operation. The risks, benefits, costs, etc., would all have to be carefully considered before implementing such a plan.

Review questions: (pages 7-11 and 7-12)

1. Discuss the **two** methods of re-ventilating a sealed fire area, and the advantages and disadvantages of each.

   Answer:

   1) The advantage of progressive ventilation is that gas conditions can be carefully controlled, and the operation can be halted at any point where conditions seem hazardous. The disadvantage is that it is a slow process.

   2) Direct ventilation is quick, but should only be used if there is **conclusive evidence that the fire is out.** Direct ventilation **must** be used if the mine was sealed on the surface.

2. Discuss the **three** preconditions for opening a sealed fire area.

   Answer:

   1) The oxygen content of the atmosphere in the sealed area should be low enough so that an explosion is impossible.

   2) There should be no carbon monoxide, indicating that the fire is out.

   3) The sealed area should have cooled enough so that the fire is not rekindled when the area is re-ventilated.

Clearing and Rehabilitating the Affected Area

Many times, as the rescue teams advance ventilation, they will also, out of necessity, be doing a great deal of construction and clean-up work. In addition to building and repairing damaged ventilation controls, this can include loading out falls and hot materials, stabilizing roof and rib**/back** conditions, pumping water, clearing roadways, and restringing communication lines.

Once ventilation has been re-established in an area, however, labor crews can take over the bulk of the clean-up effort. Until then, this work must be done by apparatus crews for safety reasons and in order to continue to advance the recovery effort.

Roof/Back and Rib Control

Fires, explosions, and other disasters frequently result in weakened roof**/back** and rib conditions. Rescue teams will have to carefully assess roof/**back** and rib conditions during recovery work. You may find that extensive timbering and cribbing is needed to stabilize conditions prior to advancing ventilation.

Pumping Water

Often in recovery operations, rescue teams will encounter large accumulations of water that must be pumped out. There are two ways of accomplishing this. One way is for the team to advance fresh air to the area and then pump out the water.

If the team needs to clear the area before they have advanced fresh air that far, and if gas conditions permit, they can use non-conducting suction lines with a pump set up in fresh air to pump out the water. When using this procedure, careful analysis should be made of the gas conditions in the area being pumped. Water soluble gases will be pumped out along with the water. And, if the line loses suction, toxic or explosive gases from the contaminated atmosphere can be drawn out.

When advancing into an area that has been inundated with water, teams should pay special attention to roof and rib conditions. Roof falls are likely in such areas.

Clearing Roadways and Track

Roadways and track will need to be cleared and restored to use as quickly as possible. Once this is done, it will be much easier to bring in the materials that are needed for the recovery and clean-up effort.

Loading Out Falls and Hot Debris

Many times the most practical means of dealing with debris found during recovery operations is to load it onto shuttle cars and/or mine cars and haul it from the mine. This is particularly true of heated debris found after unsealing a fire area. In fact, the only practical means of eliminating the possibility of rekindling the fire is to remove the heated material. The material should be wetted down before and during the loading operation. **NOTE**: Refer to **Visual 7** for a drawing of a water lance.

In situations where large areas of heated roof/**back** rock have fallen, water lances can be driven into the debris to aid in cooling it. Water lances are pipes about 10 feet long with holes cut along the length of the pipe. The lance attaches to a regular hose line. Once the rock has cooled, it can be broken up and loaded out.

Restoring Power

Power is usually restored progressively by an electrician as the ventilation is advanced. Once power has been restored in an area, the rehabilitation work can proceed much more efficiently because there will be power for transporting materials, equipment, and workers.

Re-establishing the Communication System

As fresh air is advanced, the mine's communication system should be repaired or a substitute system advanced to aid in expediting the recovery operation.

Review questions: (page 7-16)

1. Discuss the tasks normally involved in recovering a mine or section of a mine following an explosion, fire, or other mine disaster.

2. Discuss how a mine rescue team could remove standing water from an unventilated area.

ANSWER SHEET (page 7-17)

1. Answer:

    - Re-establishing ventilation
    - Securing roof and ribs
    - Pumping water
    - Clearing falls and debris
    - Loading out hot materials
    - Restoring electrical power
    - Restoring the communication system
    - Restoring track and/or beltways

2. Answer:

    - If gas conditions permit, the team can pump the water using non-conducting suction lines and a pump set up in fresh air.
    - Careful tests should be made of the gas conditions before beginning the operation. Water soluble gases would be pumped out along with the water.
    - And, if the line loses suction, toxic or explosive gases from the contaminated atmosphere could be drawn out.

Module 2 Glossary (pages 2-53 and 2-54)

Adsorption – Physical adhesion of molecules to the surfaces of solids without chemical reaction.

Asphyxiate – To suffocate or choke.

Atmospheric pressure – Force exerted by air. Atmospheric pressure is measured on a barometer.

Blower – A gas feeder under high pressure which causes the gas to issue at considerable velocity.

Casing – Piping used to support sides of a borehole and to prevent entry of loose rock, gas, or liquid.

Combustible – Capable of burning; flammable.

Contaminant – Something which fouls or impurifies.

Corrode – To eat away gradually.

Damps – Descriptive names given by miners to identify mixtures of gases.

Diffuse – To scatter, spread out, or blend.

Disperse – To scatter or get rid of; to dispel.

Explosive range – The range of concentrations within which a gas will explode if ignited (expressed in percentages).

Feeder – Small cracks through which methane or other gas escapes from coal.

Flammable – Burnable.

Ignite – To set on fire.

Inundation – The state of being flooded.

Methane outburst – Sudden emission of methane from coal seam or surrounding rock.

Mine atmosphere – The air in an underground mine.

Oxidize – To cause to combine with oxygen.

Poison – Substance which destroys life or health

PPM – Parts per million.

Smoke – Tiny particles of solid and liquid matter suspended in air.

Solubility – Ability to dissolve in water.

Specific gravity – The weight of a gas compared to an equal volume of air under the same temperature and pressure.

Sulfur – A nonmetallic element which exists either free or in combination with other elements. It often occurs as pyritic sulfur, commonly known as "fool's gold."

TLV (Threshold Limit Value) – Used to denote the average concentrations of gases to which workers can (under Federal regulations) be exposed over an 8-hour daily period.

Toxic – Poisonous.

Vacuum bottle – Container used to collect gas samples for chemical analysis.

Module 3 Glossary (pages 3-61 and 3-62)

Air lock – An area in the mine closed at both ends by two by two doors or two stoppings with flaps or doors in them. An air lock is used to prevent mixing of different atmospheres while still permitting miners to enter and exit.

Air split – The division of an air current into two or more parts.

Airway – Any passage through which air is flowing.

Anemometer – Instrument used for measuring medium-velocity (120-2,000 ft./min.) and high-velocity (2,000-10,000 ft./min.) air currents in the mine.

Area (of an airway) – Average width multiplied by average height of an airway, expressed in square feet.

Auxiliary fan – A small, portable fan used to supplement the ventilation of an individual working place.

Box check – A stopping with an opening in it to allow a conveyor to pass through, used to prevent intake or return air from flowing across the conveyor.

Check curtain or run-through check – Brattice cloth, canvas, or plastic curtain used to deflect or direct air into a working place. Constructed in a manner to allow the passage of miners and machinery.

Crosscut – A passageway driven at right angles between an entry and its parallel aircourse (or aircourses) for ventilation purposes.

Entry – An underground passage used for haulage, ventilation, or as a manway; a coal heading; a working place where the coal is extracted from the seam in the initial mining.

Face – The principal operating place in a mine; the working place where fresh ore or coal is exposed and extracted. A mine may have many operating faces.

Heading – An entry.

Inby – Toward the working face from a point; the opposite of outby.

Intake – The passage through which fresh air is drawn or forced into a mine or to a section of the mine.

Irrespirable – Unfit for breathing.

Main entry – The main haulage road.

Line brattice or brattice cloth – Fire-resistant fabric or plastic partition used in a mine passage to direct the air into the working place. Also termed “line canvas.”

Main fan – A mechanical ventilator installed at the surface which operates by either exhausting or blowing (pushing) to induce airflow through the mine.

Man door – Door installed in a permanent stopping/Bulkheads to allow persons to travel from one entry to another.

Mine door – A large hinged door used to close off a mine passage. Doors are usually installed in pairs to form an airlock.

Outby – Toward the shaft or entrance from a given point; the opposite of inby.

Overcast – Enclosed airway built at an intersection of mine passages that permits one air current to pass over another air current without mixing.

Quadrant – Any of four quarters into which something is divided.

Reagent – A substance that causes chemical activity.

Regulator – An adjustable door or opening in a stopping/Bulkhead used to control and adjust the quantity of airflow in the mine in order to ensure proper distribution.

Return – The air course along which the ventilated air of the mine is returned or conducted to the surface.

Return air – The air that has passed through all the working faces of a split and is on the way out of the mine.

Smoke tube – Instrument used for determining direction and velocity of slow-moving air (below 120 feet per minute).

Stopping/Bulkheads – A permanent stopping/bulkhead or temporary stopping/bulkhead wall or partition constructed of incombustible material across a passageway to direct the ventilating air in its proper course and to separate intake air from return air.

Traverse – To move across. A traverse measure of air velocity is one that is taken by walking across an airway.

Undercast – An enclosed airway built at an intersection of mine passages that permits one air current to pass under another air current without mixing.

Velocity – Rate of airflow in linear feet per minute.

Module 4 Glossary
(page 4-65)

Air lock – An area in the mine closed at both ends by doors, or by stoppings with flaps or doors in them. Used to prevent mixing of different atmospheres while still permitting miners to enter and exit.

Backup team – Rescue team stationed at the Fresh Air Base as a "backup" for the working team inby the Fresh Air Base.

Briefing – Session held before a team goes underground to inform team members of conditions underground and give them their work assignment.

Debriefing – Session held when a team returns to the surface after completing an assignment to review what they saw and did.

Fresh Air Base – Base of operations from which the rescue and recovery teams can advance into irrespirable atmospheres.

Lifeline – Rope line or cable from communications system that links the team to the Fresh Air Base. It may be used as a manual communications system to the Fresh Air Base [30 CFR 49.16(a)(8)].

Linkline – Line that links team members together. Used in smoke, it is usually a rope about five feet long with rings for each team member to hook onto.

Progress reporting – Information the team relays to the Fresh Air Base as it proceeds.

Standby team – Team scheduled to be on the surface in ready reserve when rescue teams are working underground.

Tying in – Systematic exploration of all crosscuts and adjacent entries so that the team is never inby an unexplored area.

Module 5 Glossary (page 5-57)

Class A fires – Fires that involve ordinary combustible materials such as wood, plastics, paper, and cloth. They are best extinguished by cooling with water or by blanketing with certain dry chemicals.

Class B fires – Fires that involve flammable or combustible liquids such as gasoline, diesel fuel, kerosene, and grease. They are best extinguished by excluding air or by special chemicals that affect the burning reactions.

Class C fires – Fires that involve electricity. They are best extinguished by non-conducting agents such as carbon dioxide and certain dry chemicals.

Class D fires – Fires that involve combustible metals such as magnesium, titanium, zirconium, sodium, and potassium. Special techniques and extinguishers have been developed to put out these fires.

Class K fires - Fires that involve combustible cooking media such as oils and grease commonly found in commercial kitchens. A special wet chemical extinguishing agent should be used for extinguishing and suppressing these extremely hot fires that have the ability to reflash.

Direct firefighting – Method of firefighting where dry chemical extinguishers, water, rock dust, or foam are put directly onto the fire to extinguish it.

Fire tetrahedron – Tetrahedron used to illustrate the four elements necessary for fire to occur: fuel, oxidizing agent, heat, and uninhibited chemical chain reaction.

Head coal – The top portion of a coal seam left unmined, either permanently, or temporarily to be mined afterwards.

High expansion foam – Foam used in firefighting that is light and resilient and can travel long distances without breaking down. It is made by mixing water, air, and a high expansion foam concentrate or detergent in a foam generator.

Hydrogen pops – Small explosions of hydrogen gas.

Indirect firefighting – Method of firefighting where the fire area is sealed or filled with foam or water to exclude oxygen from the fire, and, in the cases of water and foam, to cool the fire.

Low expansion foam – Foam used in firefighting that is wet and heavy and, therefore, must be forced directly onto the fire. It is made by mixing a low expansion foam concentrate or detergent with water in a foam nozzle attached to a fire hose.

Rock bump – Sudden, violent expulsion of coal from one or more pillars, accompanied by loud reports and earth tremors.

Rock burst – An explosive breaking of coal or rock in a mine due to pressure.

Volatile coal – Coal that gives off volatile matter (gases and vapors) when heated. (Lower rank coal, such as lignite, gives off more volatile matter than higher rank coal, such as anthracite.)

Module 6 Glossary (page 6-17)

Air lock – An area in the mine closed at both ends by doors or by stoppings with flaps or doors in them. Used to prevent mixing of different atmospheres while allowing miners to enter and exit.

Barricade – Enclosed part of mine to prevent inflow of noxious gases from a mine fire or an explosion. This may be done by doors or by building one or more airtight walls using any available material, such as rock, wood, brattice cloth, mud, clothing, etc., so as to enclose a maximum quantity of good air.

Extricate – To disentangle.

Hysteria – Uncontrollable outburst of emotion or fear.

Putrefaction – The decomposition of organic matter by bacteria, fungi, and oxidation, resulting in the formation of foul-smelling products.

Refuge chamber – An airtight, fire-resistant room in a mine, used as a method of refuge in emergencies by miners unable to reach the surface.

Rigor mortis – The progressive stiffening of the muscles that occurs several hours after death as a result of the coagulation of the muscle protein.

Trauma, physical – Injury to living tissue.

Trauma, psychological – Disordered psychic or behavioral state resulting from mental or emotional stress or physical injury.

Triage – System of assigning priorities of medical treatment to injured people.

Module 7 Glossary
(page 7-31)

Air lock – An area in the mine closed at both ends by doors or by stoppings/**bulkheads**, with flaps or doors in them. Used to prevent mixing of different atmospheres while allowing miners to enter and exit.

Direct ventilation – Re-ventilation of the entire sealed area at once.

Progressive ventilation (or stage ventilation) – Re-ventilation of a sealed area in successive blocks by means of air locks.

Water Lance – A pipe about 10 feet long with holes along the length of it with a fitting to attach to a hose line.