Advanced Mine Rescue Training
Coal Mines

U.S. Department of Labor
Mine Safety and Health Administration
National Mine Health and Safety Academy

Instruction Guide Series
IG 7

Revised 2020

Visit the Mine Safety and Health Administration
Website at www.msha.gov

Table of Contents

Introduction

As history has taught the mining industry, with such mine disasters as Monongah and Winter Quarters, to Sago and the Upper Big Branch; Mine Rescue cannot rest on past successes. Mine Rescue must continue to learn from mistakes made in rescue and recovery. Today's mine rescue efforts are highly organized operations that are constantly analyzing changing situations and environments and engaging in an orchestrated execution of tasks carried out by highly trained and skilled individuals who work together as a team.

Appropriate reaction to events such as mine fires, explosions, inundations and other hazards that require a total response plan, encompassing all of the steps from hazard recognition and containment to the involvement of teams in the rescue of survivors and the restoration of mining operations requires quality training.

Mine rescue team members, for both coal and metal and nonmetal underground mines, **must** be trained according to the requirements under **30 CFR Part 49 - Mine Rescue Teams.**

These training requirements are built on a set of systematic training principles that include both initial and advanced mine rescue team training.

The initial training requires team members (prior to serving on a mine rescue team) to complete, at a minimum, a 20-hour course of instruction as prescribed by MSHA's Office of Educational Policy and Development (EPD), in the use, care, and maintenance of the type of breathing apparatus (SCBA) which will be used by the mine rescue team.

MSHA Instructional Guide **(IG 5)** provides for team trainers on how to conduct the initial, prescribed training for team members. In addition to the initial, 20-hour requirement, IG 5 also covers basic principles and responsibilities of serving on a coal or metal and nonmetal mine rescue team.

It includes training objectives, and activities, such as donning an SCBA and team positions which allow team members to build a solid foundation for advanced mine rescue team training, as emphasized in the introduction of **IG 5:**

"As a team member, you'll be responsible for rescuing miners and recovering a mine, often under very hazardous conditions. The lives of trapped miners, those of your fellow team members, and even your own life, will depend on how well you do your job. The training program you're beginning is not just another mining course. It is a demanding pursuit, involving careful study and strenuous physical activity. It also requires a personal commitment from you to work hard, practice, and become the best team member you can possibly be."

Your Role as an Instructor

You are about to assume an important responsibility – that of building and maintaining a capable mine rescue team. What your team members learn during these training sessions could very well help to save their lives and the lives of their fellow miners.

Keep this in mind as you proceed: be sure to let your team know that this program has been developed with their health and safety in mind.

These training materials are complete and self-contained. Study the module before teaching the class so that you'll be familiar with the material. Also, take time to review applicable regulations. Be flexible and take time to tailor the material to your team's needs. Where a training exercise encompasses another mine rescue requirement in Part 49, such as the requirement to wear an apparatus while in smoke, you may credit the team members under each requirement.

Remember, the key to effective instruction is to be familiar and comfortable with the content.

Purpose of this Guide

Advanced Training for Coal Mine Rescue Teams

This instructional guide is designed to help mine rescue mine team trainers and team members build the skills necessary to perform their duties effectively, during an actual mine emergency.

Underground coal mine rescue team members must be trained according to the requirements under 30 CFR 49.18. Under Section 49.18(b)(4), this training must consist of advanced mine rescue training and procedures, as prescribed by MSHA's Office of Educational Policy and Development (EPD).

This guide is designed to be used with the material in IG 7a, Advanced Skills Training, and both guides are needed to satisfy the advanced mine rescue training requirement.

This guide is divided into self-contained units of study called "modules." Each module covers a separate subject and includes suggestions, handouts, visuals, and text materials to assist you with training.

Overview

The modules in this IG include:

- Surface Organization
- Mine Gases
- Mine Ventilation
- Exploration
- Fires, Firefighting, and Explosions
- Rescue of Survivors and Recovery of Bodies
- Mine Recovery

The modules are organized exactly the same way to help guide you logically through the lessons. Each module includes:

- Training Objectives
- Course Materials
- Notes
- Instructional Text
- Training Activities
- Visuals
- General Review Questions
- Glossary

NOTE: Take time to thoroughly review objectives and materials in each section before you conduct training activities. Remember to **always** comply with the manufacturer's recommendations for the use, care, and maintenance of the type of SCBA used by the team.

Advanced
Mine Rescue Training – Coal

Module 1
Surface Organization

Module 1- Surface Organization

Contents

Instructional Text

Course Objectives

The mine rescue team will recognize and apply the key components and resources necessary to effectively organize a mine rescue and recovery operation.

Team members will:

- Be familiar with their mine’s approved Emergency Response Plan (ERP).
- Use the mine’s emergency notification plan.
- Explain the importance of establishing a chain-of-command and identify the team’s place in this chain.
- Organize the various facilities and arrangements normally recommended for carrying out a rescue and recovery operation.
- Explain the various personnel and duties normally involved in surface organization.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member Suggested:
- Mine's Emergency Notification Plan
- Laptop computer
- PowerPoint program
- Chalkboard or flip-chart

NOTE: In addition to these materials, you are encouraged to incorporate any other up-to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness of your training.

Course Outline

I. The Mine's Emergency Notification Plan

II. Surface Arrangements

- a. Command Center
- b. Security
- c. Staging and Briefing Area for Teams
- d. Bench Area for Apparatus
- e. Laboratory
- f. Medical Facilities
- g. Information Center
- h. Liaison Function
    - i. Waiting Area for Family Members
    - ii. Press Room

III. Establishing a Chain-of-Command

IV. Key Personnel and Responsibilities

- a. Mine Superintendent and/or Responsible Persons
- b. Mine Foreman
- c. Chief Electrician
- d. Chief Mechanic or Mechanical Foreman
- e. Mine Manager (Outside)
- f. Safety Director
- g. Chief Engineer
- h. Supply/Warehouse Personnel

Instructional Text

The Mine's Emergency Notification Plan

Federal regulations require each underground mine to have and post the mine's emergency notification plan outlining the procedures to follow in notifying the mine rescue teams when there is an emergency that requires their services **(30 CFR Section 49.19).**

The mine's notification plan should also include any other people or services that will be needed at the mine site such as police officers, supply clerks, telephone operators, medical personnel, ambulances and other emergency vehicles.

NOTE: Show the team a copy of their mine's emergency notification plan, or you can refer to the sample mine emergency notification plan **(Visual 1).**

Surface Arrangements

Surface arrangements cover a wide range of activities requiring the coordinated efforts of many people, including such tasks as establishing a Command Center; briefing all mine rescue teams on vital information, conditions, and up-to-date plans; and obtaining and distributing necessary supplies and equipment necessary for the operation.

NOTE: Maintaining readiness for a mine emergency operation requires preparation, training, and planning, all of which must be a part of your mine's Emergency Response Plan (ERP).

Command Center

The Command Center is the hub of rescue and recovery operations and is typically comprised of mine management personnel, federal and state officials, and miners' representatives.

The Command Center receives a tremendous amount of information and will require secure communications equipment connected to underground phones, other surface phones, and should allow direct communications capabilities with mine rescue teams underground.

All decisions concerning the mine rescue teams such as assignments, scheduling, tracking, rotations, and methods of exploration and/or firefighting are made by the Command Center.

The decision process of the Command Center is sometimes time-consuming, but it is important to understand the impact a single decision will have on the entire operation. A hasty or wrong decision could mean disaster and the loss of life.

Security

Having good security at the mine is important in order to keep the roads open and to ensure that curious bystanders do not hinder the mine rescue effort and are not injured while on the mine property.

All roads and paths leading to the mine should be secured and guarded by assigned company personnel or police officers.

Incoming traffic on the roads leading to the mine property should also be regulated by authorized personnel to keep unnecessary vehicles off the roads so that they can remain open for needed personnel, supplies, and emergency vehicles.

NOTE: Command Center access should be maintained secure.

Staging and Briefing Area for Teams

When the teams arrive at the mine site, they should be checked in and assigned to a team area. The mine rescue team coordinators should develop a "rotation schedule" for the deployment of all teams called to the mine site.

NOTE: The rotation schedule should be designed so there is a clear working order and standby teams always available. Time should be allotted for teams to rest and to clean, test, and prepare their apparatus and other equipment. Refer to the sample rotation schedule **(Visual 2).**

Bench Area for Apparatus

An area that has work benches should be set aside as an apparatus room where the apparatus can be cleaned, tested, and prepared by bench persons and/or team members.

The area should be free of clutter, have water supply for cleaning equipment, and also safe access to the correct type of electrical outlets that provide power for compressors, dryers, and bench-testing equipment.

NOTE: Arrangements for facilities, mine emergency services, and personnel must be planned out, in advance, as part of your mine's Emergency Response Plan (ERP).

Laboratory

If it will be necessary to test samples of the mine air during the rescue and recovery operation, a laboratory with suitable air analysis equipment should be set up at the mine for testing such air. If this is not possible, the air samples may have to be sent to an off-site laboratory for analysis.

Medical Facilities

Arrangements for medical services and facilities should be made. This could range from standby ambulances and a first-aid room to a temporary hospital, depending on the nature of the emergency. These arrangements should consider identifying and/or designating a helicopter landing pad.

Information Center

An information center (which is directed by the Command Center) should be established on the surface to release information related to the emergency to families and the public. The information center must be secured, staffed, and controlled by authorized personnel only.

Liaison Function

The liaison function serves to maintain a point-of-contact between the Command Center personnel and other concerned parties such as:

- Family Members
- Mining Company Representatives
- Legal Representatives
- Local Officials
- Property Owners
- News Media

NOTE: Section 7(3) of the MINER Act of 2006 requires that in such accidents, that the Mine Safety and Health Administration shall serve as the primary communicator with the operator, miners' families, the press and the public.

Waiting Area for Family Members

A separate and secure area (preferably off-site from incident ground) will usually be set aside to brief families and friends of any affected miners.

Press Room

An area completely separate from family members and preferably offsite from incident ground, should be set up for press and media representatives to gather and receive the news releases issued from the information center.

Establishing a Chain-of-Command

A great number of people will be doing many different jobs during a rescue and recovery operation. Therefore, it is important to establish a clear chain-of-command so that rescue and recovery work can be well-coordinated and carried out efficiently.

Located at the top of the chain-of-command is the mine superintendent and/or the operator's designated Responsible Persons who will delegate duties for all mine rescue personnel, according to the mine's Emergency Response Plan (ERP).

All personnel involved in the operation, especially mine rescue team members, must know exactly the duties and responsibilities expected of them, to whom they report, and who reports to them. Teamwork, coordination, and good communications are crucial during a mine emergency operation.

Local, state and Federal (MSHA) officials will also respond and work directly with mining company officials and mine rescue team personnel. Local and Federal officials normally do not take charge of a mine rescue operation, unless it is deemed absolutely necessary. Their role is usually to provide assistance and guidance during the mine emergency, approve modifications to the rescue and recovery plan, and ensure that all rescue and recovery work is carried out safely and according to the state and Federal law.

The mine rescue team is a crucial link in the chain-of-command. The team is under the direct supervision of the team captain who also works and communicates directly with all the designated official(s) responsible for coordinating the operation.

NOTE: Responsible Persons **designated and certified by the mine operator are required to take charge in the event of a mine emergency**. Responsible Persons will need to perform and delegate a variety of duties during the initial phases of rescue/recovery efforts **(see 30 CFR Section 75.1501 for training requirements for Responsible Persons).**

Mine rescue teams must receive accurate, concise, and reliable briefing information from the Command Center to perform rescue/recovery duties in a safe, timely, and efficient manner. The teams will also need up-to-date mine maps for exploration duties.

It is extremely important to develop a standardized method of reporting gas readings and other critical information to the Command Center and the Fresh Air Base (FAB).

Conducting Effective Briefing and Debriefing Sessions

Effective, accurate briefing and debriefing sessions are extremely important during any rescue/recovery operation. Valuable information is gained through effective briefing or debriefing of teams.

Personnel from the Command Center are in charge of conducting the briefing/ debriefing sessions, and it is recommended that they determine who should be included in the sessions. It is also suggested that the team captain, map man, and, and the team's trainer be included in briefings.

Input from the working teams is crucial. Accurate information exchange from the team to the Command Center is vital. Every possible effort to ensure accuracy of information gained from teams at debriefing sessions will be used to make decisions on future activities concerning the effort.

Thorough briefing sessions with mine rescue teams, before they enter the mine or dispatched to their assigned area, are essential. The exchange of information and ideas between the Command Center and the mine rescue teams carrying out the assignments is extremely important to the successful completion of the assignment.

This exchange can be fruitful for both parties, but it must be emphasized that the Command Center makes the final decisions regarding all aspects involved in the operation.

The safety of the team and other persons is dependent upon the team receiving accurate and up-to-date information on the mine's conditions which should be accurately communicated to the oncoming team(s).

The team(s) should ask questions concerning items about which they are unsure, and the team(s) should express to the Command Center any concerns they have with their assignment. Below are the types of items that may be covered in a team briefing:

- Mission of the exploring team
- Missing miners (if any) and their possible location
- Team Safety
- Conditions in the affected areas such as:
    - current air readings and methane liberation
    - adverse roof conditions
    - water accumulation
    - mine height
- Environmental conditions:
    - ambient air temperatures and/or humidity
    - barometric pressure
    - electrical storms, etc.
- Condition of the mine fan(s)
- Mine rescue work that has already been completed and covered in the debriefing of the previous team
- Review of the Approved Rescue/Recovery Plan

Key Personnel and Responsibilities

NOTE: The following list suggests a sample break-down of personnel and various duties to be carried out during a mine emergency. Thoroughly review and understand the Emergency Response Plan (ERP) and procedures in place at the mine(s) covered by your team.

Mine Superintendent and/or Responsible Persons – The mine superintendent and/ or other Responsible Person(s), designated and trained by the company, will have a wide variety of crucial responsibilities during mine emergency and rescue operations.

These designated persons will be part of the group from the Command Center. Working in cooperation with state and federal officials, they will oversee and manage numerous aspects of rescue and recovery operations, which include:

- Brief and coordinate mine rescue teams and other mine rescue personnel.
- Maintain up-to-date mine maps.
- Obtain and monitor gas readings and other conditions.
- Monitor underground communications continuously.
- Communicate directly with the FAB personnel and mine rescue teams underground.
- Notify and brief family members of any trapped or missing miners and other personnel (this should be done in person).
- Brief news media (if and when necessary).

Mine Foreman – Duties of the mine foreman may include the following:

- Organize underground operations for each shift in cooperation with the person in charge, Federal inspectors, and, if involved, state inspectors and miners' representatives.
- Provide suitable transportation for people and supplies, as needed.
- Notify all persons on the notification plan and inform them of the emergency.
- Attend the telephone at the Command Center.
- Assign people for errand duty.

Chief Electrician – Duties of the chief electrician may include the following:

- De-energize, lock-out, and tag-out all electric switches controlling the electricity to the mine, when authorized by the person in charge.
- Maintain the communication infrastructure, both voice and data, on-site.
- Provide power connection needs of mine rescue equipment that arrives on-site.
- Arrange for any needed assistants.

Chief Mechanic – Duties of the chief mechanic may be:

- Check explosion doors (for exhausting fan) or weak wall (for blowing fan) for damage. Make sure explosion doors are closed or weak wall is repaired.
- Check fan and, if necessary, instruct an electrician or machinist to make repairs to the fan.
- Monitor the operation of the fan and the atmosphere in and around the fan house if the fan is exhausting.
- With an exhausting fan, proper precautions should be taken to avoid asphyxiation or an explosion in the fan house.

Mine Manager (Outside) – Duties of an outside manager may include:

- Arrange for guards and state and/or local police to:
    - Rope off and guard all mine openings.
    - Guard all roads and paths leading to the mine.
- Designate a check person to monitor people entering and leaving the mine. The check person should:
    - Attend to assigned station within the roped-off area.
    - Allow no one to go underground except persons authorized by the officials in charge.
    - Examine each person (entering the mine) for matches and smoking materials, making no exceptions.
    - Check off each person by name and number and record the time as they go in and come out of the mine.
- Set up an area where food and drinks are available for the rescue teams and other personnel.
- Set up medical facilities and make arrangements for sleeping quarters.

Safety Director – Duties of the safety director may include:

- Assemble mine rescue teams and first-aid crews.
- Provide facilities and equipment for testing, cleaning, and recharging the breathing apparatus.
- Assign personnel to issue, record, and return mine rescue equipment.
- Consult with the mine manager or superintendent regarding plans for rescue and recovery operations.

Chief Engineer – The chief engineer may perform the following duties:

- Provide copies of up-to-date maps (both hard copy and in electronic form) showing the regular flow of air and the location of ventilation controls, doors, pumps, substations, machinery, and the electrical system (with control switch locations).
- Alert adjoining mines if they are connected underground with the affected mine.
- Obtain maps of adjoining mines.
- Make arrangements to furnish drilling rig equipment, if needed.
- Direct surveyors to establish control points on the surface should drilling be necessary.

Supply/Warehouse Personnel – A supply person may be responsible for the following duties:

- Have ready for immediate use: nails, brattice cloth, hatchets, axes, saws, picks, boards, telephones, wires, any needed gas testing equipment, sledge hammers, slate bars, shovels, suitable roof supports, lifting jacks, stretchers, batteries, first- aid supplies as needed, and apparatus parts and supplies.
- Obtain and distribute all equipment, supplies, and non-sparking tools used for the operation.
- Prepare an inventory of existing equipment and supplies.
- Contact other mines and suppliers to obtain other needed supplies and equipment.
- Provide coveralls, safety shoes, gloves, caps, flashlights, safety glasses, and lamp belts.
- Keep a record of all equipment issued and returned.

Visuals

Sample Mine Emergency Notification Plan				
Contact	Name	Address	Telephone (Home)	Telephone (Office)
1. Mine Superintendent and Responsible Persons				
2. Mine Rescue Team Trainer				
3. Mine Rescue Team Members				
4. Mine Foreman				
5. Safety Director				
6. General Mine Manager				
7. General Mine Superintendent				
8. District Inspector (State and Federal)				
9. Chief, State Department of Mines				
10. District MSHA Office				
11. Miners' Representative				
12. Law Enforcement Agencies				
13. Medical personnel, ambulances, and other emergency vehicles				
14. Hospital to be alerted				

Visual 1: Sample Mine Emergency Notification Plan

SAMPLE SIX-TEAM ROTATION SCHEDULE
(24-Hour Period)

Team No. and Captain	Two-Hour Time Periods										
1	Work	R	R	Standby	Standby	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB
2	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB	Work	R	R	Standby	Standby
3	Standby	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB	Work	R	R	Standby
4	Standby	Standby	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB	Work	R	R
5	R	Standby	Standby	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB	Work	R
6	R	R	Standby	Standby	Backup at FAB	Work	R	R	Standby	Standby	Backup at FAB	Work

NOTE: This schedule is a sample of how six teams could be rotated during a 24-hour period. If a larger number of teams are available, the schedule of rotation would, of course, be different.

R = Reserve FAB = Fresh Air Base

Visual 2: Sample Six-Team Rotation Schedule

Glossary

Backup team – The rescue team stationed at the FAB as a “backup” for the working team beyond the FAB.

Bench area – An area where apparatus is cleaned, tested, and prepared for use.

Chain-of-command – Order of authority and division of responsibilities among personnel.

Command Center – Headquarters for the rescue and recovery operation.

Emergency Response Plan – An accident response plan shall -

(i) provide for the evacuation of all individuals endangered by an emergency; and

(ii) provide for the maintenance of individuals trapped underground in the event that miners are not able to evacuate the mine.

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

Mine’s emergency notification plan – Plan for notifying necessary personnel when there is an emergency at the mine.

Rotation schedule – Schedule that establishes a clear order of team usage during a rescue and recovery operation.

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

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

Advanced
Mine Rescue Training - Coal

Module 2
Mine Gases

Module 2 – Mine Gases

Contents

Course Objectives

The mine rescue team members will distinguish the physical properties and characteristics of gases they may encounter during rescue and recovery work.

They will explain where the gases are normally found, conduct tests for dangerous gases, and interpret their findings.

Team members will:

- Use these concepts: Specific gravity, explosive range, toxicity, asphyxiate, and solubility.
- Explain the physical properties and characteristics of each gas they may encounter following a fire, explosion, inundation, or other disaster.
- Analyze the mine for locations where such gases might be found, conduct tests to detect them, and explain the meanings of their findings.
- Explain the composition, physical properties, and characteristics of smoke, rock strata gases, and the damps.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member
- Gas detecting equipment and devices the team will use to test gases they encounter in the mine, and the manufacturer's instructions
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams

Suggested:

- Evacuated bottle or syringe for taking air samples
- Laptop computer
- PowerPoint program
- Chalkboard or flipchart

NOTE: In addition to these materials, you are encouraged to incorporate any other up-to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction
   a. Gas Detection
   b. Gas Detector Requirements
   c. Portable Gas Detectors
   d. Air Sampling and Chemical Analysis
   e. Sampling Locations

II. Basic Gas Principles
   a. Description
   b. Diffusion of Gases
      i. Atmospheric Pressure and its Effects on Rate of Diffusion
      ii. Temperature and its Effects on Rate of Diffusion
      iii. Specific Gravity or Relative Weight
   c. Explosive Range and Flammability
   d. Solubility
   e. Color/Odor/Taste
   f. Health Hazards
      i. Toxic Gases
      ii. Asphyxiating Gases

III. Mine Gases and Their Detection
   a. Oxygen
   b. Carbon Dioxide
   c. Methane
   d. Carbon Monoxide
   e. Nitrogen
   f. Oxides of Nitrogen
      i. Nitric Oxide
      ii. Nitrogen Dioxide

g. Hydrogen
h. Hydrogen Sulfide
i. Sulfur Dioxide
j. Heavy Hydrocarbons
    i. Ethane
    ii. Propane
    iii. Butane
k. Acetylene
l. Radon

IV. Smoke, Rock-Strata Gases, and the Damps
a. Smoke
b. Rock-Strata Gases
c. Damps

Instructional Text

Introduction

Under normal conditions, many gases are present in a mine. The mine's ventilation system is designed to bring in fresh air to disperse and remove harmful gases and to supply oxygen. During a disaster, however, the situation may be quite different. Fires or explosions may release dangerous gases into the atmosphere. A disrupted ventilation system could result in an oxygen-deficient atmosphere and/or a buildup of toxic or explosive gases.

Gas Detection

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 FAB. 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

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 Section 49.16(a)(6)).**

Portable Gas Detectors

The type of gas detection equipment most often used by mine rescue teams is the portable gas detector. Portable gas detectors include such devices as electronic instruments that provide direct readings of gas concentrations and pumps used in conjunction with various stain tubes.

Multi-gas detectors are direct reading instruments that monitor several gases at once: typically methane, oxygen, carbon monoxide, or other mine gases. The multi-gas detectors the team uses should also be equipped with sensors to detect other gases encountered at their mine. The team uses these devices to test the mine atmosphere repeatedly as it advances beyond the FAB.

NOTE: Show the team the portable gas detectors they may be using.

Air Sampling and Chemical Analysis

Another way to test for gases is to collect air samples in special syringes, sample bags, evacuated bottles (bottles from which air has been removed) or gas or liquid displacement containers.

A sample pump is needed to fill sample bags. These samples are then sent to a laboratory for analysis. Analysis is sometimes performed at the mine site with portable equipment.

NOTE: Show the team a syringe, evacuated bottle, or sample bag, if available, or the graphic provided **(Visual 2).**

Chemical analysis is generally a more time-consuming process than testing with a portable device, but its advantage is accuracy. It tells exactly what gases the sample contains, and in precisely what amounts. A complete chemical analysis can also reveal the presence of gases that portable detectors are not designed to detect.

Air samples aren't taken as often as portable detector readings, but they're still an important part of rescue and recovery operations. For example, you may be required to take air samples from ventilation shafts and return airways.

This method is often used to get information about existing conditions prior to sending teams underground. Air samples taken from behind sealed areas of the mine are analyzed to determine when it's safe to begin recovery work.

NOTE: Any air samples collected by the Team Members should include the name of the person collecting the sample, the location it was collected, date of collection, time of collection, the hand held readings measured (at the same time) in location the sample was drawn.

Sampling Locations

In many cases, you will be monitoring the main fan exhaust or main return. It is important to obtain these samples as soon after the event as possible. This will help to trend the progression of the event. Another typical sampling location is as near to the undiluted return side of a fire as possible. In some mines, boreholes, rock dust holes, and other openings into the mine will provide surface access to sampling locations. Boreholes can be drilled directly into affected areas and sampling lines can be lowered into the mine atmosphere. It is expected that sampling locations will be revised as firefighting and recovery operations progress.

Surface sampling equipment should be set up in a location protected from the elements and safe from the effects of a possible explosion or contaminants emitted from within the underground workings. A rule of thumb is to keep at least 1000 feet away from any mine opening when there is a concern about an explosion. Remember that you are often pumping noxious gases through the sampling equipment. The area should be well ventilated to avoid accumulations of explosive or harmful gases. Always discharge the sample stream from the pump outside any sampling enclosure. The discharge ends should be run a minimum of 50 feet from the pump to a ventilated area where no sparking/fire hazards exist A multi-gas detector must be operated continuously within any enclosure to ensure safe working conditions.

Underground sampling can be performed by a permissible sampling pump or an AC powered pump. If using an AC pump, it must be located in intake air. For an illustration of the pump sampling system refer to **Visual 3.**

Basic Gas Principles

In order to test for gases and to understand what the test readings mean, you should first know a little about the characteristics and properties of gases. After we've discussed these general principles, we'll talk about specific gases you may encounter during rescue and recovery work.

Description

To help you understand what a gas is, let's compare it with a liquid and a solid. A solid has a definite shape and volume. A liquid has a definite volume, but changes shape according to the shape of its container. However, a gas is a substance with neither a definite shape nor volume. It expands or contracts to fill the area in which it's contained.

Diffusion of Gases

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.

NOTE: Refer to Visual 4.

The gas's rate of diffusion is also affected by the ventilating air currents in the mine. The rate of diffusion is greatly increased by higher velocities of air currents or by turbulence in the air.

Knowing the effects of air current, temperature, and pressure on a gas will help you determine its rate of diffusion. The rate of diffusion is how quickly the gas will mix or blend with one or more other gases and how quickly it can be dispersed.

Atmospheric Pressure and its Effects on Rate of Diffusion

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.

NOTE: Refer to **Visual 5** for an illustration of the effects of atmospheric pressure on a gas.

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

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.

NOTE: Refer to Visual 6 for an illustration of the effects of temperature on a gas.

Specific Gravity or Relative Weight

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.

NOTE: Refer to **Visual 7**.

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.

NOTE: In this module, specific gravities **are carried out to four digits.** You may wish to round these numbers off to make them easier to work with.

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.

NOTE: Refer again to **Visual 4 and Visual 5**, as you review the effects of temperature and pressure on rate of diffusion.

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

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

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

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

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.

NOTE: Refer to Visual 8 as you discuss the factors that determine the effects of a toxic gas.

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

NOTE: You may wish to mention that each toxic gas has a **Threshold Limit Value (TLV).** TLVs denote average concentrations of gases to which workers are permitted to be exposed over an 8-hour daily period. The Threshold Limit Value (TLV) of a gas is expressed in **"parts per million" (PPM).**

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 (CO2) is higher—5,000 PPM (.500 percent). You can tolerate concentrations of up to ½ of 1 percent CO2 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-face piece 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

"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

Ask the team members the following questions and allow time for them to answer. Then discuss the answers with them so they understand the material covered in this section.

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?
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

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.

Mine Gases and Their Detection

NOTE: Refer to **Visuals 9 through 11,** as you discuss mine gases and detection methods. Make copies of each visual and distribute them to the team members. If the team may encounter a gas that's **<u>not</u> included here**, be sure to supply them with information on that gas.

Normal Air

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.

NOTE: Refer to the pie chart **(Visual 9)** showing the composition of normal air.

Air is normally colorless, tasteless, and odorless. It supplies us with the oxygen necessary for life. However, during the day-to-day operations of a mine, normal air can become contaminated. For example, the carbon dioxide and water vapors miners exhale during respiration are contaminants.

Forces exerted on the mine's roof, rib, floor, and face during blasting may allow trapped gas pockets to escape into the mine air. Blasting may also produce pollutants such as carbon monoxide, hydrogen sulfide, and oxides of nitrogen.

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.

The gases present in a mine following a disaster will vary according to the type of mine and the disaster situation. The type of equipment used in the mine (electrical, compressed air, or diesel) will also affect which gases are present. However, for all mines, rescue teams must know how to test for oxygen deficiency and carbon monoxide.

In addition to this, the teams may have to know how to test for hydrogen sulfide, oxides of nitrogen, and so on. You should know how to test for all the gases that may be present in the mines in which you will be working as a mine rescue team.

NOTE: Refer to **manufacturer's instructions and recommendations** for the use and maintenance of specific testing devices. It's suggested that you discuss gas-testing equipment and devices **only** **after** you've discussed all the gases the team may encounter.

Oxygen (O_2)

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.

For example, you're accustomed to breathing air containing about 21 percent oxygen. When the oxygen content of air drops to about 17 percent, you'll begin to breathe faster and deeper because your body is trying to compensate for the lack of oxygen. A 15 percent concentration will cause dizziness and headaches. If the oxygen content of the air you're breathing drops as low as 9 percent, you may lose consciousness. A 6 percent concentration or less is almost always fatal.

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.

Solubility. Moderately soluble in water.

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

Cause or Origin. Oxygen is the second largest component of normal air. About 21 percent of normal air is oxygen.

Detection Methods. Modern electronic oxygen indicators are used to detect oxygen-deficient atmospheres. Hold your portable detector below waist level when you test for oxygen deficiency. Chemical analysis will also detect oxygen deficiency.

When to Test. During exploration, test as often as necessary to determine whether the atmosphere is oxygen-deficient.

Meaning of Findings. If the fan is still operating, an oxygen-deficient atmosphere could indicate that an explosion has taken place, or that a fire somewhere in the mine is consuming oxygen. Oxygen deficiency may also indicate that the mine's ventilation system has been disrupted. Very low oxygen levels reduce the possibility of methane explosions.

Carbon Dioxide (CO_2)

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.

Where Found. Because it's relatively heavy, CO_2 will be found in greater concentrations along the floor and in low places in the mine. It also often shows up in abandoned workings, during fires, and after an explosion or detonation of explosives.

Detection Methods. You can use a carbon dioxide detector, a multi-gas detector, or chemical analysis to test for carbon dioxide. Because CO_2 tends to collect near the mine floor, hold your portable detector low.

When to Test. Test for CO_2 after a fire or explosion. Also test for it when you're entering an inactive area of the mine or reopening a sealed area.

Meaning of Findings. Elevated CO_2 readings may indicate that a fire or explosion has taken place somewhere in the mine. High readings may also indicate an oxygen- deficient atmosphere.

Methane (CH_4)

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.

NOTE: Cold dry air from outside a mine will be warmed as it goes through the mine. Warm air will hold more water vapor than cool air, so therefore it picks up moisture from inside the mine. This will cause a dry condition in the mine even though the humidity is higher underground than on the surface.

Health Hazards. Methane is not toxic. In high concentrations, however, it can cause asphyxiation by lowering the oxygen content of normal air. The most dangerous aspect of methane is the fact that it is explosive.

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.

Where found. Because methane is relatively light, it collects in high places, so you can expect to find it in roof areas of the mine. You'll also normally find it at freshly cut faces, in poorly ventilated areas, and in abandoned or unused sections of the mine.

Other Information. There is usually more methane in deep workings than at the outcrop.

Deeper mines also usually contain more methane than shallow ones, and shaft mines contain more methane than drift mines.

You can expect to find more methane in coal beds that are adjoined by tight, compact strata than in coal beds adjoined by loose or porous strata. Methane is also a problem in areas of faulting of the coal seam.

You'll generally also find more methane in regions where the strata is uniform and unbroken rather than where the strata is folded or broken. Mines below the water table tend to have more methane than those above the water table. Because it is a relatively light gas (low specific gravity), methane is usually easy to disperse and remove from the mine by means of ventilation.

Detection Methods. To test for methane, use a methane detector or chemical analysis. Remember that methane is a light gas, so hold your portable detector high. Don't rely on the low range reading from a methane detector in low oxygen, it won't read correctly as it needs oxygen to function.

Where to Test. During any team exploration, test as often as necessary to determine the methane content of the surrounding atmosphere. Also test for methane when normal ventilation is disrupted, and when you are entering abandoned workings.

Meaning of Findings. If methane is present, it's important to monitor it carefully because it is potentially explosive if there is enough oxygen present. If methane exists in potentially explosive concentrations or in combination with other gases or coal dust that extend its explosive range, your team may be required to leave the mine.

Carbon Monoxide (CO)

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.

Carbon monoxide is produced by the burning or detonation of explosives, and it is emitted from the exhaust of internal combustion engines.

NOTE: You may wish to mention that carbon monoxide is the deadly gas associated with automobile exhausts.

Where Found. Carbon monoxide is found during mine fires and after explosions or detonations of explosives. It can also usually be detected near internal combustion engines.

Detection Methods. Carbon monoxide can be detected by means of carbon monoxide detectors, multi-gas detectors, or by chemical analysis. Since CO is slightly lighter than air, hold your portable detector at chest level.

When to Test. During any team exploration, test as often as necessary to determine the atmosphere's CO content, especially if fire is suspected.

Meaning of Findings. The presence of CO for a continued period of time definitely indicates there is a fire somewhere in the mine.

Nitrogen (N_2)

Specific Gravity. 0.9674

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.

Where Found. You can expect to find elevated nitrogen readings at the face areas because they adsorb oxygen. Increased nitrogen levels are often present after explosives have been detonated.

Detection Method. Chemical analysis.

When to Test. Test for nitrogen when you suspect that the atmosphere is oxygen- deficient, and in abandoned or inactive workings where ventilation is inadequate. Also test for it in mines where nitrogen is known to issue from rock strata.

Meaning of Findings. An elevated nitrogen content indicates an oxygen-deficient atmosphere.

Oxides of Nitrogen

Nitric Oxide (NO), Nitrogen Dioxide (NO_2 or N_2O_4)

Specific Gravity. (NO_2) – 1.5894

Explosive Range and Flammability. NO_2 will neither burn nor explode.

Health Hazards. Oxides of nitrogen are highly toxic. Breathing even small amounts will irritate your throat.

When mixed with the moisture in your lungs, oxides of nitrogen form acids that corrode your respiratory passages and cause them to swell. Often, such symptoms don't show up until several hours after you're exposed to the gas.

Exposure to .01 to .015 percent can be dangerous for even short exposures, and .02 and .07 can be fatal for short exposures. If exposure has been severe, the victim may die, literally drowned by water that has entered the lungs from the body in an attempt to counteract the corrosive effects of the acids formed by the oxides of nitrogen.

Solubility. Very slight solubility in water.

Color/Odor/Taste. Oxides of nitrogen are colorless at low concentrations and become reddish-brown at higher concentrations. They smell and taste like blasting powder fumes.

Cause or Origin. Oxides of nitrogen are produced by burning and by the detonation and burning of explosives. They are also emitted from the exhaust of diesel engines. In the presence of electrical arcs or sparks, nitrogen in the air combines with oxygen (oxidizes) to form oxides of nitrogen.

Where Found. Because they're heavier than air, oxides of nitrogen tend to collect in low places in the mine. They can be found when electrical malfunctions produce arcs or sparks, and after blasting operations.

Detection Methods. To test for nitrogen dioxide or nitric oxide, you can use a multi-gas detector, stain tubes, or chemical analysis.

Hold portable detectors low when you test for these relatively heavy gases. Their characteristic reddish-brown color may be another indication that there is nitrogen dioxide present.

When to Test. Test for oxides of nitrogen following a fire or explosion and after the detonation of explosives. Since diesel exhaust is a source of these gases, test in areas where diesel equipment is used.

Meaning of Findings. High NO_2 readings could indicate there has been a fire or that explosives are burning. Malfunctioning electrical equipment producing arcs or sparks could also be the source. If diesel equipment is causing the elevated NO_2 readings, that indicates ventilation is inadequate.

Hydrogen (H_2)

Specific Gravity. 0.0695

Explosive Range and Flammability. Hydrogen is a highly explosive gas. Air containing 4 to 74.2 percent hydrogen will explode even when there is as little as 5 percent oxygen present. Very violent explosions are possible when air contains more than 7 to 8 percent hydrogen. The presence of small quantities of hydrogen greatly increases the explosive range of other gases.

Health Hazards. At high concentrations, hydrogen can replace oxygen in the air and act as an asphyxiant. The most hazardous aspect of hydrogen, however, is the fact that it is highly explosive.

Solubility. Not soluble in water.

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

Cause or Origin. Hydrogen is produced by the incomplete combustion of carbon materials during fires and explosions. It may also be liberated when water or steam comes in contact with hot carbon materials during firefighting. Battery charging also produces hydrogen.

Where Found. You can expect to find hydrogen in the vicinity of battery charging stations, where explosives have been detonated, and after explosions. Hydrogen may also be detected during firefighting when either water or foam extinguishing methods are used. You can also expect to find hydrogen in an area that's been sealed to extinguish a fire. Because hydrogen is relatively light, it tends to collect in high places.

Detection Methods. Hydrogen can be detected with a multi-gas detector, stain tubes, or by means of chemical analysis. Hold portable detectors high.

When to Test. Test for hydrogen after any fire or explosion and near battery charging stations in the mine. Also test for it when water, water mists, or foam is used to fight fires.

Meaning of Findings. The presence of hydrogen could indicate that a fire or explosion has taken place. Firefighting with water or foam could also be producing the hydrogen. Elevated readings could also indicate that there is inadequate ventilation around battery charging stations.

Hydrogen Sulfide (H_2S)

Specific Gravity. 1.1906

Explosive Range and Flammability. Hydrogen sulfide is flammable and explosive in concentrations from 4.3 to 45.5 percent in normal air. It is most explosive at 14.2 percent.

Health Hazards. Hydrogen sulfide is one of the most poisonous gases known. In low concentrations (.005 to .010 percent), hydrogen sulfide causes inflammation of the eyes and respiratory tract. Slightly higher concentrations (.02 to .07 percent) can lead to bronchitis or pneumonia. Higher concentrations (.07 to .10 percent) can cause rapid unconsciousness, cessation of respiration, and death. And .10 to .20 percent or more can cause rapid death.

Solubility. Soluble in water.

Color/Odor/Taste. Hydrogen sulfide is colorless, has the odor of rotten eggs, and a slight sweetish taste.

Cause or Origin. Hydrogen sulfide is produced when sulfur compounds decompose. It is found in certain oil and gas fields and in some gypsum mines. It also may be liberated from methane feeders in mines with methane.

Hydrogen sulfide is often liberated when acid mine water corrodes metallic sulfides. It can also be released from mine water which contains the gas in solution. Heating sulfides in the presence of moisture (as in mine fires may also produce the gas.

Blasting in sulfide ores can also liberate hydrogen sulfide.

Where Found. Hydrogen sulfide is found in low places of the mine because it is a relatively heavy gas. It's also often found in pools of water. In some mines, it may be found near oil or gas wells. Hydrogen sulfide may also be detected during mine fires. Since it is a water-soluble gas, hydrogen sulfide is often liberated from water in sealed areas of the mine when recovery crews walk through the water or begin pumping operations.

Detection Methods. You can test for hydrogen sulfide with a hydrogen sulfide detector, a multi-gas detector, stain tubes, and by chemical analysis. Because H2S is relatively heavy, hold your portable detector low (close to the mine floor) when testing for this gas. You may recognize H2S by its distinctive "rotten egg" odor. However, continued exposure to the gas will dull your sense of smell, so this may not always be a reliable detection method. Eye irritation is another indication that hydrogen sulfide is present.

When to Test. Test for hydrogen sulfide in poorly ventilated areas of the mine, during unsealing operations, and following mine fires.

Meaning of Findings. A buildup of hydrogen sulfide could indicate that ventilation is inadequate. It may also be produced by seepage from an oil or gas well. The presence of hydrogen sulfide might also indicate that excess water is accumulating in sealed or inaccessible areas of the mine.

Sulfur Dioxide (SO_2)

Specific Gravity. 2.2638

Explosive Range and Flammability. Will not burn or explode.

Health Hazards. Sulfur dioxide is a very toxic, irritating gas that is dangerous even in small concentrations; as little as 0.04 to 0.05 percent is dangerous to life. Even very tiny amounts of sulfur dioxide (.001 percent or less) will irritate your eyes and respiratory tract. Larger concentrations can cause severe lung damage and may cause respiratory paralysis and the complete inability to breathe.

Solubility. Highly soluble in water. (Sulfur dioxide is one of the most soluble gases found in mines.)

Color/Odor/Taste. Sulfur dioxide is colorless, but it has a bitter, acid taste and a strong sulfurous odor.

Cause or Origin. Sulfur dioxide may be produced by blasting in sulfide ores and by fires containing iron pyrite (commonly known as “fool’s gold”). Sulfur dioxide may be released during the burning of some diesel fuels and by sulfide ore dust explosions.

Where Found. Because it is relatively heavy, sulfur dioxide tends to collect in low places in the mine and near sumps. You can expect to find it after some fires or explosions.

Other Information. Because of its high specific gravity, sulfur dioxide is hard to disperse by ventilation.

Detection Methods. You may test for sulfur dioxide by means of a multi-gas detector, stain tubes or by chemical analysis. Because sulfur dioxide is a relatively heavy gas, hold portable detectors low (close to the mine floor) when you test for it. Sulfur dioxide’s distinctive odor and taste, and the respiratory tract and eye irritation you’ll experience when exposed to it are also reliable indicators of its presence.

When to Test. Because it’s highly soluble in water, test for sulfur dioxide when stagnant water is disturbed. Test for this gas following fires or explosions, and when sealed areas of the mine are opened after mine fires.

Meaning of Findings. High SO_2 readings could indicate a mine fire or a sulfide ore dust explosion.

Heavy Hydrocarbons

Ethane (C_2H_6) Propane (C_3H_8) Butane (C_4H_{10})

Specific Gravity.

- Ethane - 1.0493
- Propane - 1.5625
- Butane - 2.0100

Explosive Range and Flammability.

- Ethane – from 3 to 12.5 percent in normal air.
- Propane – from 2.12 to 9.35 percent in normal air.
- Butane – from 1.86 to 8.41 in normal air.

Health Hazards. These gases are not toxic. At high concentrations they can displace enough oxygen to cause death by asphyxiation, but you'll rarely find them in such high concentrations in mines.

Solubility. All three are slightly soluble in water.

Color/Odor/Taste. All three are colorless and tasteless. In certain concentrations, propane and butane may produce a characteristic "gassy" odor. Ethane is odorless.

Cause or Origin. After mine fires, small concentrations of these gases are often detected along with methane in mines that have methane. They also sometimes leak from gas or oil wells.

Where Found. The heavy hydrocarbons are often found in mines adjacent to oil or gas wells. Because they are heavy, these gases collect in low areas of the mine.

Detection Methods. You can detect ethane, propane, and butane with a portable detector or by chemical analysis. Because these gases are combustible, they will register on low range methane detectors, however the readings will not be accurate. Because these gases are relatively heavy, hold your portable detector low (close to the mine floor) when you test for them.

When to Test. Test for these gases following fires or explosions when methane is present. You should also test for the heavy hydrocarbons if oil or gas casings are accidentally entered during mining operations.

Meaning of Findings. In significant concentrations, the heavy hydrocarbons can extend methane's explosive range if the mine has methane. Elevated readings could indicate there has been a methane explosion, if this is possible in the mine, or that there is seepage from an adjacent gas or oil well.

Acetylene (C_2H_2)

NOTE: For some mines, acetylene will not be a potential problem. Therefore, teach this material only if necessary.

Specific Gravity. 0.9107

Explosive Range and Flammability. Acetylene is combustible but it will not support combustion. Its explosive range in normal air is 2.5 to 80 percent.

Health Hazards. Acetylene is slightly toxic. In high concentrations, it can cause asphyxiation by depleting the oxygen in the atmosphere.

Solubility. Slightly soluble in water.

Color/Odor/Taste. Acetylene is colorless and tasteless. It has a slight garlic odor.

Cause or Origin. Acetylene is formed when methane is burned or heated in air having low oxygen content.

Where Found. Acetylene is found after methane explosions in air having low oxygen content.

Detection Methods. Test for acetylene with stain tubes or by chemical analysis. You may also recognize it by its characteristic garlic odor. Since acetylene's specific gravity is near that of normal air, hold portable detectors at chest level.

When to Test. Test for acetylene after a methane explosion in air that is oxygen deficient.

Meaning of Findings. The presence of acetylene could indicate that an explosion has taken place in an area with low oxygen content, such as in a sealed area.

Radon (Rn)

Specific Gravity. 7.526

Explosive Range and Flammability. Nonexplosive and nonflammable.

Health Hazards. Radon is not toxic. However, radon and radon daughters—a decay product of radon—are radioactive and emit radiation. Continued exposure to high levels of these gases has been linked to the incidence of lung cancer. Mines are required to keep exposure to radiation below 4 Working Level Months (WLM) per year. The exposure for any one month is limited to one WLM.

NOTE: The working level is a measure of the potential alpha particle energy of radon daughters in the mine atmosphere.

Solubility. Radon is highly soluble in water.

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

Cause or Origin. Radon is a gaseous decay product of the uranium series and is found in all uranium mines. It can also be liberated, but to a lesser extent, from almost any rock or soil. As radon is liberated into a mine atmosphere, it continues to decay and forms airborne particles the size of atoms called radon daughters.

Radon daughters are particularly dangerous. They adhere to respirable dust, and can be inhaled with the dust. Once inhaled, they become deposited in the lungs where they continue to decay, giving off radiation and damaging lung tissue. Radiation can also be absorbed by the skin. If the radiation hazard in an area is very high, breathing protection and protective clothing may be required.

Where Found. Radon is mostly found in uranium mines. Stagnant air carries heaviest concentrations. Also, pools of water will carry radon. Radiation levels can jump extremely fast when ventilation is disrupted.

Detection Methods. Survey meters are used to sample particulate matter in the air on a scheduled basis. Dosimeters can be used to monitor an individual's exposure. They can be worn by the miners.

When to Test. Regular tests are required in uranium mines. Tests should be made when ventilation is disrupted and when opening a sealed area.

Meaning of Findings. Excessive readings would indicate a disruption of ventilation.

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.

NOTE: Smoke from burning conveyor belts or cable insulation also contains toxic substances produced by the decomposition of Neoprene. These are **very toxic when inhaled.** For more information on these gases, refer to **Module 5 –** ***Fires, Firefighting, and Explosions.***

Rock Strata Gases

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

“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.

NOTE: The word “damp” comes from the German word “dampf,” which means “vapors or gases.”

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.

NOTE: Discuss the explosive ranges of the gases that are a problem at **the mine or mines your team will be serving.**

REVIEW QUESTIONS

Ask the team members the following questions and allow time for them to answer. Discuss the correct answers with them so they fully understand the material covered in this section.

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.

NOTE: Discuss the explosive ranges of the gases that are a problem at **the mine or mines your team will be serving.**

ANSWER SHEET

1.

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.

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%

NOTE: Discuss the explosive ranges of the gases that are a problem at **the mine or mines your team will be serving.**

3.

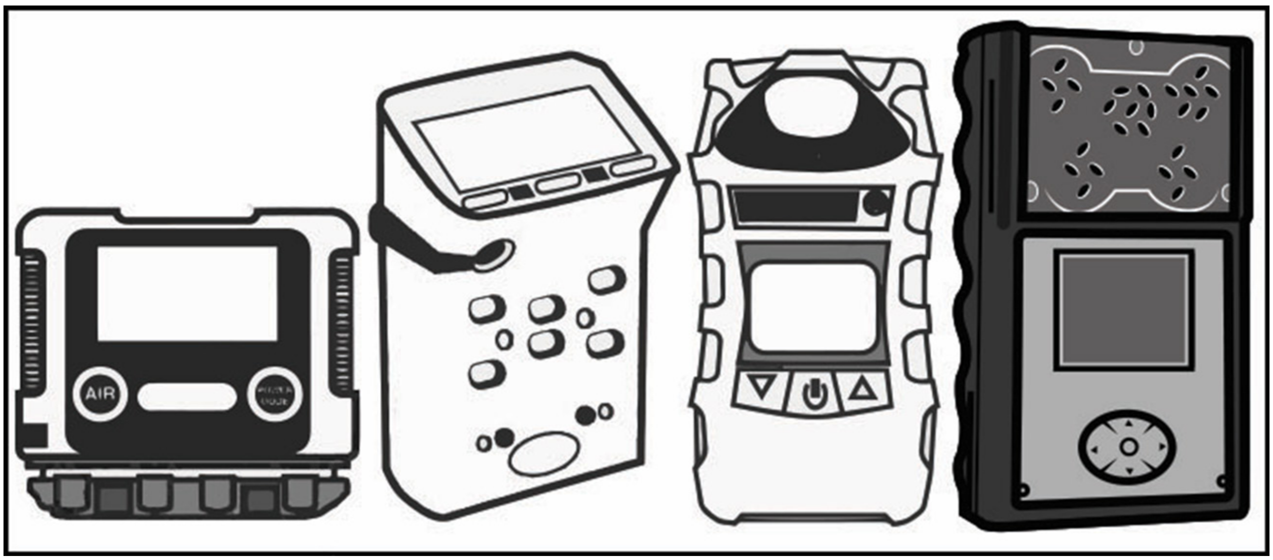
1) Carbon dioxide—acid taste in high concentrations.
2) Nitrogen dioxide—reddish brown in higher concentrations, odor and taste of blasting powder fumes.
3) Hydrogen sulfide—rotten egg odor (however, continued exposure deadens your sense of smell), slight sweetish taste.
4) Sulfur dioxide—sulfur odor,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

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

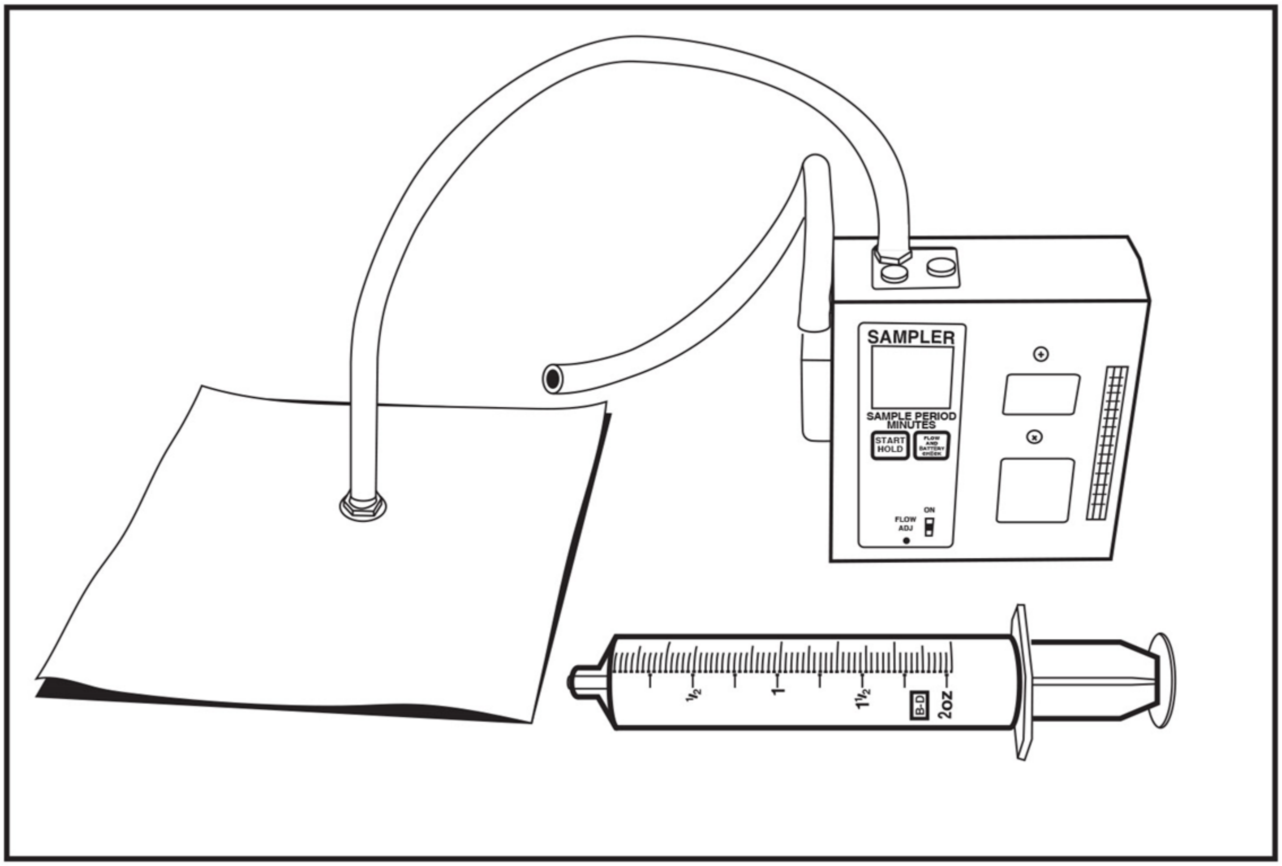
5.

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.

Visuals

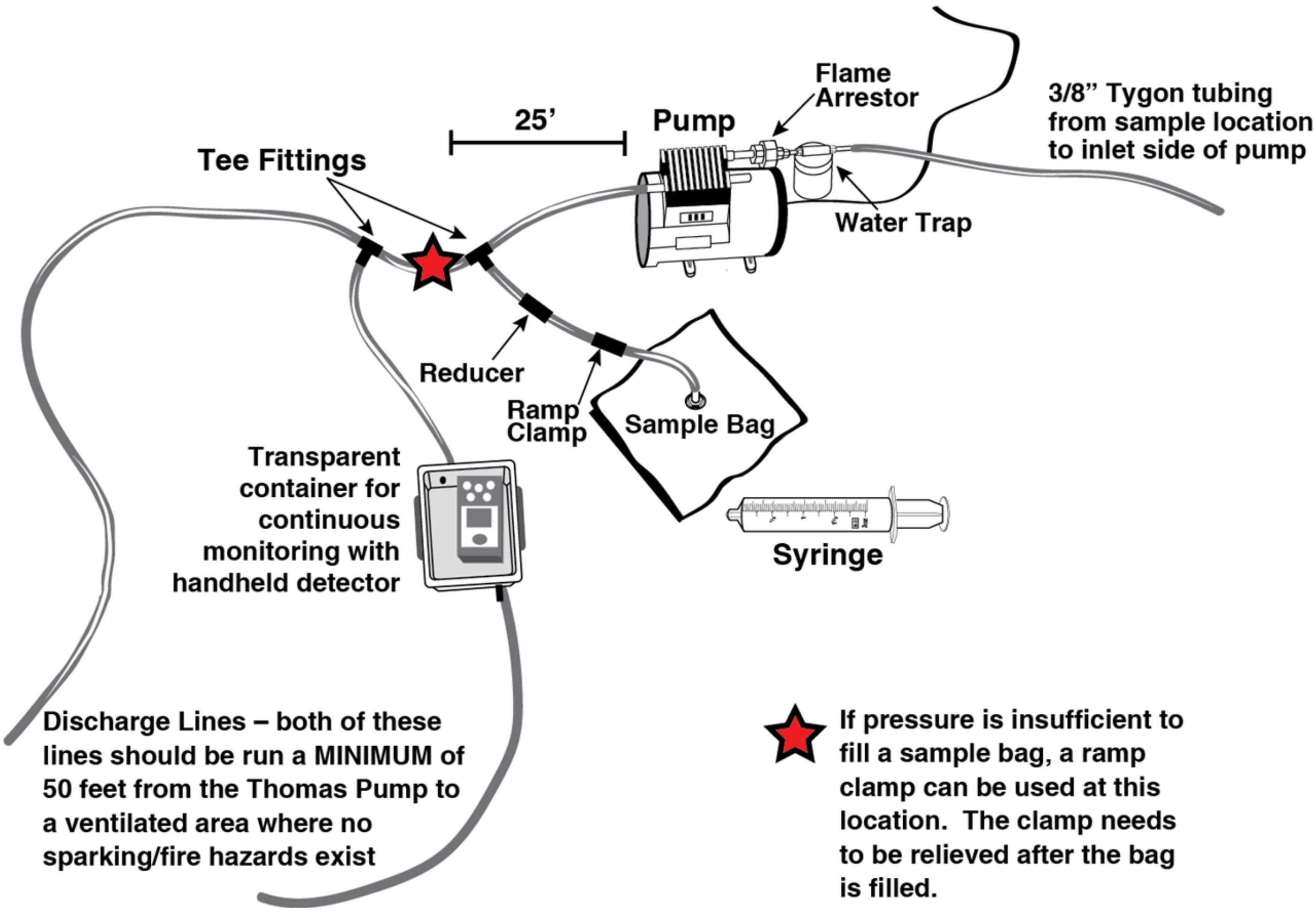


Visual 1: Gas Detectors



Sample Bag, Sampler Pump and 60mm Syringe

Visual 2: Gas Sampling



Visual 3: Sampling Setup

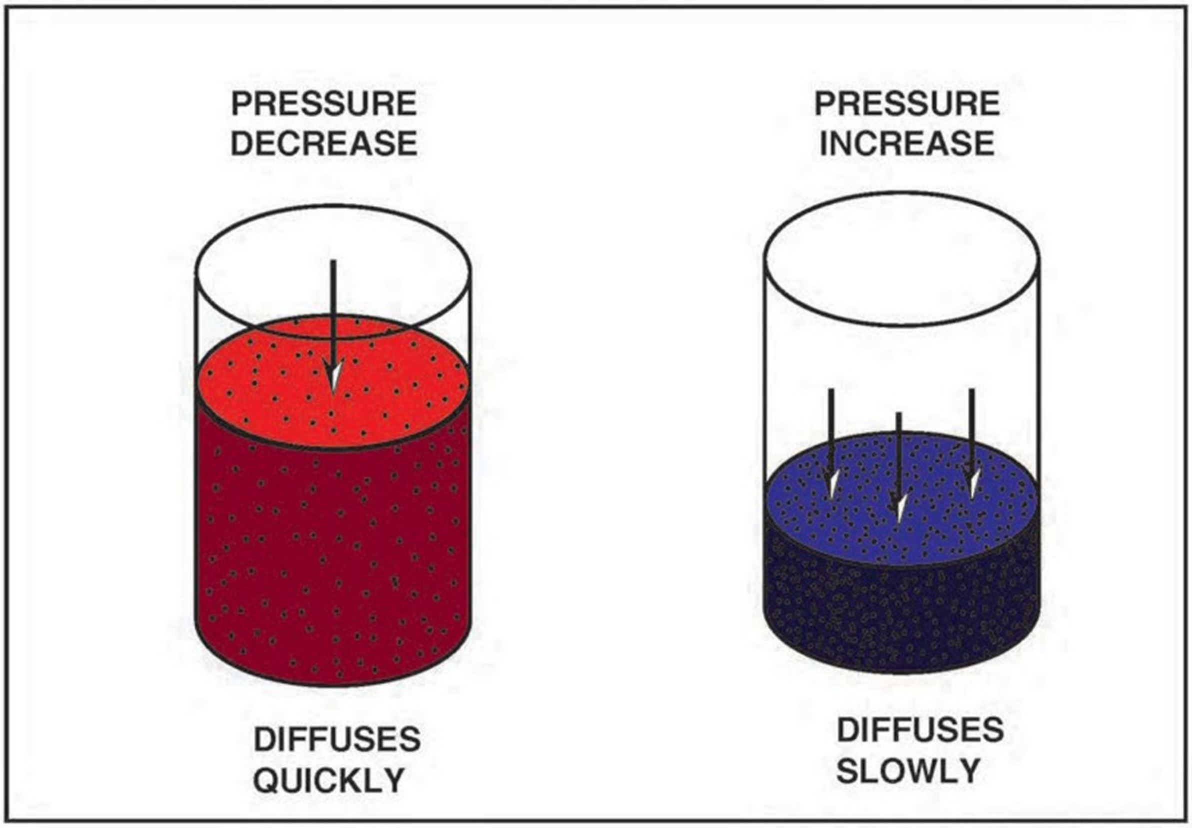
Effects of Temperature and Pressure

Pressure increases – gas contracts
Pressure decreases – gas expands

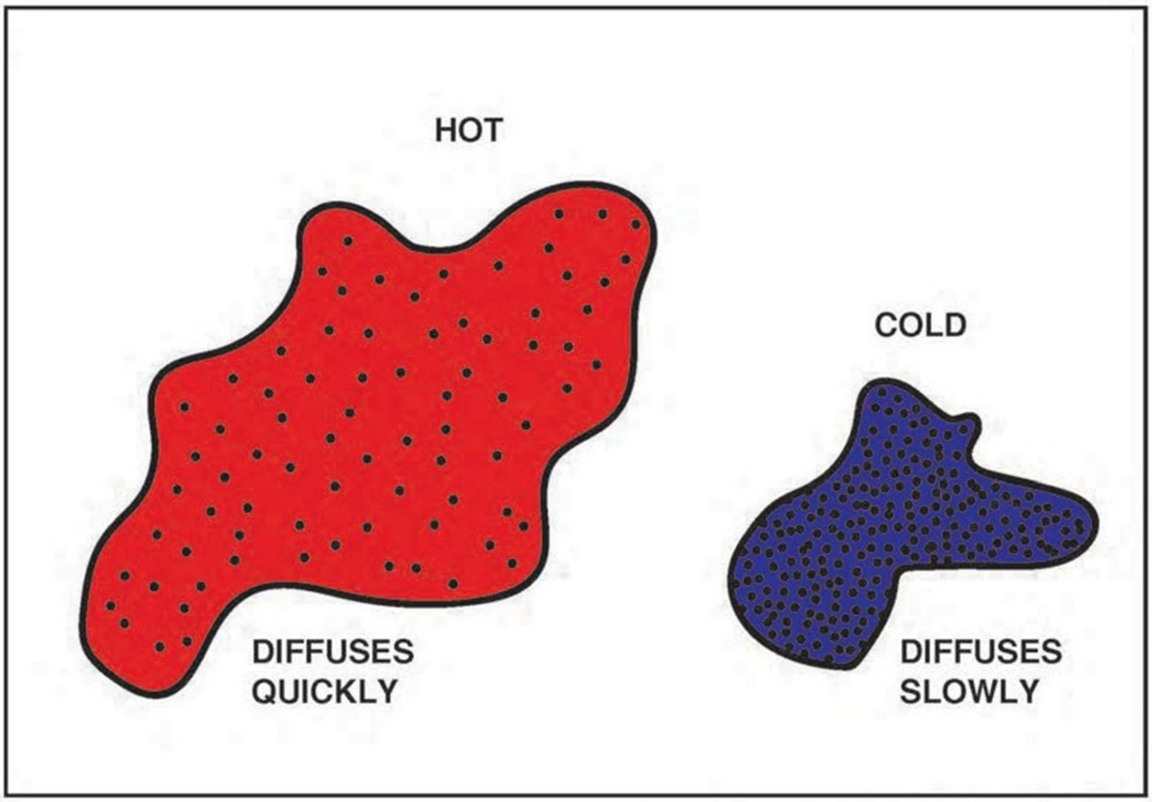
Temperature increases – gas expands

Temperature decreases – gas contracts

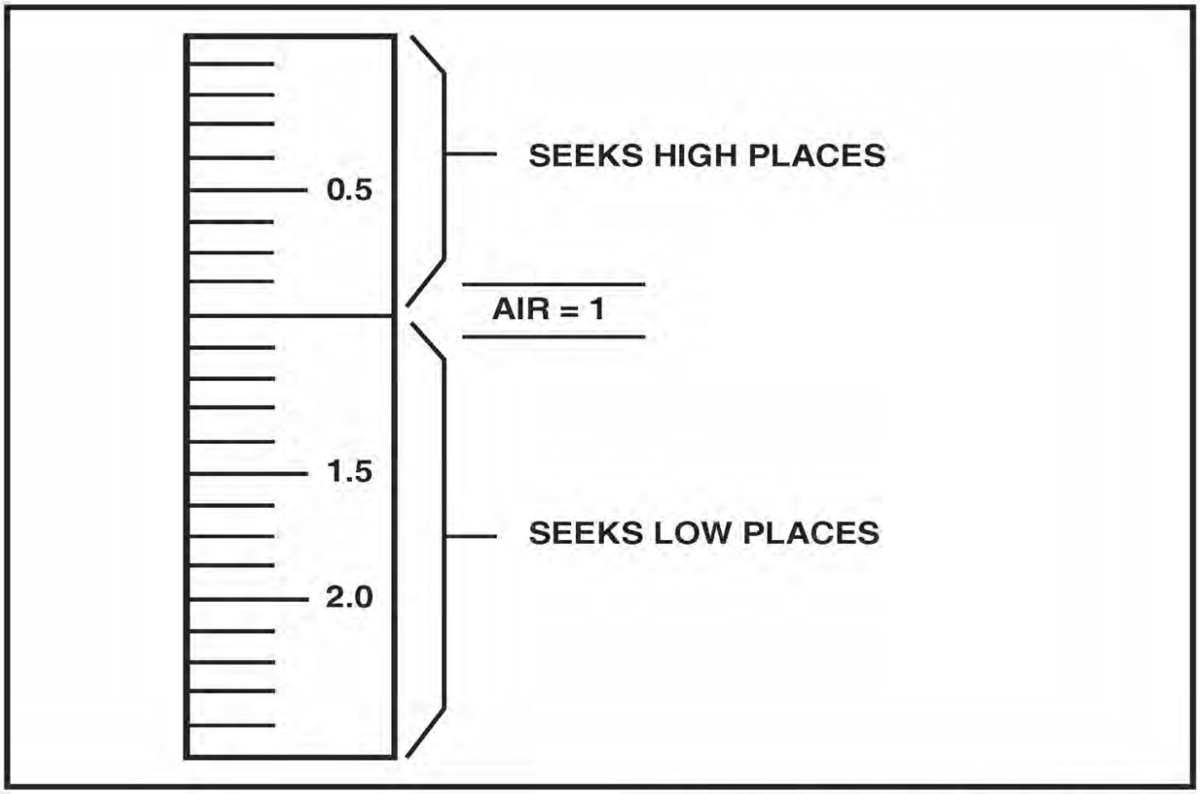
Visual 4: Effects of Temperature and Pressure on Gas



Visual 5: Effects of Pressure on Gas



Visual 6: Effects of Temperature on Gas

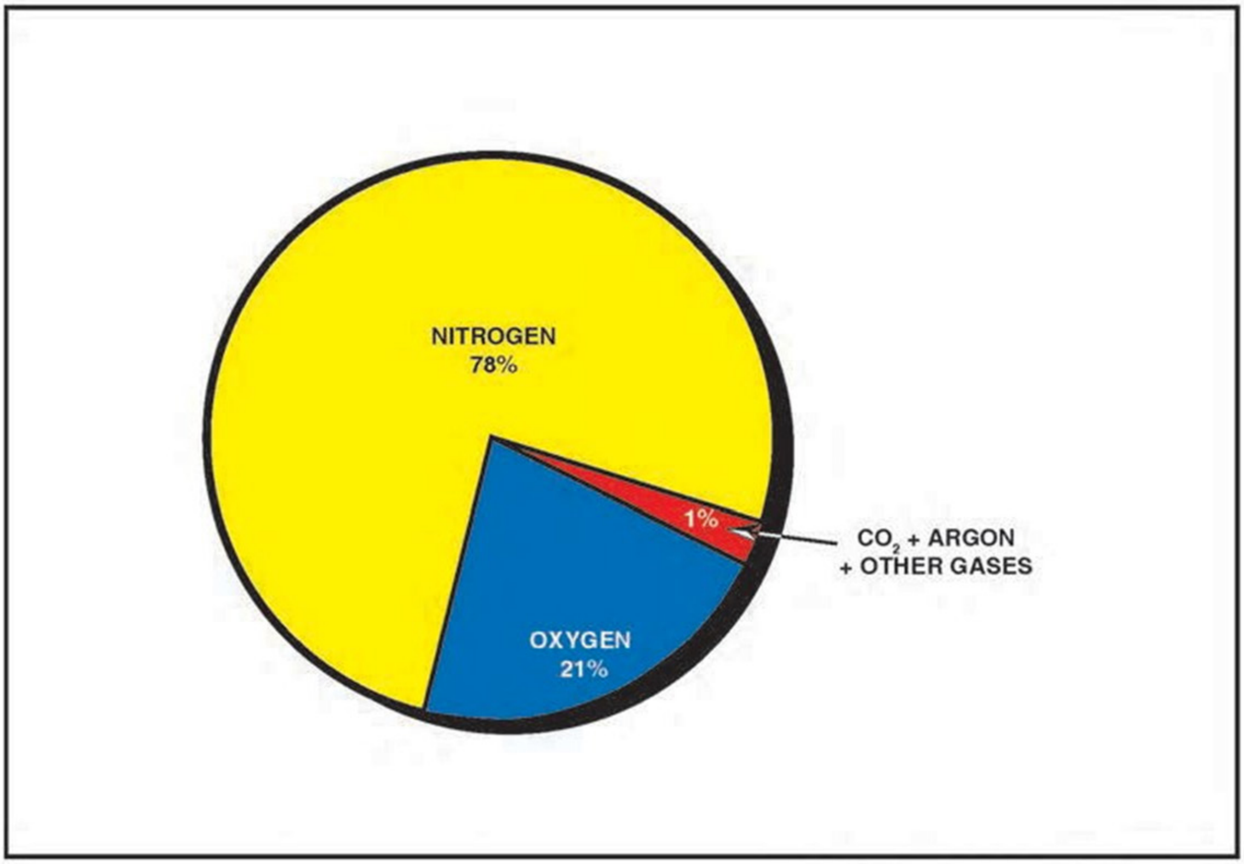


Visual 7: Specific Gravity (Relative Weight)

EFFECTS OF TOXIC GAS DEPEND ON :

1. CONCENTRATION
2. TOXICITY
3. LENGTH OF EXPOSURE

Visual 8: Effects of Toxic Gas



Visual 9: Contents of Normal Air

Mine Gases and Their Properties

GAS	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLU-BILITY	COLOR/ ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Normal Air	-	1.0	-	-	-	-	-	-
Oxygen	O_2	1.1054	Supports combustion	Moderate	-	Respiratory/ cardiovascular in oxygen deficient atmosphere	8-10%	Respiratory/ cardiovascular in oxygen deficient atmosphere
Carbon Dioxide	CO_2	1.5291	-	Soluble	Acidic taste- high concentrat-ions	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 concentra-tions, 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

Gas	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLUBILITY	COLOR/ ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Ethane	C_2H_6	1.0493	3-12.5%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas
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

Visual 10: Mine Gases 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.

Visual 11: Gas Detection Chart

GENERAL REVIEW

Mine Gases

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

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

Glossary

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.

Advanced Mine Rescue Training - Coal

Module 3 Mine Ventilation

Module 3 – Mine Ventilation

Contents

Instructional Text

Course Objectives

The mine rescue team members will analyze how air is coursed through a mine and be able to identify ventilation controls, take air measurements, and build or alter ventilation controls when ordered to do so by the officials in charge.

The team members will:

- Explain the purpose and methods of mine ventilation.
- Interpret a section of a ventilation map, identify ventilation controls, and explain how they affect the movement of air.
- Explain the purpose and importance of following the proper chain-of-command when altering ventilation.
- Use air measurement devices.
- Construct ventilation controls.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member
- Your own mine maps showing ventilation
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams Suggested:
- Anemometer
- Smoke tube (and stopwatch)
- Chalkboard or flipchart
- PowerPoint program
- Laptop computer

NOTE: In addition to these materials, you are encouraged to incorporate any other, up-to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction

II. Understanding Ventilation

   a. Airflow
   b. Mine Fans

III. Ventilation Maps

   a. Map Symbols

IV. Ventilation Controls

   a. Why Used
   b. Types of Stoppings
      i. Permanent
      ii. Temporary
   c. Check Curtains or Run-Through Checks
   d. Line Brattice
   e. Auxiliary Fans and Tubing
   f. Overcasts and Undercasts
   g. Mine Doors
   h. Regulators
   i. Box Checks and Belt Regulators

V. Assessing Ventilation

   a. Reporting Condition of Existing Ventilation
   b. Measuring Airflow
      i. Anemometer
      ii. Smoke Tube
      iii. Magnehelic

VI. Building Ventilation Controls

   a. Constructing Temporary Stoppings
   b. Constructing Permanent Stoppings
   c. Air Locks
   d. Line Brattice

Instructional Text

NOTE: Before you conduct training on this topic, it is suggested that you **thoroughly review all relevant sections of 30 CFR Part 75, Subpart D—Ventilation.** As you present the material, use the ventilation plans and maps of the mine(s) **covered by your team.**

Introduction

As mine rescue team members, you should be familiar with mine ventilation, in particular the ventilation of the mine in which you will be working. You should know the basics about ventilation methods and ventilation controls, as well as the more practical side for you as a team—how to build those ventilation controls.

After a fire, explosion, or flood in a mine, rescue teams are usually needed to go into the mine to assess and re-establish ventilation.

During exploration of the mine, your team will be checking the condition of the mine's ventilation system as you advance. You might find controls that have been destroyed or altered. Your initial responsibility will be to report these conditions to the Command Center.

NOTE: Under no circumstances do you ever alter ventilation without orders to do so from the Command Center.

From your team's reports, the Command Center will have a good overview of the mine's ventilation system and the degree to which it has been damaged, if at all. The Command Center can then issue directions to the team on how to re-establish ventilation in the mine.

Because the Command Center must make their decisions based on what you see, it is extremely important that you assess the ventilation accurately. Additionally, the Command Center will be counting on you to correctly build ventilation controls.

Understanding Ventilation

NOTE: For this section, refer to the following Federal regulations:

- 30 CFR Section 75.333 – Ventilation controls
- 30 CFR Section 75.350 – Belt air course ventilation
- Any Petitions of Modifications that affect Mine Ventilation

Airflow

NOTE: Display a mine ventilation or section map and trace the intake and return air.

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

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

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.

NOTE: You can refer to Visual 1 when you discuss commonly-used mapping symbols. ALSO, refer to ventilation maps from the actual mines covered by your team(s), and incorporate those specific mapping symbols into your training.

Intake and Return Airway Symbols

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:

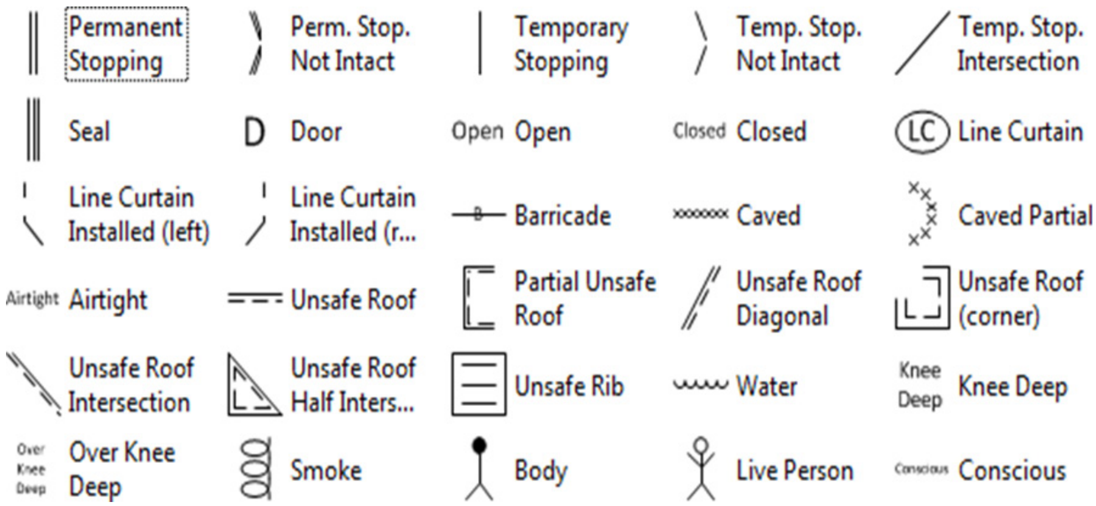
Symbol	Meaning
————→	Direction of Intake Airflow
——→——→	Direction of Return Airflow
∿∿∿→	Direction of Low-Velocity Airflow

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).

NOTE: If the ventilation system is badly damaged or is out completely, the **distinction between intake and return air may not be valid**. Also, teams should realize that during an emergency, the maps they receive may have been **photocopied** and, therefore, the colors of any **color-coded lines will not show up.**

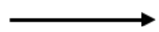
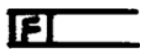
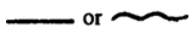
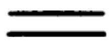
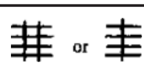
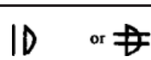
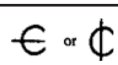
Mapping Symbols

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



Other Mapping Symbols

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

	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)
	Regulator
	Belt Regulator
	Box Check
	Belt Conveyor with Belthead and Tailpiece
	Mine Door
	Track
	Man Door
	Check Curtain or Run-through Curtain (if used)

Ventilation Controls

NOTE: Refer to Visual 2 for a diagram showing how ventilation controls direct air to the working faces of the mine.

Ventilation controls are used underground to properly distribute the air to all sections of the mine. Ventilation controls do this by controlling both the direction of the airflow and the amount of air that travels.

It is important to “control” and “course” air underground so that it reaches all areas of the working places of the mine without short-circuiting. Short-circuiting occurs when air from the intake goes directly into the return rather than moving up to ventilate the working faces.

Because each working section is required to be ventilated with its own separate supply of fresh, uncontaminated air (air split), ventilation controls are used to split the air from the main intake and direct it to the various sections.

The following ventilation controls that we are going to discuss work collectively to control the movement of air from the main intake (or intakes) to the working sections and out the returns.

Stoppings

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

Permanent stoppings 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.

NOTE: Refer to **Visuals 3 and 4.**

Sometimes permanent stoppings 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

NOTE: Refer to Visual 5 for a picture of a temporary stopping.

Temporary stoppings 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 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 are used to advance ventilation as the exploration or mine recovery work progresses.

There are specially designed temporary stoppings 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.

Check Curtains or Run-Through Checks

NOTE: Refer to **Visual 6** for a picture of a check curtain or run-through check.

A check curtain (or run-through check) is a brattice cloth, canvas, or transparent plastic curtain that is hung across a passageway and opens to allow miners and equipment to pass through. Check curtains are used to deflect the intake air current into a working area. They are fastened at the top only and can be either one piece or have a slit in them or overlapping flaps. Check curtains are designed to close automatically after you have passed through them so that they continue to direct air to the working place.

If check curtains get pulled down or they do not fully close, they can cause the air to short-circuit so that it never reaches the working face. Nevertheless, if your team finds a fallen check curtain while exploring a mine, you should leave it as it is for the time being and report the condition to the officials at the Command Center. The Command Center will decide what changes to make in the ventilation, if any are necessary.

Line Brattice

NOTE: Refer to **Visual 7** for an illustration of line brattice.

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

NOTE: Refer to Visual 8 for a picture of how auxiliary fans and tubing affect ventilation at the face of the mine.

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.

Overcasts and Undercasts

NOTE: Refer to **Visual 9** for a picture of overcast.

Because intake and return air frequently cross paths at intersections within the mine, overcasts and undercasts are used to permit the two air currents to cross without the intake air short-circuiting into the return.

Overcasts are like enclosed bridges built above the normal roof level of the mine. Undercasts are like tunnels built below the normal floor of the mine.

Undercasts are seldom used in a mine because they are apt to fill with water or debris which would severely slow down the flow of air through them. Overcasts are used more often. They are usually built with concrete block walls sealed against the ribs and floor, and with some type of airtight roof made of pre-stressed concrete, railroad ties, or steel beams. This type of overcast is frequently used to allow air to cross over a conveyor belt without mixing with the split of air that ventilates the belt.

Sometimes overcasts are made of pipes going from one stopping to another, across an intake airway, allowing the return air to pass over the intake air.

Mine Doors

NOTE: Refer to **Visual 10** for a picture of a mine door.

In areas of heavy traffic, such as along haulageways, mine doors are used as ventilation controls. The doors are usually hung in pairs, forming an air lock that prevents a change in ventilation when one of the doors is opened.

The doors serve to direct the airflow away from the main haulage entry and into another entry. At the same time they can be opened to allow equipment and people to pass through without disturbing the ventilation. The doors should always be opened and closed one at a time in order to maintain the air lock. Mine doors can also be used to isolate separate splits of air.

Mine doors are always hung so that the ventilating air pressure will push them closed if they are accidentally left open. However, the **doors should always be closed after you pass through them.** Some doors must be closed manually while others can be closed automatically.

NOTE: If the normal **flow of air is reversed** in the mine, the ventilating air pressure will no longer keep the mine doors closed.

Regulators

NOTE: Refer to **Visual 11** for an example of a regulator.

So far we have talked mainly about devices used to control the **direction of airflow**. Now we will discuss the regulators used to control and adjust the **quantity** of airflow in the mine in order to ensure proper distribution.

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.

Box Checks and Belt Regulators

Conveyor belts are usually in or near intake air passages. This presents a problem since a fire on the belt would cause smoke and carbon monoxide to mix with intake air.

Conveyor belts must be isolated from both intake and return air. Box checks are temporary or permanent stoppings built at each end of the belt to limit the intake air flowing over the belt. The box checks are built with openings in them to allow the belt to pass through.

Box checks are designed to let a little air flow through them into the isolated belt entry so that the belt will be ventilated with its own split of air. After the belt has been ventilated, the air is then drawn out through a belt regulator into the return airway.

The belt regulator regulates the quantity of air that flows along the belt. This can be done by removing blocks from a permanent stopping when the belt is beside the return.

The opening made by the missing blocks allows air from the beltway to go directly into the return airway. The size of the opening can be adjusted to regulate the flow of air along the belt.

If the belt is beside the intake, the belt's return air must cross the intake airway through an overcast.

NOTE: Refer to **Visual 12** for an illustration of a belt regulator.

REVIEW QUESTIONS

Ask the team members the following questions and allow time for them to answer. Then discuss the correct answers with the team so they fully understand the material covered so far.

1. Have the team members define and discuss the purpose or function of the following:
   - Stoppings
   - 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
   b. Permanent stopping
   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)

ANSWER SHEET

1. Stoppings – Stoppings 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.

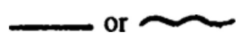
   Line Brattice – Line brattice is used to channel intake air from the last open crosscut to the working face.

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

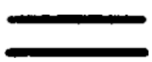
   Auxiliary Fans and Tubing – Auxiliary fans and tubing are used to provide sufficient airflow to face areas during mining operations.

2.

   a. Temporary stopping

   b. Permanent stopping

   c. Line brattice

   d. Overcast (if used)

   e. Undercast (if used)

   f. Regulator

   R

   g. Mine door

   D

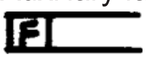
   h. Box check

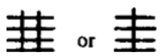
i. Belt regulator

j. Main fan

k. Auxiliary fan and tubing

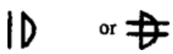


l. Track

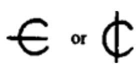


m. Conveyor belt with belthead and tailpiece

n. Man door



o. Check curtain or run-through check (if used)



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

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 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 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 across entries near intersections. The movement of blocks from stoppings 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 (FAB), 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

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.

The Pitot tube has a U-tube water gauge or some other differential pressure gauge for determining the velocity pressure inside the duct or tubing.

Anemometer

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.

NOTE: Refer to **Visual 13** for a picture of a common type of anemometer.

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.

NOTE: Refer to **Visual 14** to illustrate how to traverse the airway.

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 (ft2) 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

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.

NOTE: Refer to **Visual 15** for a picture of a smoke tube and an aspirator bulb. You may want to demonstrate how to use it, as you describe the procedure in the following section.

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).

NOTE: Always refer to manufacturer's instructions on how to handle and use glass or plastic smoke tubes.

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.

NOTE: Refer to **Visual 16** for an illustration of how to take smoke tube readings at quarter points within the airway.

Inform the team that quarter points are at approximately the center of each quadrant if the airway were divided into four approximately equal parts. This is done to determine the average velocity in the airway since it varies at different parts of 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. Refer to **Visual 17** for a smoke tube conversion chart to assist with this calculation.

1. Determine the average area of the entry along the measured distance by multiplying the width times the height.
2. 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. 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:

$$\frac{(25\text{ feet of travel})}{(.38\text{ minute})}$$

This equals 65.7 ft./min.

Now plug 65.7 into the formula:

$Q\,(ft.^3) = A(ft.^2) \times V(ft./min.)$

Quantity = Area (let's use 200) x 65.7

Quantity of airflow = 13,140 $ft.^3$/min.

If you intend to use the smoke tube over again in a short time, you should keep it tightly stoppered with a rubber cap or plug because the reagent is corrosive and tends to clog the openings of the tube.

Magnehelic

Pressure differentials effect the way air moves and requires significant evaluation during mine rescue exploration. Advancing through airlocks, mandoors, or any other rigid structure should be examined for conditions on the opposing side. Pressure exerted by a fire (there may be other causes such as explosions or ignitions that cause this) may cause reversal in flow or short circuit and increase hazardous conditions to team members and/or survivors in need of rescue.

The magnehelic has a very sensitive diaphragm that responds to changes in pressure. When pressure is exerted on the diaphragm, the dial of the magnehelic responds accordingly and moves to the appropriate pressure. That movement as measured in inches of water shows pressure differential of the opposite side and indicates which way the pressure is exerted on the structure.

For this diaphragm to function correctly, positioning of the instrument is important. It must be level and in the vertical position when zeroed and measuring pressure. If the magnehelic is in any position other than level and vertical, the diaphragm can sag and cause inaccurate readings.

REVIEW QUESTIONS

Ask team members the following questions and allow time for them to answer. Then discuss the correct answers with the team so they fully understand the material covered in the previous section.

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

2. Discuss the conditions under which a smoke tube would be used to determine air velocities.

3. Discuss the conditions under which an anemometer would be used to determine air velocities.

ANSWER SHEET

1.

- 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 FAB.

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

3. 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

As we discussed before, mine rescue and recovery work often involves building or rebuilding ventilation controls in the mine in order to re-establish ventilation. Therefore, it is necessary that you know how to properly build ventilation controls, whether it be building a stopping or hanging line brattice.

Some of you will be skilled in building ventilation controls, while others may have little or no experience. But for all of you, whether or not you've done this type of work before, it's going to take time to get used to working with your apparatus on.

It will be especially hard if you are working in smoke or trying to work rapidly in order to reach survivors as quickly as possible.

NOTE: <u>NEVER</u> make alterations or do any construction without the approval of the Command Center.

Constructing Temporary Stoppings

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

The site for the temporary stopping 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. 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 rods made of PVC pipe springs and most often include spikes at each end, can be used to quickly install 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, 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 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

As soon as possible after ventilation has been restored to the mine, permanent stoppings should be built to replace any temporary stoppings. Under normal circumstances these permanent stoppings would be constructed outby the advancing FAB, 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. We will discuss this task later when we talk about mine fires and firefighting.

NOTE: Building seals to seal a fire area will be covered in ***Module 5 – Fires, Firefighting, and Explosions.***

Air Locks

An air lock consists of two doors or two stoppings 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 FAB and enable teams to move forward into questionable air without contaminating the air at the FAB.

Air locks are also used any time a team is required to break open a stopping 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 as close together as possible, yet with enough space to allow room for the team and their equipment to fit between.

NOTE: Air locking will be covered in more detail in ***Module 7 – Mine Recovery.***

Line Brattice

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

Ask the team members the following questions and allow time for them to answer. Then discuss the correct answers with the team so that they fully understand the material covered in the previous section.

1. Have the team members discuss why they need to be able to build temporary stoppings quickly and effectively.

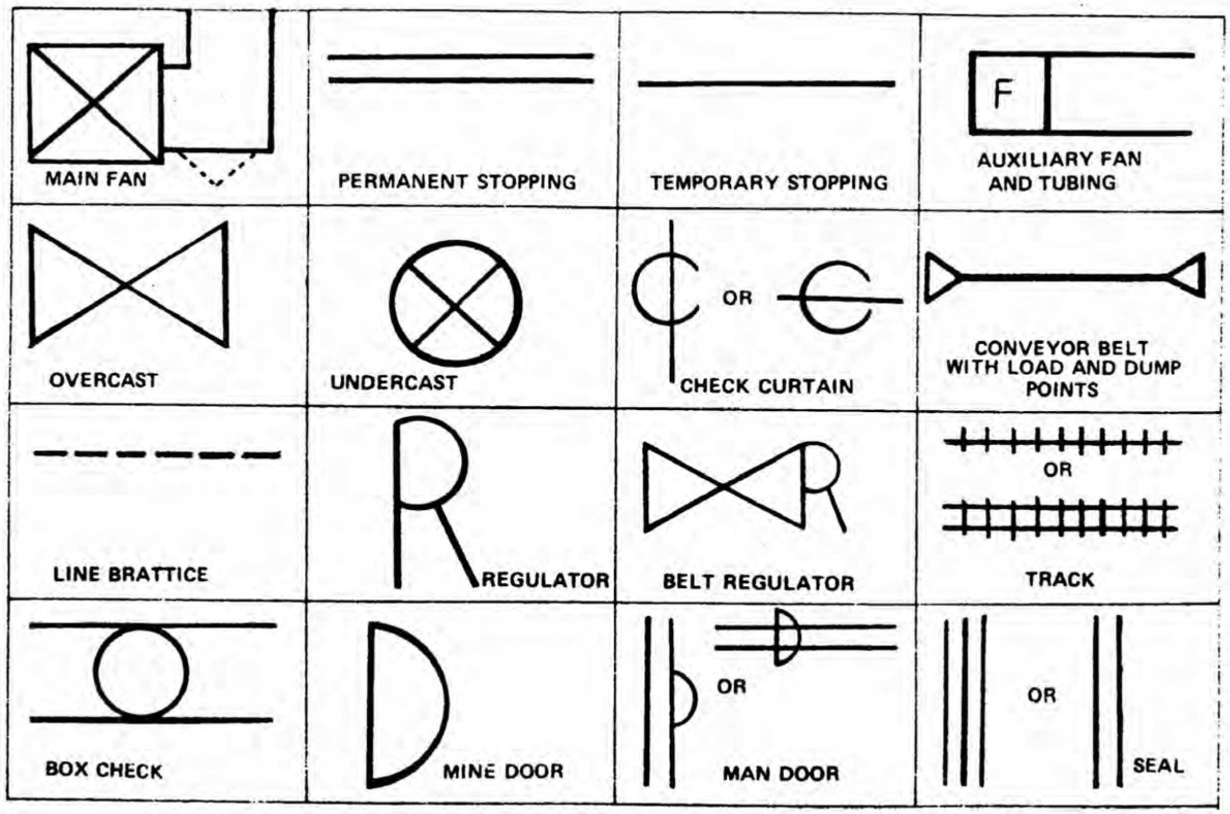
2. Have the team members discuss how they would build a temporary stopping in a crosscut that has equipment in it.

ANSWER SHEET

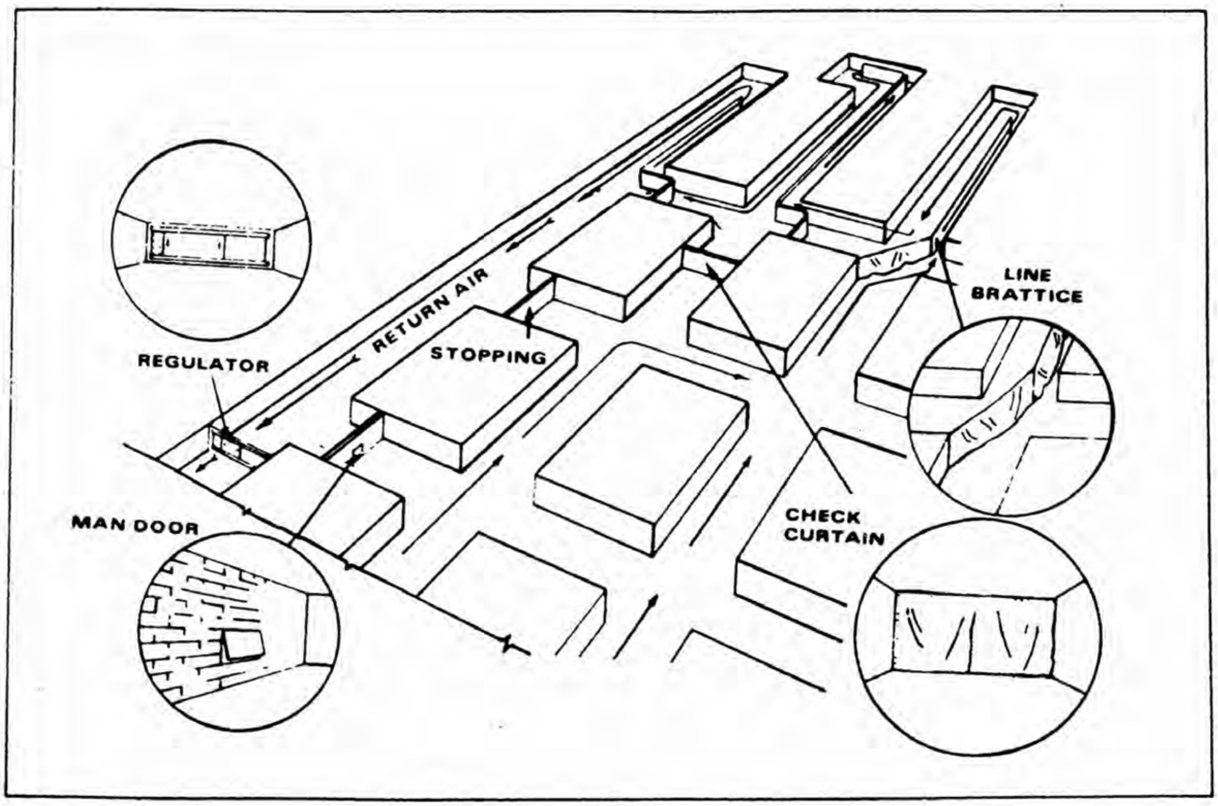
1. Re-ventilation is essential for the advancement of the FAB and the flushing out of dangerous gases. In particular, when miners are trapped, it is very important to be able to advance the FAB quickly in order to rescue the miners.

2. 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

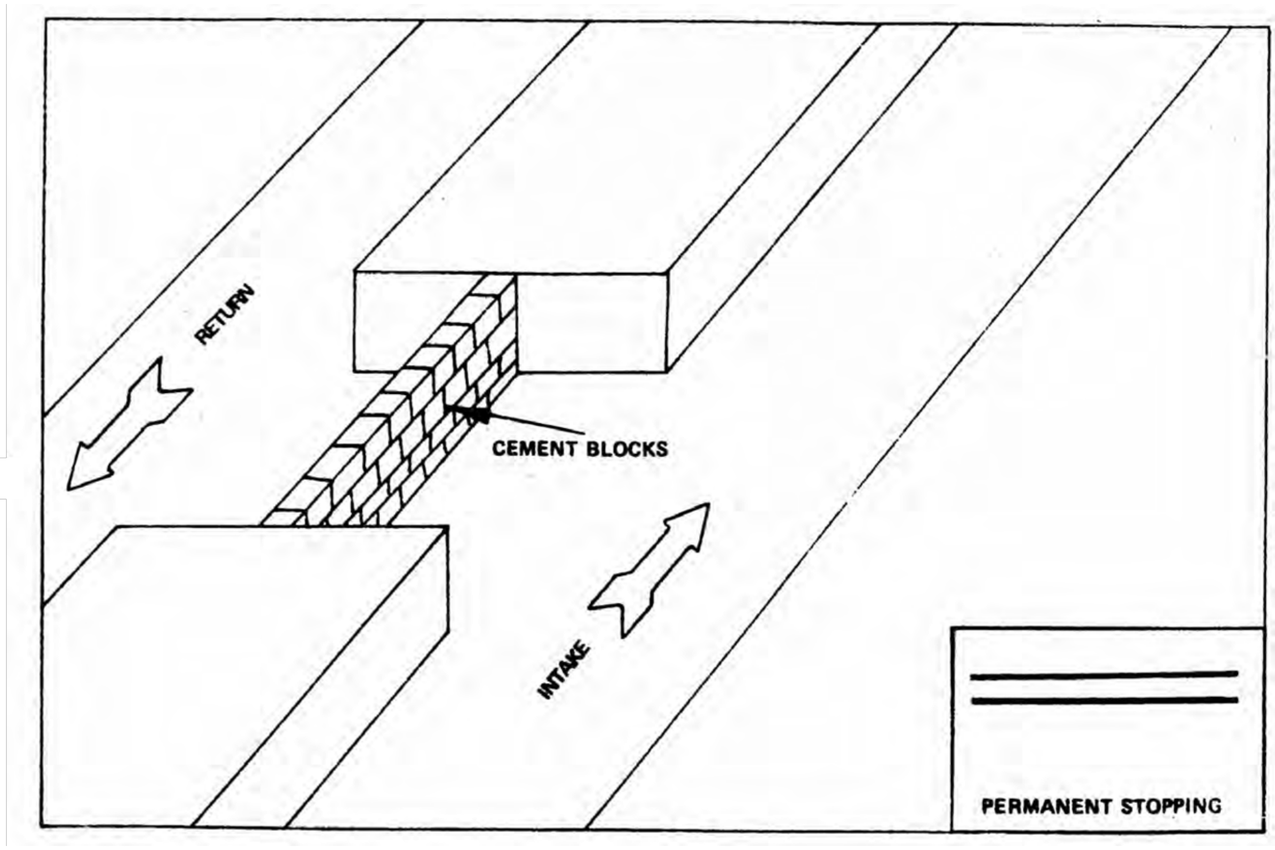
Visuals



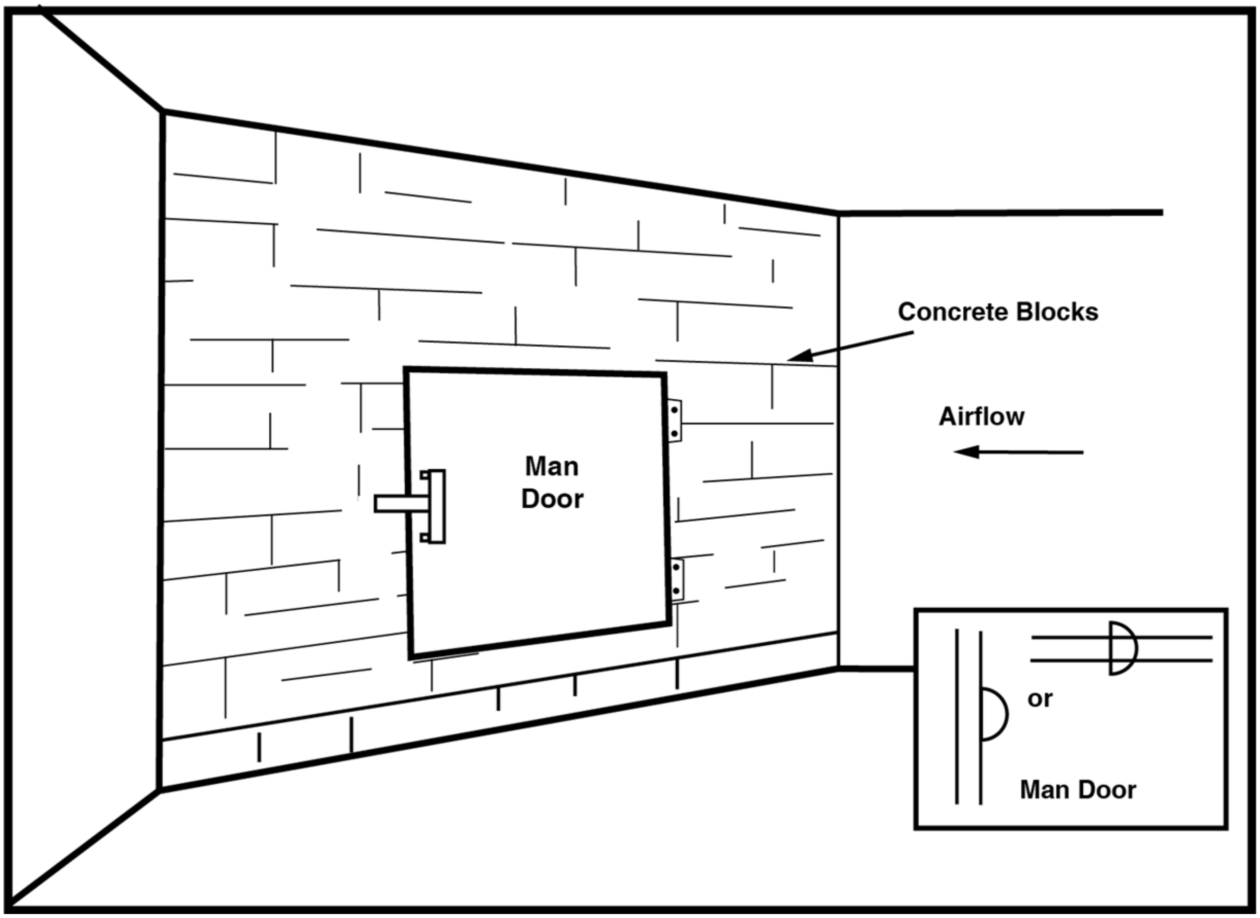
Visual 1: Sample Mine Map Symbols



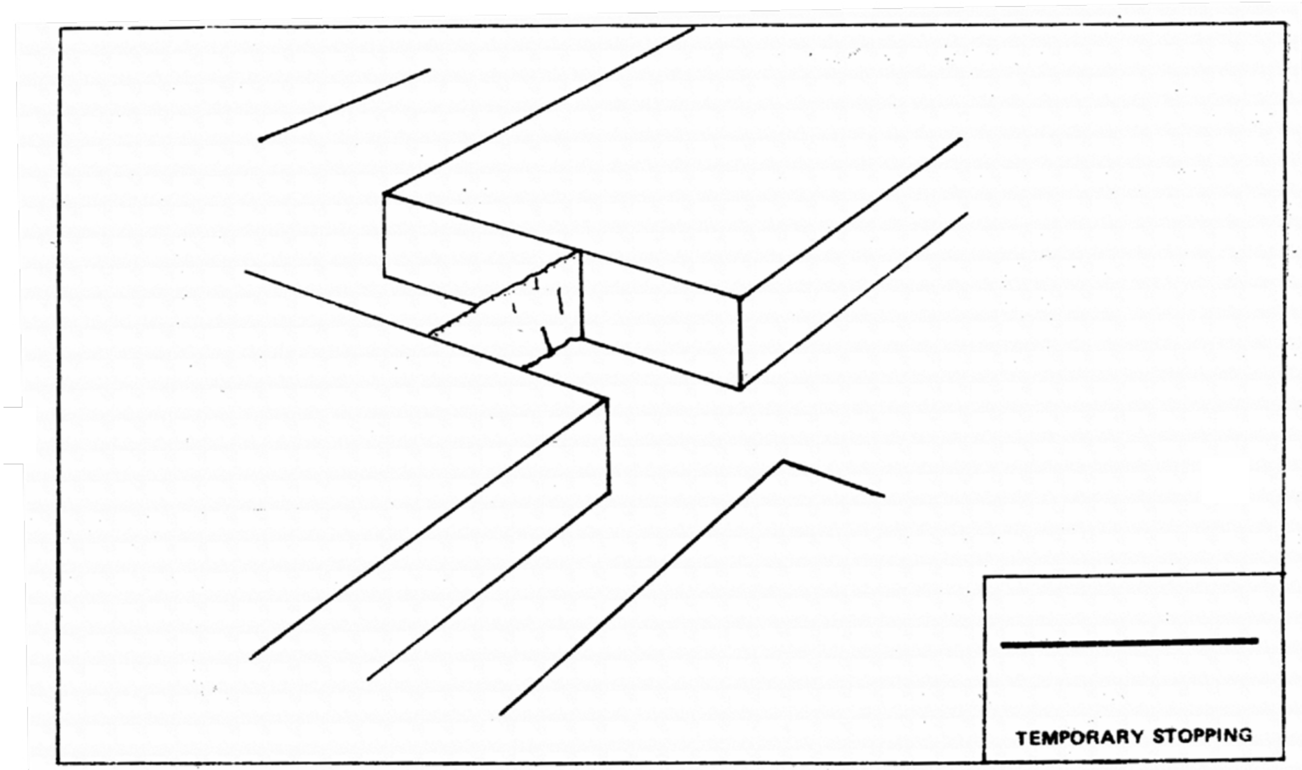
Visual 2: Ventilation Controls



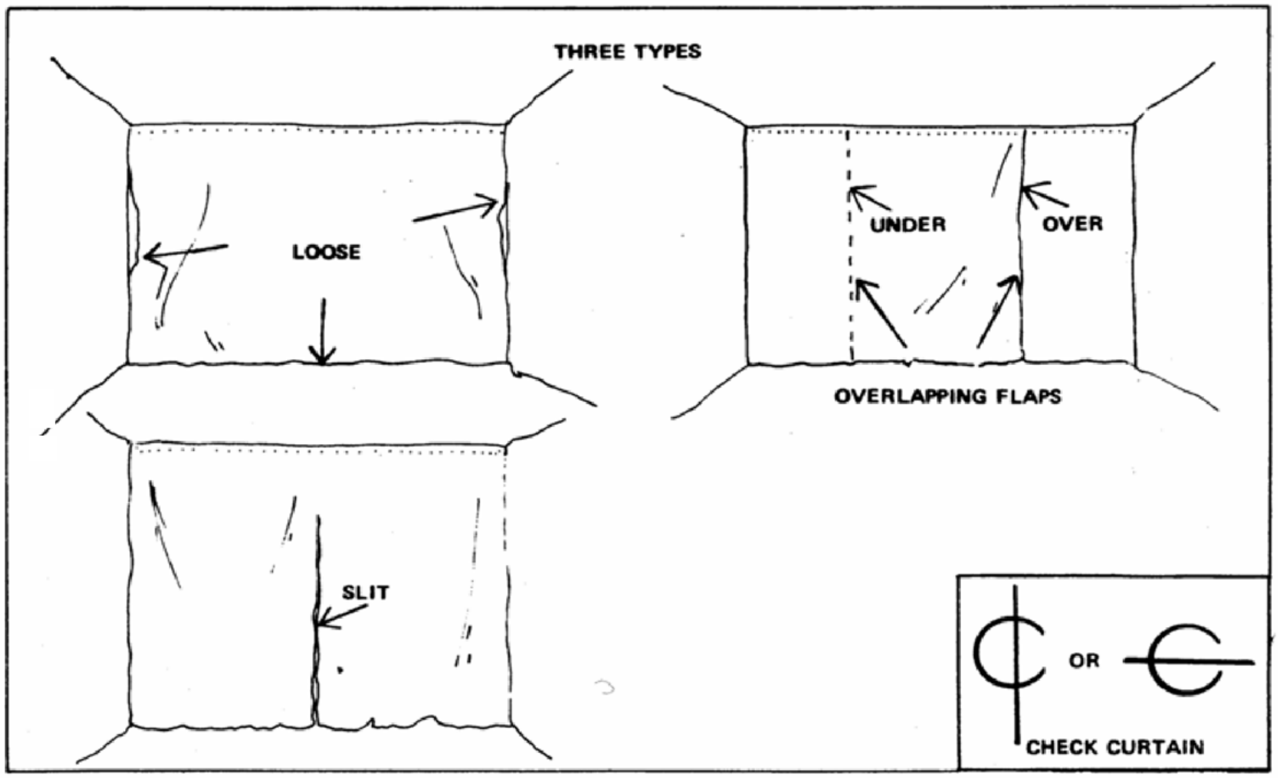
Visual 3: Permanent Stopping



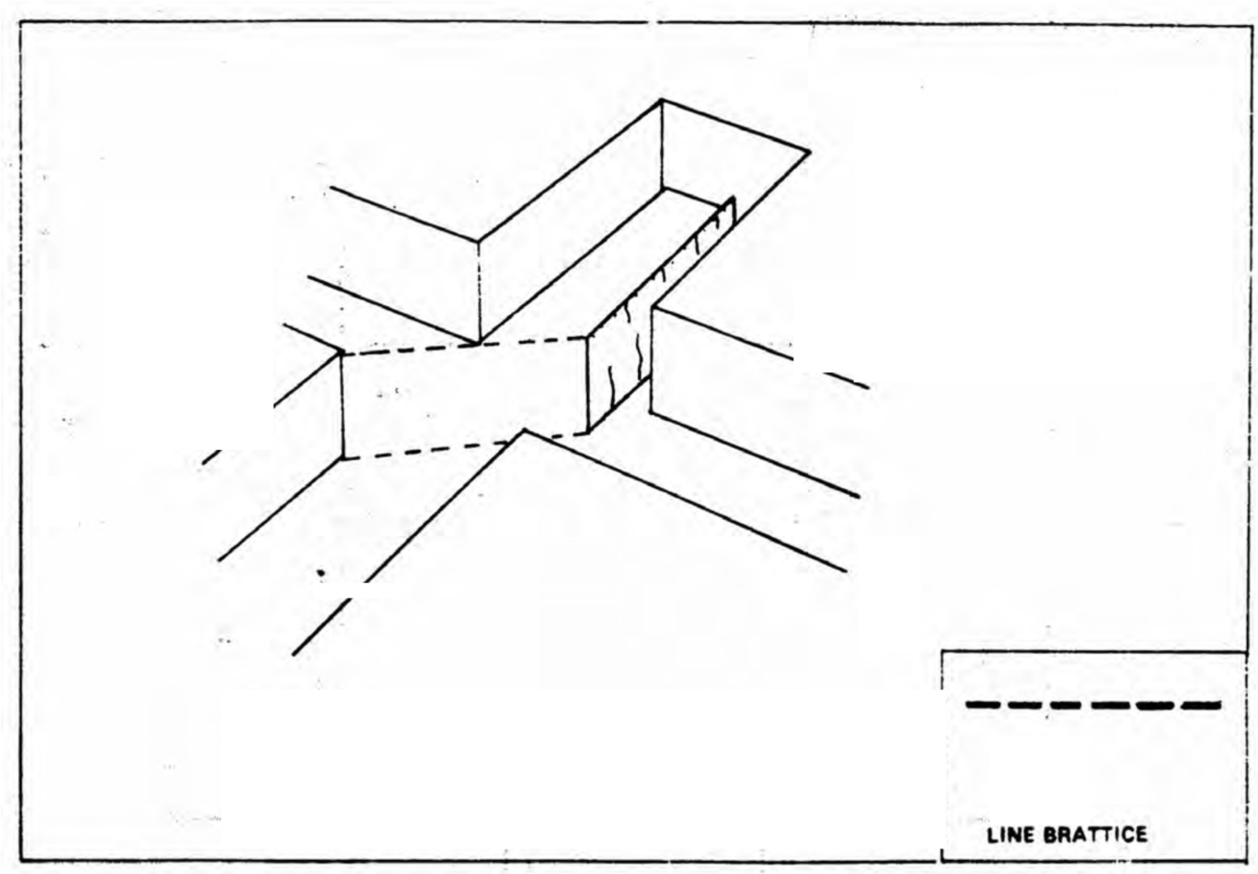
Visual 4: Permanent Stopping with Man Door (or Drop Door)



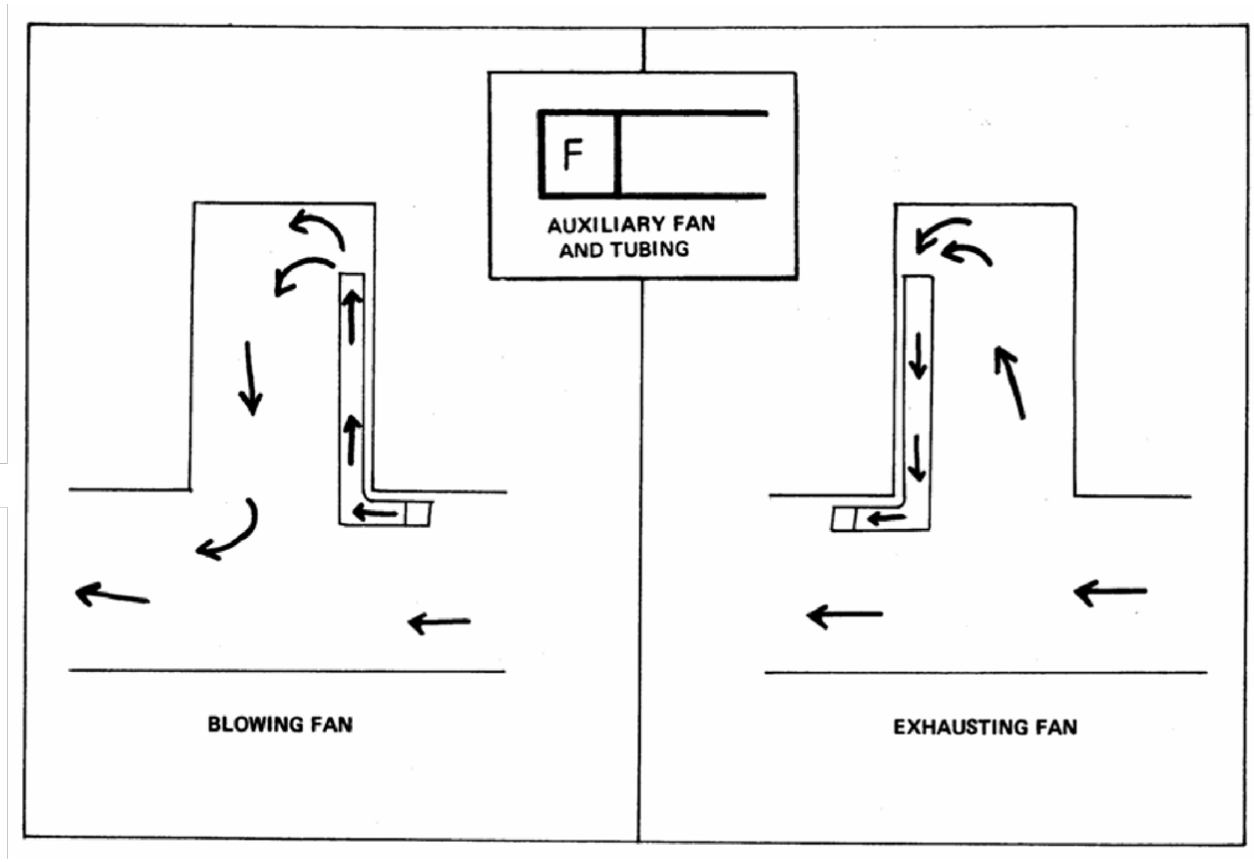
Visual 5: Temporary Stopping



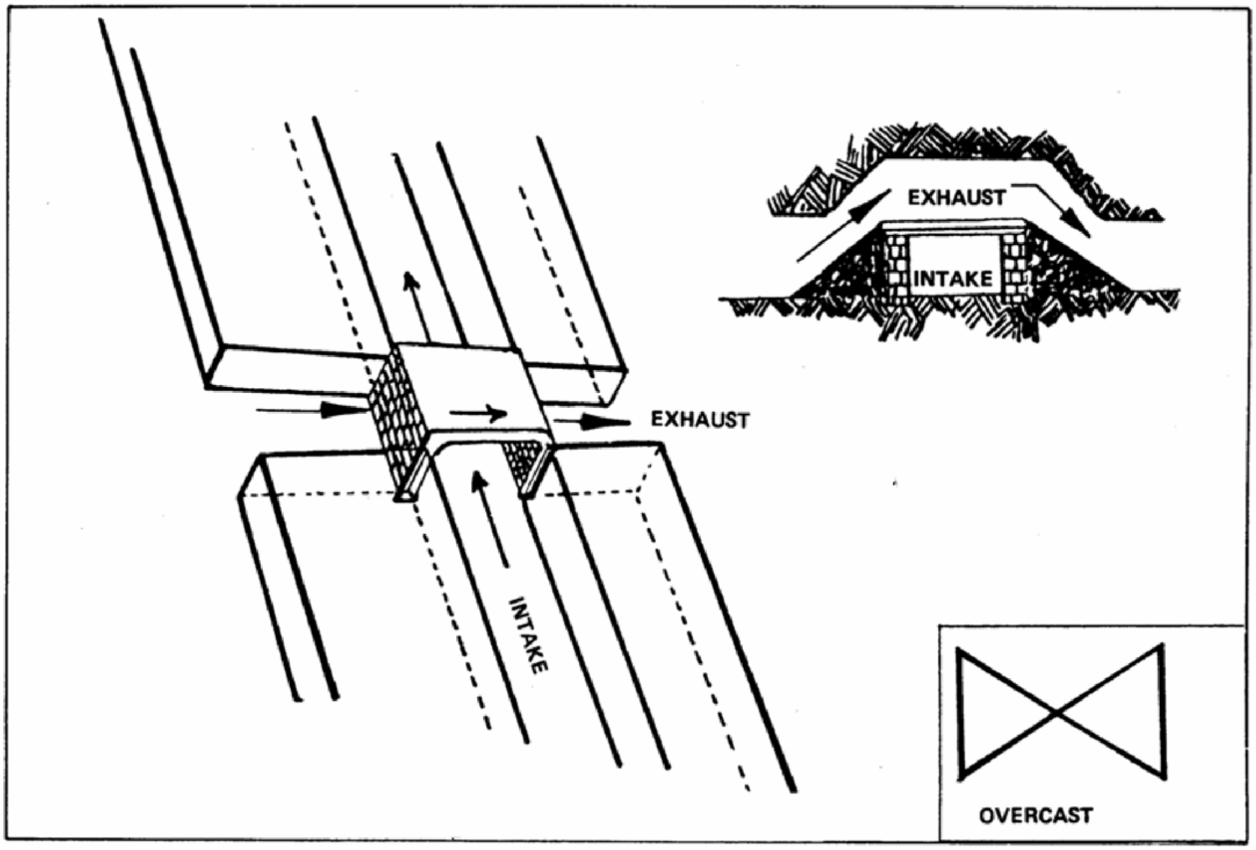
Visual 6: Check Curtains or Run-Through Checks



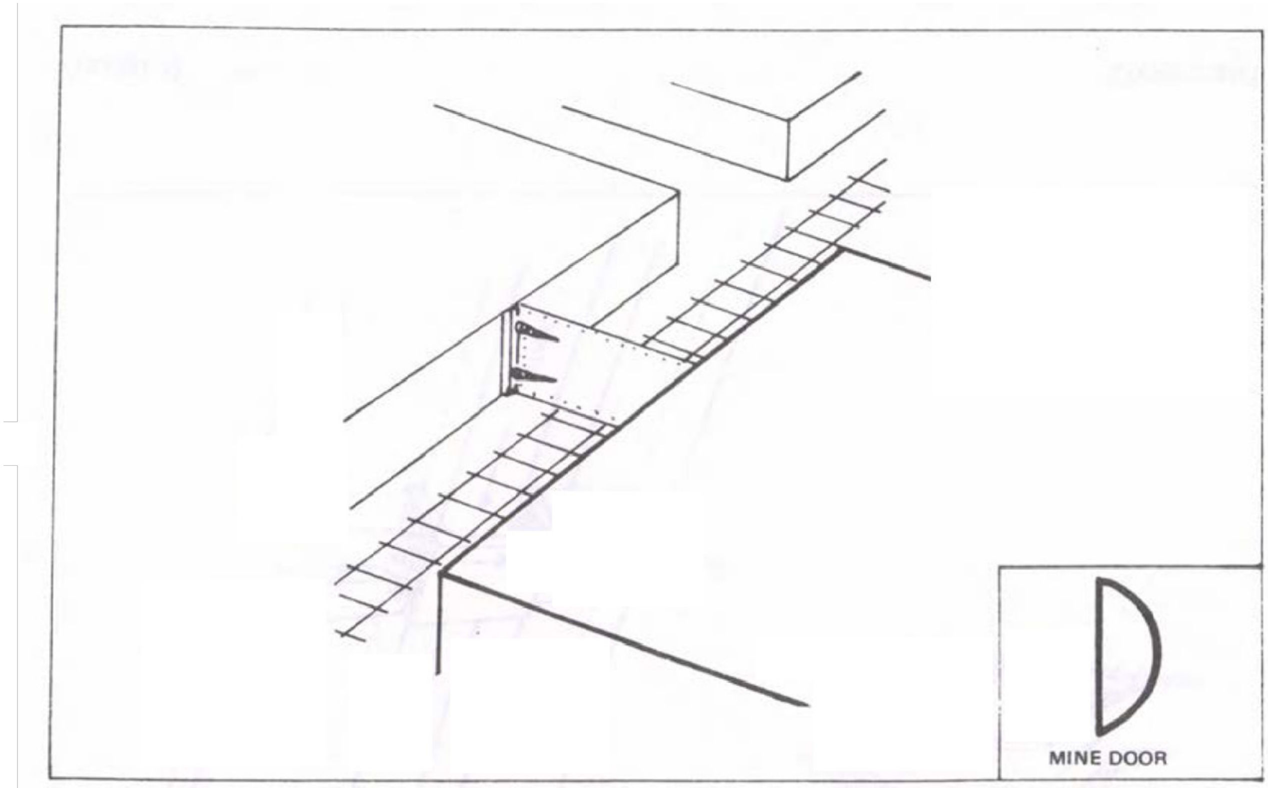
Visual 7: Line Brattice



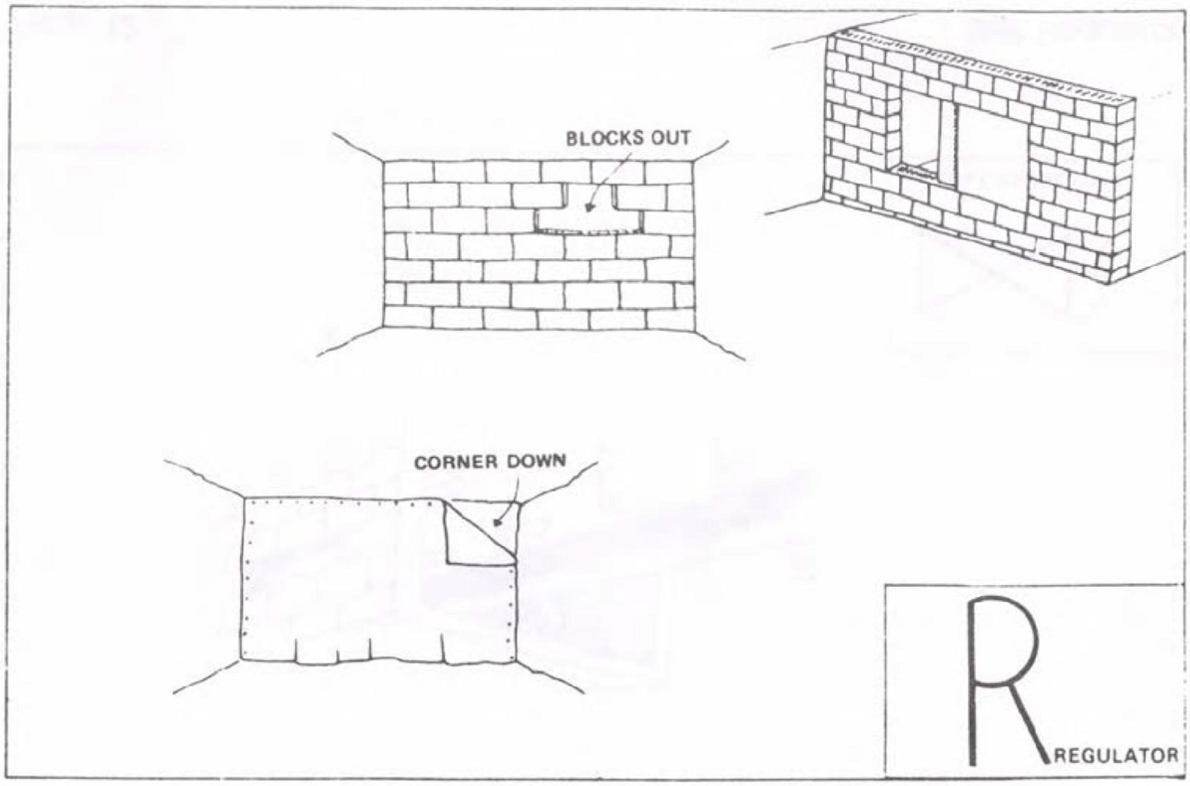
Visual 8: Auxiliary Fan and Tubing



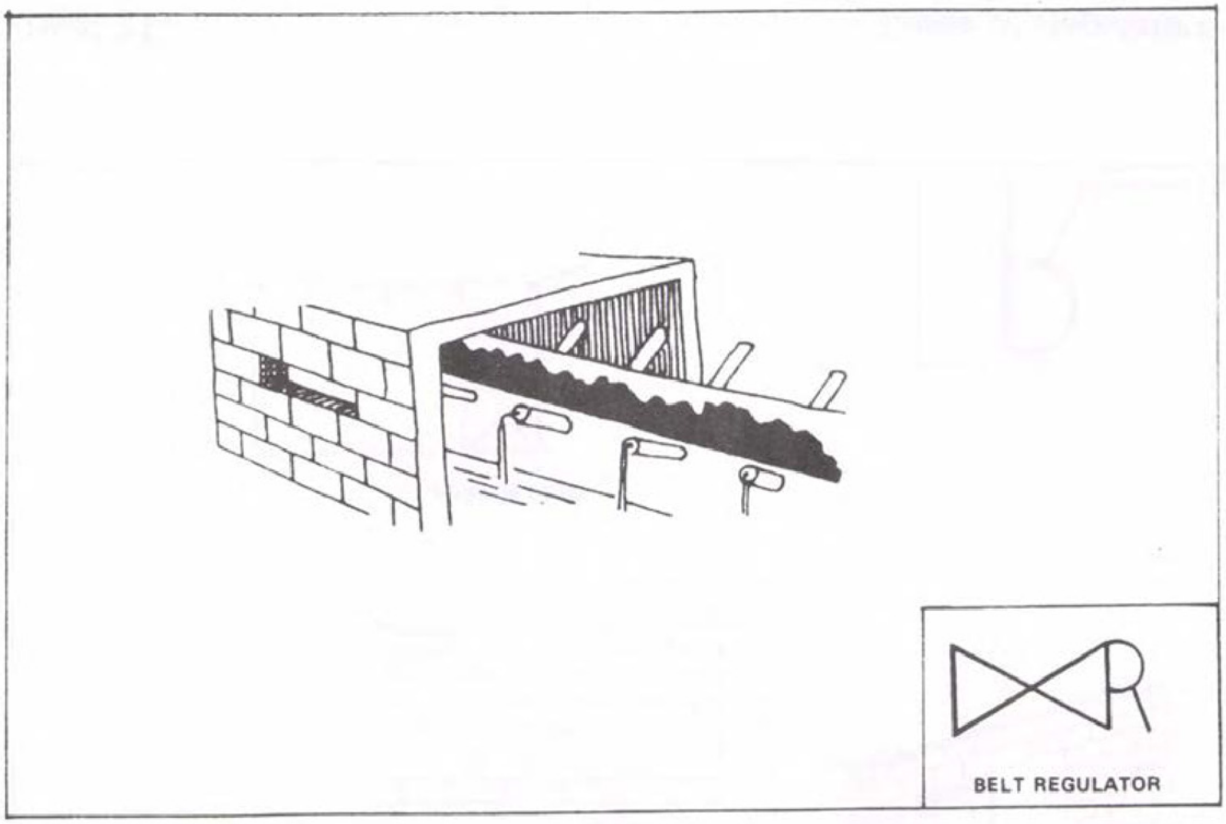
Visual 9: Overcast



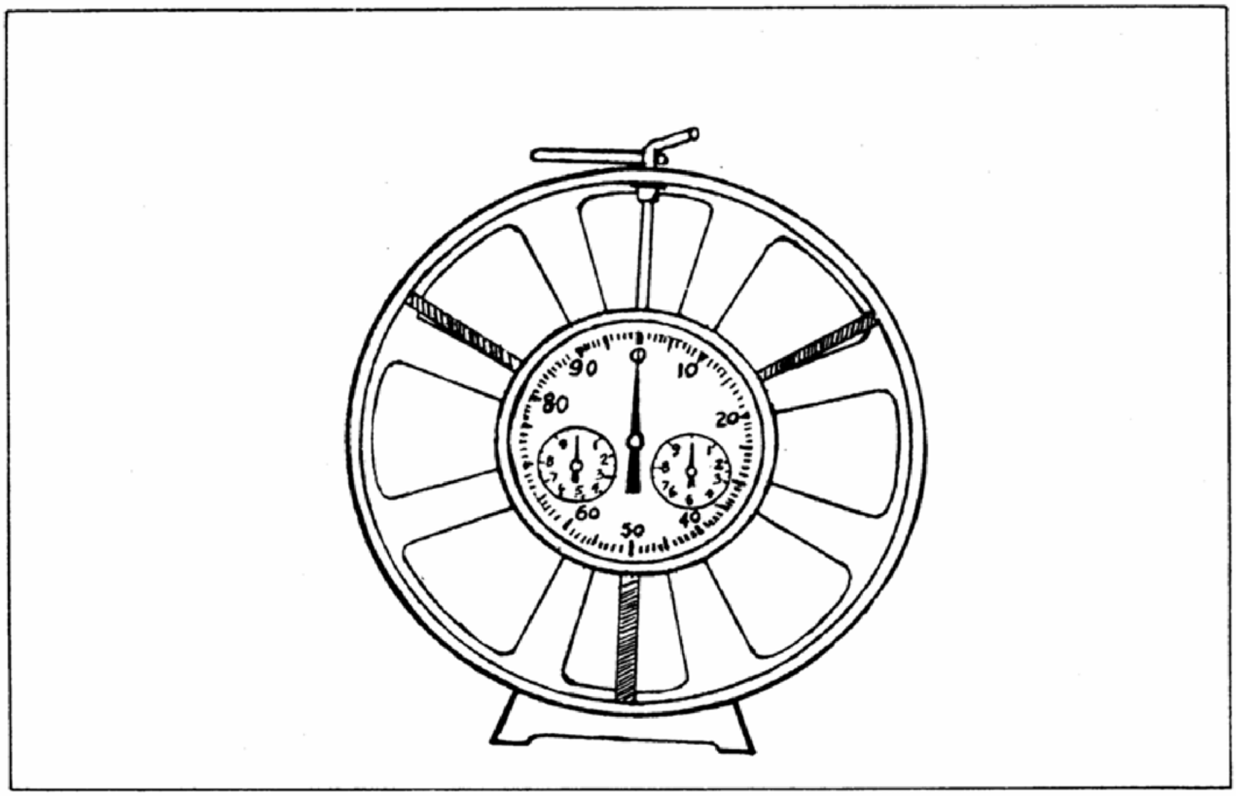
Visual 10: Mine Door



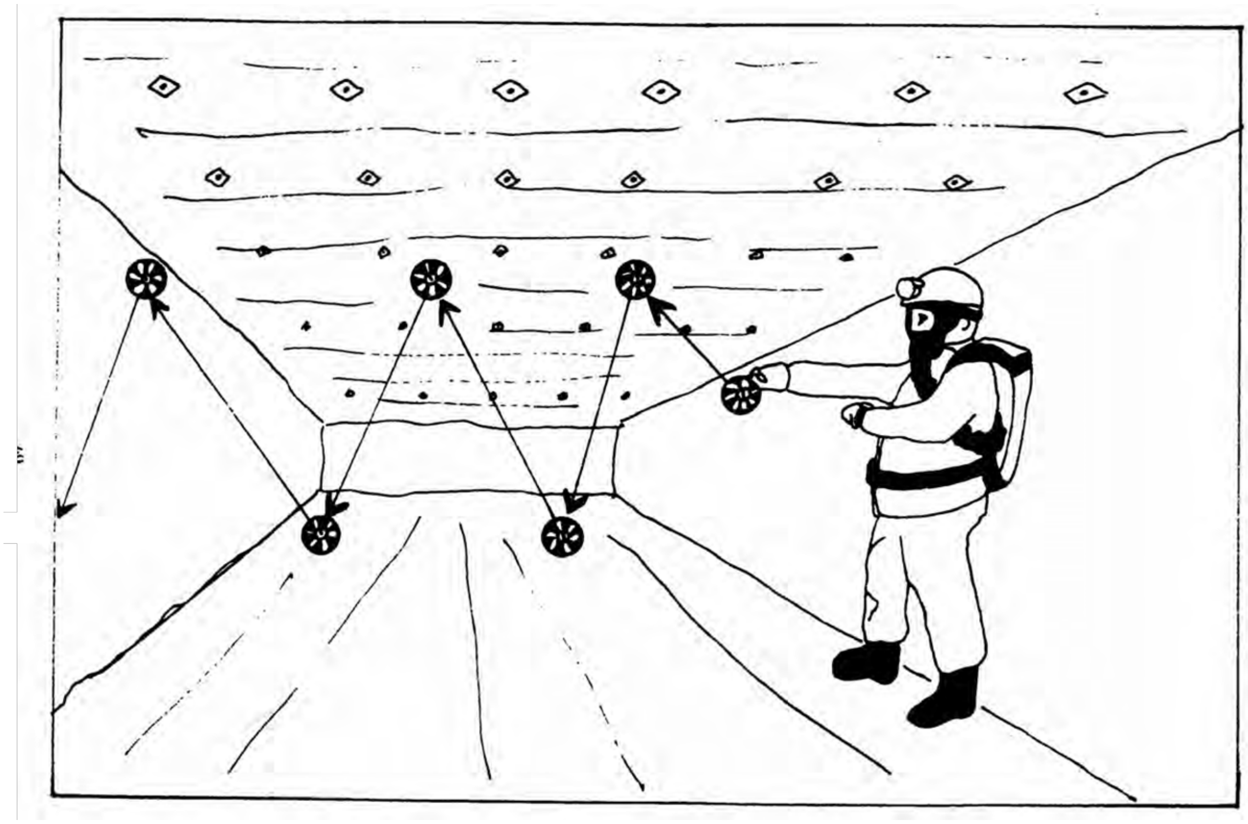
Visual 11: Types of Regulators



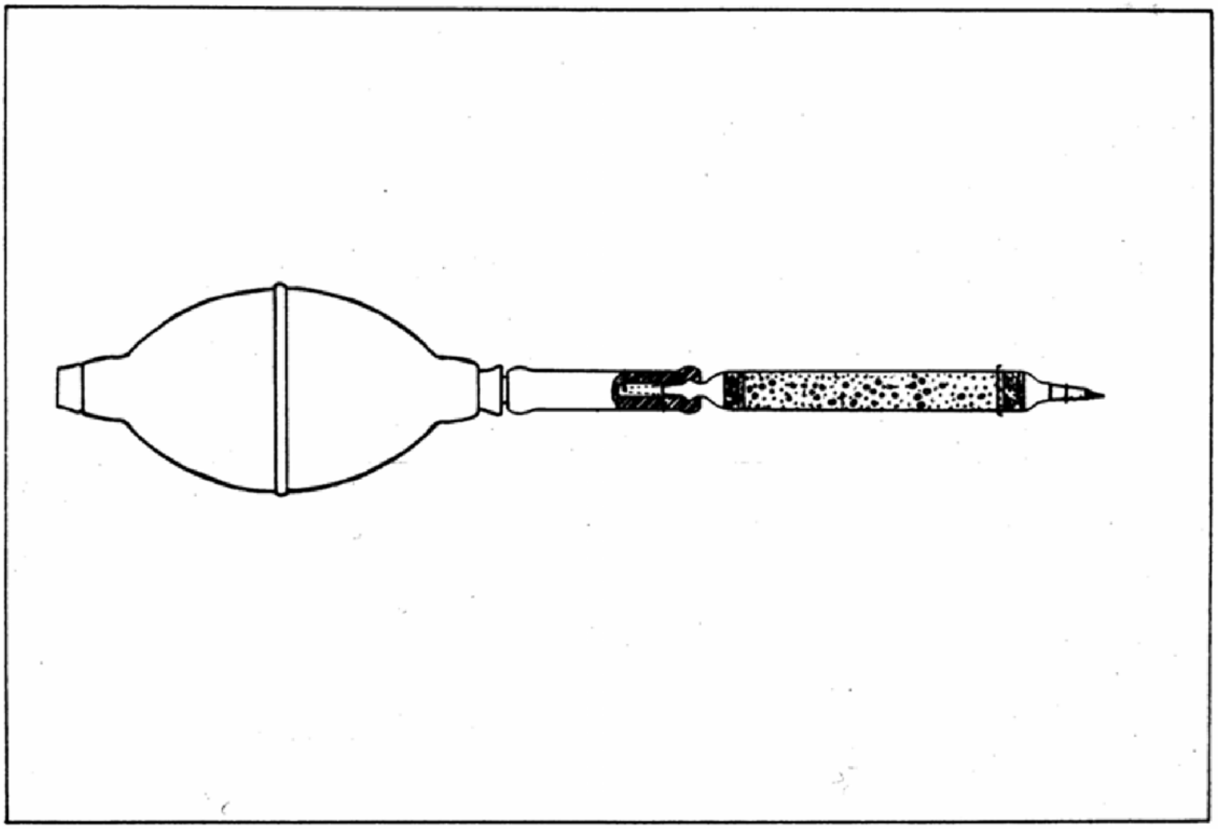
Visual 12: Belt Regulator



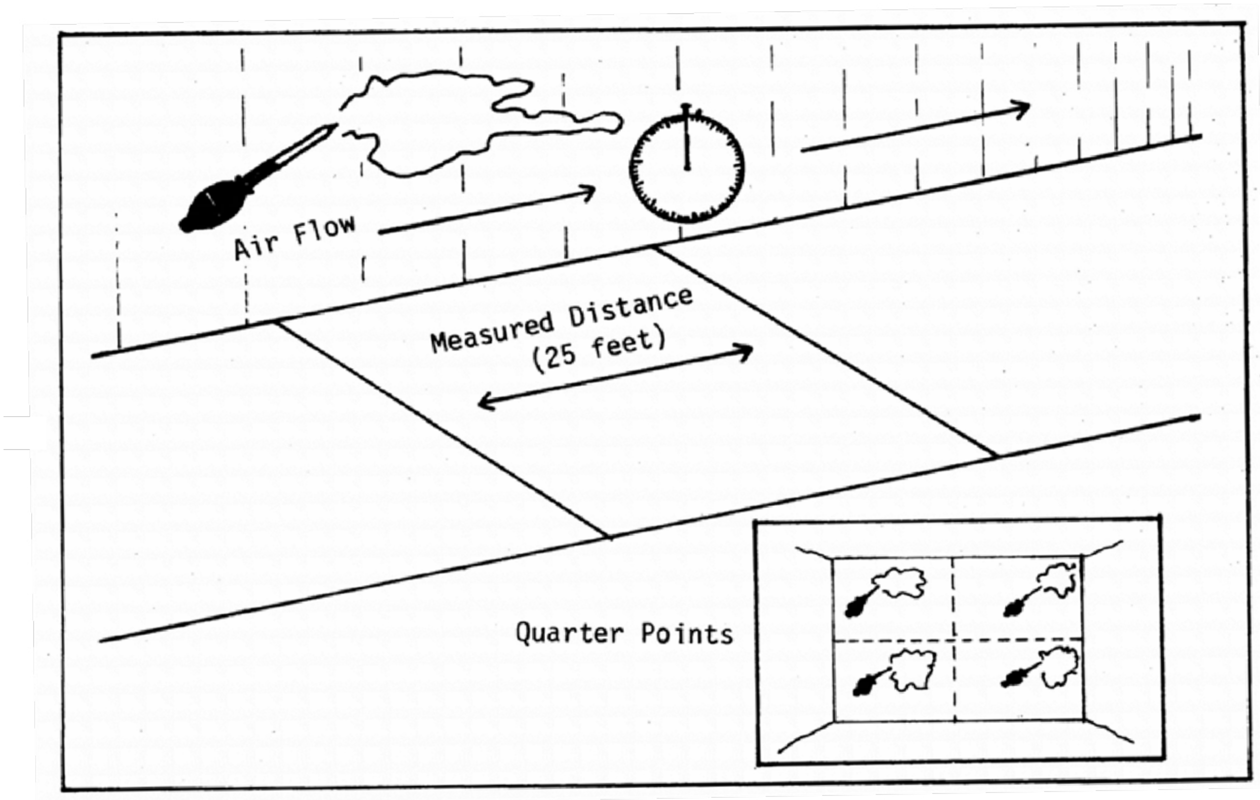
Visual 13: Anemometer



Visual 14: Anemometer Reading Using Traverse Method



Visual 15: Smoke Tube



Visual 16: Taking a Smoke Tube Reading

Smoke Tube Conversion Chart

$$V = \frac{Distance\ (feet)}{Time\ (seconds)}\ x\ 60\ x\ 0.9$$

TIME	VELOCITY (fpm)			TIME	VELOCITY (fpm)		
(sec)	10 ft.	15 ft.	20 ft.	(sec)	10 ft.	15 ft.	20 ft.
5.0	108	162	216	15.0	36	54	72
5.2	104	156	208	15.2	36	53	71
5.4	100	150	200	15.4	35	53	70
5.6	96	145	193	15.6	35	52	69
5.8	93	140	186	15.8	34	51	68
6.0	90	135	180	16.0	34	51	68
6.2	87	131	174	16.2	33	50	67
6.4	84	127	169	16.4	33	49	66
6.6	82	123	164	16.6	33	49	65
6.8	79	119	159	16.8	32	48	64
7.0	77	116	154	17.0	32	48	64
7.2	75	113	150	17.2	31	47	63
7.4	73	109	146	17.4	31	47	62
7.6	71	107	142	17.6	31	46	61
7.8	69	104	138	17.8	30	46	61
8.0	68	101	135	18.0	30	45	60
8.2	66	99	132	18.2	30	45	59
8.4	64	96	129	18.4	29	44	59
8.6	63	94	126	18.6	29	44	58
8.8	61	92	123	18.8	29	43	57
9.0	60	90	120	19.0	28	43	57
9.2	59	88	117	19.2	28	42	56
9.4	57	86	115	19.4	28	42	56
9.6	56	84	113	19.6	28	41	55
9.8	55	83	110	19.8	27	41	55

TIME	VELOCITY (fpm)			TIME	VELOCITY (fpm)		
(sec)	10 ft.	15 ft.	20 ft.	(sec)	10 ft.	15 ft.	20 ft.
10.0	54	81	108	20.0	27	41	54
10.2	53	79	106	20.2	27	40	53
10.4	52	78	104	20.4	26	40	53
10.6	51	76	102	20.6	26	39	52
10.8	50	75	100	20.8	26	39	52
11.0	49	74	98	21.0	26	39	51
11.2	48	72	96	21.2	25	38	51
11.4	47	71	95	21.4	25	38	50
11.6	47	70	93	21.6	25	38	50
11.8	46	69	92	21.8	25	37	50
12.0	45	68	90	22.0	25	37	49
12.2	44	66	89	22.2	24	36	49
12.4	44	65	87	22.4	24	36	48
12.6	43	64	86	22.6	24	36	48
12.8	42	63	84	22.8	24	36	47
13.0	42	62	83	23.0	23	35	47
13.2	41	61	82	23.2	23	35	47
13.4	40	60	81	23.4	23	35	46
13.6	40	60	79	23.6	23	34	46
13.8	39	59	78	23.8	23	34	45
14.0	39	58	77	24.0	23	34	45
14.2	38	57	76	24.2	22	33	45
14.4	38	56	75	24.4	22	33	44
14.6	37	55	74	24.6	22	33	44
14.8	36	55	73	24.8	22	33	44

Visual 17: Smoke Tube Conversion Chart

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 in atmosphere with elevated methane readings should:
    a. Use only inflatable seals.
    b. Leave a corner of the stopping 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 FAB.
    b. When opening a door or knocking out a stopping 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 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.
    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 — a. 

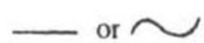
(2) Line brattice — b. X

(3) Overcast — c. 

(4) Main fan — d. 

(5) Man door — e. ¢

(6) Permanent stopping — f. R

g. 

(7) Regulator — h. D

(8) Mine Door — i.

(9) Box Check — j. 

(10) Check Curtain — k.

GENERAL REVIEW ANSWER SHEET

1. b
2. b
3. a
4. c
5. c
6. d
7. d
8. a
9. d
10. (1) g
    (2) k
    (3) a
    (4) c
    (5) j
    (6) i
    (7) f
    (8) h
    (9) d
    (10) e

Glossary

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.

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 entry – The main haulage road.

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 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 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 – A permanent or temporary 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.

Advanced Mine Rescue Training - Coal

Module 4
Exploration

Module 4 – Exploration

Contents

<u>Instructional Text</u>

Course Objectives

The mine rescue team members will be able to prepare for and perform underground explorations under rescue and recovery conditions.

The team members will:

- Explain the purpose of mine rescue exploration.
- Describe the purpose and demonstrate how to establish the Fresh Air Base (FAB).
- Describe and demonstrate how to advance the FAB.
- List and describe the types of equipment needed for mine rescue.
- Explain the purpose of team briefing and debriefing sessions, and list the information that should be included.
- Explore a section of the mine using the two primary methods of exploration.
- Demonstrate proper traveling procedures.
- Use gas testing devices.
- Explain the purpose of progress reporting, identify the items covered in a progress report, and demonstrate the procedure.
- Explain the purpose of mapping, identify the items a team will map, and demonstrate proper mapping.
- If available for training, demonstrate proper set-up and use of real-time communications and electronic mapping equipment.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member
- Communication System(s)
- Gas testing devices team uses
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams Suggested:
- Communication equipment used by MSHA Mine Emergency Operations (MEO)
- Gas testing devices used by MSHA MEO
- Linkline
- Map board
- Laptop and Mapping Software used by MSHA MEO
- Chalkboard/Flipcharts
- PowerPoint program

NOTE: In addition to these materials, you are encouraged to incorporate any other up-to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction

II. Examination of Mine Openings

III. Barefaced Exploration

IV. The Fresh Air Base (FAB)

- a. Establishing a FAB
- b. The FAB Coordinator
- c. Advancing the FAB

V. Apparatus Teams

- a. Team's Role in Exploration
- b. Team Equipment
- c. Equipment Required by Law
- d. Other Equipment

VI. Team Briefing Sessions

VII. Preparing for Exploration

- a. Team Captain's Responsibilities
- b. Donning the Apparatus and Getting Under Oxygen

VIII. Exploration Methods and Procedures

- a. Rapid Exploration
  - i. Encountering Irrespirable Atmosphere
  - ii. Encountering Smoke
- b. Advance, Tie Across and Behind
  - i. Advancing and Tying In
- c. Standard Exploration Procedures and Practices
  - i. Team Checks
  - ii. Rate of Travel
  - iii. Traveling in Smoke
  - iv. Traveling Through Ventilation Controls
  - v. Traveling Through Water
  - vi. Crawling or Climbing
  - vii. Marking Route of Travel
  - viii. Marking Areas Explored
  - ix. Inspecting and Testing Roof and Rib

x. Visual Inspections
xi. Roof and Rib Tests
xii. Testing for Gases
xiii. Progress Reporting
xiv. Mapping
xv. Communication
1. Communication Systems
2. Communication with the FAB and Command Center
3. Using the Lifeline Cable to Communicate (Signaling)
4. Problems with the Use of the Lifeline

d. Returning to the FAB

IX. Debriefing

X. Improvements in Mine Rescue Tracking Technologies

a. Wireless Communications and Tracking Technologies
b. Computer-Assisted Mapping

Instructional Text

Introduction

“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.

Exploration is a broad topic. We’ll be talking about preparations for explorations, team briefings and debriefings, standard procedures for advancing inside the mine, and the equipment you’ll be using during exploration.

NOTE: Rescuing survivors and recovering bodies is covered in Module 6.

Examination of Mine Openings

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

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 (FAB) 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 FAB 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 FAB without apparatus. Teams equipped with apparatus continue exploration from the FAB.

The Fresh Air Base

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

Establishing a FAB

Usually, the operation's initial FAB 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 FAB on the surface.

Whether you put it underground or on the surface, the FAB 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 FAB to the surface should be secure.

When the FAB is set up underground, an air lock must be built to isolate the FAB 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 FAB.

NOTE: Refer to the list of requirements for a FAB on Visual 1.

Here are some specific factors to consider when you select a site for a FAB:

- Be sure the FAB is located where it's assured positive ventilation and fresh air.
- If the FAB 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 FAB. 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 FAB.

These factors are probably the most important that help determine where to establish a FAB, 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 FAB 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 FAB is isolated from any possible stray or direct current.

The FAB is normally outfitted with supplies and other equipment to be used during the operation. For example, a typical FAB 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 FAB, as well as tools and replacement parts for self-contained breathing apparatus and a map of the affected area.

If possible, the FAB 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

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

Stationed at the FAB, there will be a person who is responsible for establishing and maintaining orderly operations. This is the "Fresh Air Base Coordinator." The FAB Coordinator plays a key role in ensuring that the entire operation runs smoothly and efficiently. Because the FAB Coordinator's job is so important, it is absolutely essential that everyone at the FAB 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 FAB.

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

The primary responsibilities of FAB Coordinator include the following:

- Maintain and 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 FAB 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 FAB.

These primary responsibilities include a great number of duties that may be delegated to other personnel, but it's still the FAB 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 FAB 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 FAB Coordinator's responsibility to make sure someone is stationed at the FAB to monitor it. Additionally, the FAB Coordinator should also make sure no unauthorized personnel or equipment are permitted to go inby the FAB.

An incoming FAB 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 FAB Coordinator's duty to check communications between the FAB and the Command Center to make sure the system is operating properly. The Coordinator should reports his or her arrival at the FAB and ensure the Command Center logs the arrival time.

Sometimes, "runners" are stationed at the FAB to carry messages from the FAB 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 FAB

The FAB 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.

NOTE: Refer to Visual 3, as you explain to the team how to advance a FAB.

To advance the FAB, the team will have to build a new air lock at the site of the new FAB 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 FAB and the new one. However, be sure to leave open the last stopping outby the new FAB 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 FAB and remove or open that air lock and any stoppings in parallel entries. This permits air to enter inby the old FAB and flush the area up to the new FAB.

Before everyone is moved up to the new FAB, 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 FAB.

NOTE: If gases are found to have accumulated in areas that are difficult to clear by means of regular ventilation (very high or low spots, etc.), it may be necessary to use line brattice to channel the flow of air directly into these areas. The team may do this by holding up the brattice so that it directs air into the places where the gases have collected.

REVIEW QUESTIONS

Ask the team members the following questions and allow time for them to answer. Discuss the answers with them so they fully understand the material covered in this section.

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. The FAB is the underground base of operations and starting point for rescue and recovery work into irrespirable atmospheres.

2.
   - The FAB 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. The FAB 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 FAB.

4. To advance the FAB,
   - Construct a new air lock and any stoppings in parallel entries that are needed, repair ventilation controls to the point where the new FAB is located, and provide an opening to the return.
   - Then return to the old FAB and remove that air lock and any stoppings in parallel entries in order to ventilate the new area.
   - Prior to moving everyone up to the new FAB, 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

Once the FAB 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

During exploration, the team travels in potentially hazardous atmospheres. Roof 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 FAB 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 FAB 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.

NOTE: While a team is "at rest," it's important to allow enough time for their apparatus to be cleaned, tested, and prepared for use (and repaired, if necessary).

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

30 CFR Section 49.16 – Equipment and maintenance requirements

(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.

Other Equipment

Beyond what is required by law, the other equipment your team will use depends on the situation. For example, if you are rescuing survivors, the team will probably carry a stretcher or stokes basket, and an extra approved breathing apparatus for the rescued person. But if your task is to build ventilation controls, the team will probably carry tools and other construction equipment.

Some of the material you need to build ventilation controls (such as brattice cloth) may already be underground, so you will simply pick up what you need as you progress through the mine. This also applies to other team tasks that require the use of materials already inside the mine.

Here are some examples of other equipment typically used during exploration:

- High-Range Multi-Gas Detectors

  NOTE: Detectors can be configured with an interface and radio in order to provide real-time gas readings, enabling the Command Center to continuously monitor a specific area for gases, in real-time, as opposed to having a team member remain in that area to monitor and communicate gas readings back to the FAB and Command Center.
- Communications Equipment (Including real-time communications system components)
- Ventilation measuring and air sampling devices such as anemometers, pressure gauges, smoke tubes, syringes, etc.
- Lifeline – This refers to the powered communication/lifeline system used as a backup if the main system fails. The team's communication line is normally used for this.
- Linkline – This is a line or rope, usually equipped with rings, that is used to hook team members together in smoke.
- Chemical light sticks – Teams may want to use these as "bread crumbs" to indicate areas of travel during exploration.
- Mapboard and marker – The mapboard may be fitted with a Plexiglas cover to protect the map from water damage in wet mines.
- Roof testing device
- Walking stick – The captain can use a walking stick to probe water depth or to avoid obstructions in heavy smoke.
- Stokes basket or stretcher and blankets
- First aid kit
- Fire extinguisher
- Tools – May include a hammer, nails, axe, shovel, brattice cloth, and possibly a saw, and a wrench to open water line valves, tape measure, utility knife and channel locks.

  NOTE: Use non-sparking tools, nails, spads, etc.
- Extra approved breathing apparatus and/or a CAREvent (if missing miners are involved).
- Washers with streamers or flags attached for marking hazardous areas, such as bad roof. Mention these items if your team uses them.
- Carpenter's apron – The captain may use an apron to carry a notebook, pen, and chalk. Other team members may use one for carrying nails, hand tools, etc.
- Thermal Imaging Camera – A thermal imaging camera enables you to locate "hot spots" that you cannot see with your eyes. It works extremely well, especially in smoke, to quickly locate miners and/or fires.

NOTE: A Thermal Imaging Camera is Not MSHA-Approved. Any thermal imaging camera shall be used **according to the approved plan** for mine rescue and recovery operations. It is important to continuously monitor the atmosphere for the presence of explosive gases.

Team Briefing Sessions

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 FAB.

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:

NOTE: Refer to Visual 4.

- 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 FAB, 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

Before your team proceeds to the FAB, 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 be allowed underground or serve as a surface backup during the event.
- Ensure that all apparatus have been tested, checked (including confirmation that the CO_2 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 FAB 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 FAB, 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 FAB 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 FAB Coordinator.
- Check battery levels for radios, detectors, and communications systems.
- Synchronize watches with the FAB Coordinator.
- Discuss with the FAB Coordinator the type of communication system that will be used.

NOTE: To ensure that radio signal strength remains consistent throughout exploration, determine **IN ADVANCE** at what intervals and/or locations signal strength will be checked.

Donning the Apparatus and Getting Under Oxygen

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

NOTE: At this point, you may want to review your team's procedure for getting under oxygen.

Once all preparations and last-minute checks have been made, including a check to assure all team members have CO_2 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 FAB, 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

Ask the team members the following questions and allow time for them to answer and discussion.

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?

ANSWER SHEET

1. 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.

- 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

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

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 FAB, 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 FAB 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, radio communication between the team members must be maintained. If unplanned interruptions in radio communication are experienced for any reason, exploration stops until communication is reestablished.

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

Changing Conditions

The team may encounter changing conditions or circumstances that would require them to immediately reassemble and continue exploration using the “Advance, Tie Across and Behind” method. These changing conditions include:

- Rapid change in mine atmosphere.
- Smoke that limits visibility.
- Discovery of a fire.
- Discovery of a Refuge Alternative or Rescue Chamber.
- Discovery of a victim requiring assistance, including first aid and/or extrication.
- Team member experiences a “problem” such as apparatus malfunction or physical issues.
- Travel in an entry is blocked.

NOTE: If this happens, the affected team members will need to travel to an adjacent entry and advance in that entry, until they can gain access to their assigned entry. Once the team member regains access to their assigned entry, they must or should tie in behind them and resume explorations.

Guidelines for Rapid Exploration

If mine rescue teams are to be deployed using the Rapid Exploration method:

- A wireless communication system must be in place and operating.
- The communication system’s radio signal strength must be monitored.
- Radio communication must be maintained between ALL exploring team members, the FAB, and the Command Center.
- All team members must be familiar with and have up-to-date training on the wireless communication system to be used.
- Must have a minimum of two persons per entry to be explored: one person operating radio and one person monitoring the gas detector.
- Must have “good” visibility in the areas to be explored.
- Teams must map relevant information in all entries explored.

Advance, Tie Across and Behind

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

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

Communication between team members is critical and a true assessment of one's condition or state of equipment must be known by all team members as soon as possible so corrective actions can be taken, which may include travelling back to the FAB. If a team member is feeling unfit to travel or an apparatus is malfunctioning, the team member should communicate this immediately to the rest of the team. Delay in relaying this information to other team members could affect the safety of the entire team.

If the team has donned their apparatus, team captains observe each team member's physical condition while requesting a verbal response from each member confirming their condition, observe each SCBA gauge reading at each stop, and reporting their observations including the lowest reading to the FAB and the Command Center. The lowest reading may then be used as a reference point to determine when the team should return to the FAB.

In addition to checking each team member and their apparatus, team stops allow the team a chance to rest. If your team is searching for survivors, you'll probably want to advance rapidly, but pacing yourself is critical to your safety. Team members should understand the physical activity they are able to endure while under apparatus. The work that team members are asked to perform is very arduous. The oxygen, restricted airflow, and heat can cause overheating; therefore, it is important to continuously monitor the condition of your team throughout all of your activities.

Rest stops are important; be sure to allow time for them. How long you stop for each check will be determined by the conditions you encounter and the work you are doing. Rest stops are also important (perhaps more so) on the return trip. The team will usually be more tired once they've completed their work. Don't forget to allow time for team checks as you travel back to the FAB.

Rate of Travel

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.

If the team is on their way back to the Fresh Air Base, or if they've been doing strenuous work, they will naturally be more tired. The captain should always observe and understand the condition of their team, and manage the rate of their activity considering the condition of his team into account. This includes the rate of travel and the number of rest needed back to the FAB.

Traveling in Smoke

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."

When spatial disorientation occurs, you lose your sense of "which end is up," so to speak. You may bump into things and perhaps even completely lose your balance and fall down.

For these reasons, when mine rescue teams travel in smoke, all team members must be joined together by means of a linkline and attached to a lifeline.

The captain can use a walking stick that is attached to the person through a wrist lanyard or gear keeper as an aid in checking the area in front of the team for roof falls and other obstructions.

There are also two methods commonly used to help you see a little better when you're traveling in smoke. One method is to remove your cap lamp from your cap and hold it at waist level.

Because your cap lamp is normally above eye level, it can produce glare in smoke. If you've ever tried to travel through dense fog with your car's high beams on, you know how difficult it is to see. You can see much better in fog with the low beams on because they produce less glare.

Another way to improve your visibility in heavy smoke is to let the lamp hang from its cord to light up the rail or rib that you're moving along. This technique helps you see a little easier because the smoke is usually less dense closer to the mine floor.

If smoke is so dense as to make visibility very poor, you may need to keep in constant physical contact with a rail, a compressed air or water line, or the rib in order to “feel” your way along.

In certain circumstances (under the direction of the Command Center) conditions may allow the use of a Thermal Imaging Camera in smoke (less than 1% of methane in the area affected Thermal Imaging Cameras, when used properly, can greatly enhance the efficiency and effectiveness of rescue/recovery teams.

NOTE: A Thermal Imaging Camera is Not MSHA-Approved. Any thermal imaging camera shall be used according to the approved plan for mine rescue and recovery operations. It is important to continuously monitor the atmosphere for the presence of explosive gases.

Traveling Through Ventilation Controls

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

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.

NOTE: It’s recommended that you don’t travel through water that is more than knee deep (less in low coal). It may be a better option, if possible, to travel an alternate route and detour the water.

There is still one other alternative to be considered: If you have pumping equipment, and gas conditions in the area permit, your team may be able to pump the water out. The pump itself can be set up at the FAB (or outby), with non-conducting suction lines leading to the water.

Hazards Associated with Pumping Water

When pumping water out of an affected area, the water itself may contain hazardous, water-soluble gases which can be released into the “good” atmosphere, outby the FAB, as the pumping operation proceeds.

Also, any air that’s sucked into the line could carry hazardous gases.

NOTE: Keep in mind that it’s **extremely important** to know the gas conditions at the site.

Crawling or Climbing

As you advance, it may be necessary to crawl or to climb inclines or ladders. Keep in mind that this tires the team, so you should do it only when absolutely necessary.

Marking Route of Travel

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 FAB.

As the team returns to the FAB, 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 FAB, and (2) if a backup team is sent in to look for you, it shows them which way you traveled.

Marking Areas Explored

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 and Rib

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

Visual Inspections

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 and Rib Tests

Roof tests should be conducted when visual inspection indicates that the roof 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 or ribs, also indicate the need to test.

In addition, the captain should make roof 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.

If conditions permit, roof tests should be made from rib to rib. Whenever possible, it's best to test all parts of an area that indicate the need for testing.

If you encounter bad roof, the team may need to timber it before you advance under it. If space permits, the team can simply detour the bad roof by walking to the right or left of it.

It's standard practice to mark this hazardous area with chalk or some other type of marker, and note the location on the mine map. This makes the hazardous area easy to spot, so you can detour it again when the team retreats.

When you retreat, you should leave the markers in place so that they will serve as a warning for other teams that may enter the area.

NOTE: Some teams use other methods of marking the bad roof.

Testing for Gases

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.

NOTE: Be prepared to discuss any other gases for which the team may be required to test.

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.

NOTE: When using the wireless communication system, high-range, multi-gas detectors with specialized software and interface, teams can transmit gas readings in "real time," directly and accurately to the Command Center and allows for continuous monitoring for gases in specific areas, without leaving mine rescue personnel behind to monitor and report gas readings.

Progress Reporting

During exploration, information the team relays to the FAB 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 FAB 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 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 FAB 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 FAB, be sure you clearly and correctly identify the location.

Mapping

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 FAB 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 FAB 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.

NOTE: Refer to **Visual 5** as you explain what information should be marked on the map. Point out each marking as you discuss it.

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.

The map person and the Command Center Attendant should also practice together to develop their method of simultaneous mapping.

NOTE: ALL mine rescue teams should be trained on computer-assisted, electronic mapping systems like those used by MSHA's Mine Emergency Operations (MEO) Division of the Technical Support Program Area.

This system incorporates software that includes "click and drag" mapping symbols. Computer-assisted mapping is also included in the National Mine Rescue Contest Rules. **Refer to Visuals 6 and 7.**

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 FAB, 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 Systems

Discuss and/or demonstrate the **Underground Communication and Tracking System** used by MSHA's Mine Emergency Operations (MEO). Provide and facilitate hands-on set-up and use of the equipment, when available.

A secure and reliable communication system, utilizing a sound powered communication or lifeline cable and/or radios, must be established and maintained between the mine rescue teams, FAB, and the Command Center.

NOTE: For radio communications, agree (in advance) on which team members will check and monitor radio signal strength and connection to the FAB during the rescue operation. You'll need to:

- **Ensure that clear radio communication is maintained at all times.**
- **Determine, in advance, at what intervals and/or locations that signal strength will be checked.**

When using radios during exploration, use standard radio terminology and protocol for transmitting and receiving messages. For example, when you call out information:

- **Identify the receiver; then identity yourself.**
- **Always confirm messages received.**

Communication with the FAB and Command Center

As the team advances, it's essential to stay in close contact with the FAB 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 FAB and relaying instructions from the FAB to the team.

Using the Lifeline Cable to Communicate (Signaling)

In the event that your team's communication system fails, you can still communicate some with the FAB 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.**

At the FAB, 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 FAB 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 FAB, it will be the attendant's job to receive and send signals to and from the team by means of the lifeline.

NOTE: Refer to **Visual 8** as you discuss the following signals:

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

If the team is stopped at one location for an extended period, or if it is performing a specific task, such as building a stopping or clearing a roadway, it is common practice for the FAB to signal one long pull about every five minutes to check on the team's condition. The team should then acknowledge that they are okay by returning the signal.

When you're using the lifeline to communicate with the FAB, the captain's signals to the team should also be relayed back to the FAB.

The No. 5 person relays the captain's signals to the FAB by repeating them on the lifeline and then waits for the FAB to acknowledge that it has received the signal before sounding a response to the captain's signal. All this is done before the team executes the instructions dictated by the signal.

Actually, this is a lot less complicated than it sounds. Here's how it works: Say the captain wants to halt the team. He or she signals to stop the team.

For the benefit of the FAB, the No. 5 person repeats the captain's signal by tugging once on the lifeline. The attendant at the FAB then acknowledges receiving the signal by sending it back to the team.

Once the No. 5 person receives the FAB's acknowledgment, he or she then returns the signal to the captain. This means that 1) the No. 5 person has heard the captain's signal; 2) the signal has been relayed to the FAB; and 3) is acknowledged by a return signal. The team may then proceed to execute the command dictated by the signal.

Problems with the Use of the Lifeline

Using the lifeline as a signaling device can present problems. For example, it becomes more difficult to signal with the lifeline if the team has advanced any great distance from the FAB.

When your team travels up headings, crosscuts, and entries, the lifeline drags along behind you and has a tendency to get caught as it travels around corners. Debris and other obstructions encountered after an explosion or fire may also snag the line and limit its use, but the use of carabiner or pulleys can help mitigate the problem.

REVIEW QUESTIONS

Ask the team members the following questions and allow time for them to answer.

1. What team signals do you use during exploration?

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

3. Describe how a team marks its route of travel on advance and retreat.

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

REVIEW ANSWERS

1. One—stop, two—advance, three—retreat, four—emergency

2. Falls and obstructions, water, smoke, fatigue, amount/weight of equipment carried, degree of slope

3. 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 FAB.) On retreat, the captain or co-captain puts an “X” through each arrow.

4. 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 FAB

It's very important for the team to pace its work so that it can return to the FAB on time. Also, you must be sure to allow an ample supply of oxygen for the return trip to the FAB 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 FAB, 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.

NOTE: If your **state sets a limit** for advance during exploration, be sure to **mention the regulation that applies** to that at this time.

If your team is late getting back to the FAB and has stopped communicating, a backup team will be sent in to look for you, even if it means delaying the entire operation. So, if you're going to be late, be sure to communicate your intentions to the FAB and Command Center.

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 FAB, 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 FAB 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.

The team may be permitted to advance under these conditions if it's definitely known that a life will be saved by the action, and **if you have the approval of the officials in charge of the operation.**

Debriefing

When you return to the FAB, your team captain will confer with the FAB Coordinator and the captain of the incoming team to exchange information about what the team saw and found. At this time, the team captain and the Coordinator should compare maps to make sure their markings correspond.

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.

If your team built stoppings, your captain should explain what you constructed and what remains to be completed. Be specific about any equipment and supplies your team left in the area. Your team captain may also make suggestions as to what equipment the ingoing team should take with them.

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.

Besides reviewing your team's findings you'll also review the team's map to make sure the markings on it correspond with the master map. During the debriefing session, you are also generally told what you should and should not say to media representatives and to others.

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.

The following is important information that the Command Center should receive from the mine rescue team:

- Percentage of assignment completed.
- Location on map of their stopping point indicated by "Furthest Point of Advance" or FPA.
- Location and Identity of any persons encountered and left in the mine.
- All potential ignition sources encountered by the team such as fires, batteries or other sources.
- Condition of ventilation system, including the condition of ventilation controls.
- Any condition that hindered or stopped team travel.
- Any specific notable conditions or problems while exploring.
- Any problems with your equipment.
- Additional supplies, including potable water, needed at the FAB.

REVIEW QUESTIONS

Discuss the answers with the team so they fully understand the material covered in this section.

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 FAB?

3. Why is the debriefing session important?

ANSWER SHEET

1. 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. 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. 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.

Improvements in Mine Rescue Technologies

Wireless Communications and Tracking Systems

NOTE: Refer to **Visual 9.**

Mine rescue communications and tracking systems which have been developed in recent years can now be deployed to allow for direct, real-time communication between all team members and the Command Center.

These systems enable direct and simultaneous communication between the advancing mine rescue teams, Command Center, FAB, and backup mine rescue teams.

The Command Center now has the capability to continuously monitor (in real time) the progress of the advancing team, along with gas readings from sensors and detectors left in specific areas by mine rescue teams and personnel. As the team advances, or if they are forced to retreat, the sensors will continue to transmit data back to the Command Center.

Computer-Assisted Mapping

MSHA's Mine Emergency Operations (MEO) uses computer-assisted mapping systems that feature easy-to-use "click and drag" symbols. Computer-assisted mapping is also included in the National Mine Rescue Contest Rules.

For an actual mine emergency, an updated AutoCAD map should be supplied to MSHA's MEO, which they would use as a base map in their Underground Communication System (USC) software for mapping purposes.

Team members should receive training on all communications and tracking equipment they may use during a mine rescue operation.

An MSHA MEU member should be assigned to each advancing team to aid in the setup of the Underground Communication System (UCS).

NOTE: Computer-assisted mapping may be included in Mine Rescue Contest Rules.

TRAINING TIP: If you are training with multiple teams, you could create a scenario to help team members better understand the decision-making process of the Command Center. For example:

- Assign Team A to explore, while members of Team B coordinate and direct exploration activities from the FAB and/or Command Center.

- When team A completes their assignment, they return to the FAB and/or the Command Center, where Team B will conduct a debriefing session.

- Then, have them to switch responsibilities so that Team B can explore, while Team A directs them from the FAB and/or Command Center.

NOTE: Refer to **IG 7a – Advanced Skills Training Activities for Coal Mine Rescue** for other practical exercises related to exploration.

Visuals

REQUIREMENTS FOR A FAB

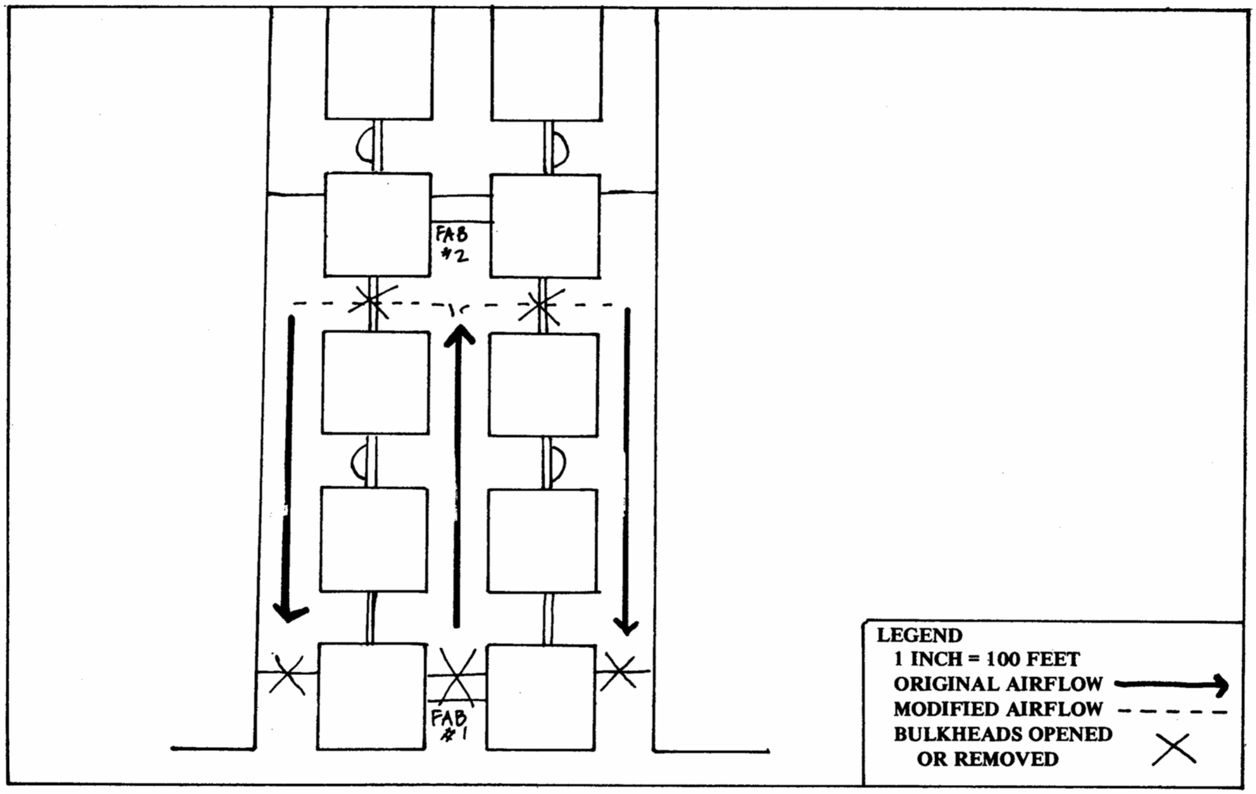
1. Positive ventilation and fresh air
2. Travelway for people and supplies
3. Communication with Command Center
4. Communication with team

Visual 1: Requirements for a FAB

COORDINATOR'S RESPONSIBILITIES

1. Communication with team and Command Center
2. Follow and mark team's progress on map
3. Coordinate and oversee all activities

Visual 2: FAB Coordinator's Responsibilities

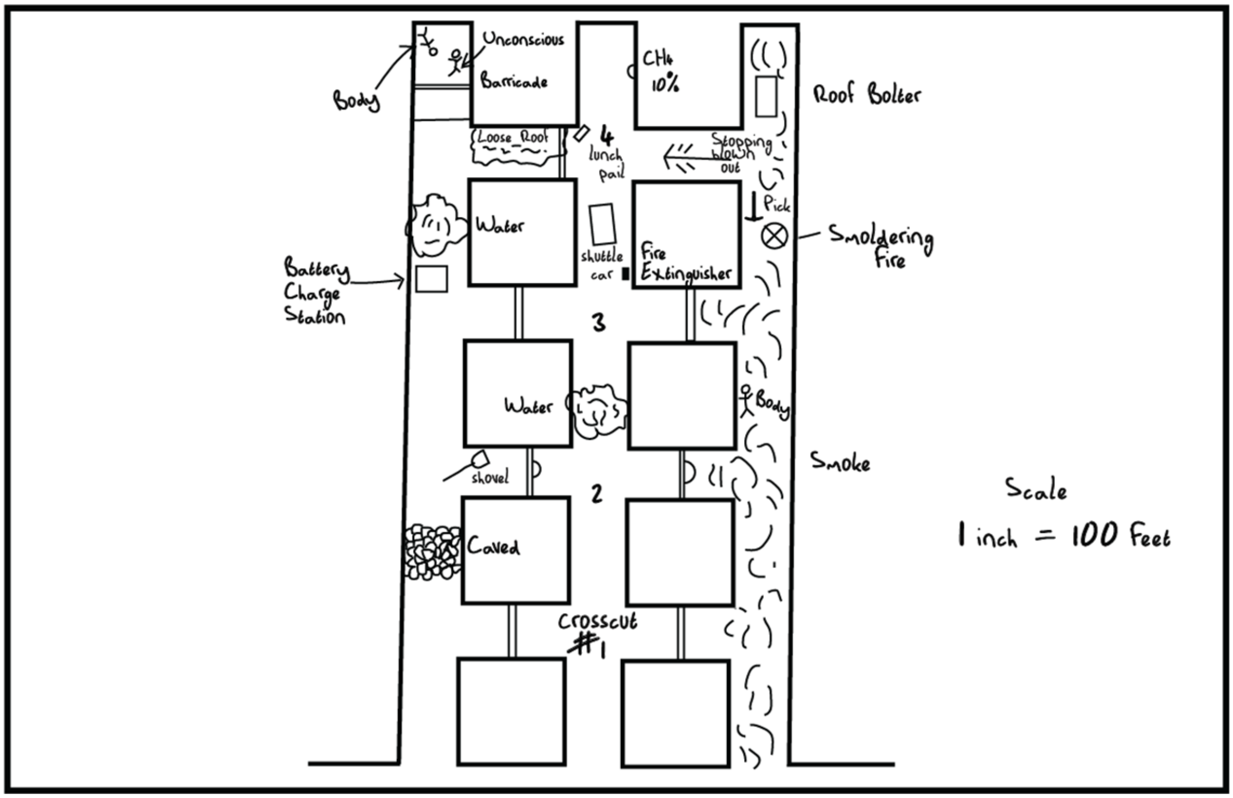


Visual 3: Advancing the FAB

BRIEFING QUESTIONS

1. Is the evacuation complete? Are any miners missing? If so, how many and what are their possible locations?
2. What is known about the cause of the disaster?
3. Is your team the first one to explore? (In multi-level mines, the team would also want to know if there are any other teams working on other levels.)
4. Have state and Federal officials been notified?
5. Are guards stationed at all mine entrances?
6. Is the ventilation system operating? Is it a blowing or exhausting system? Are attendants posted at the surface ventilation controls? Have air samples been taken? If so, what are the results?
7. Will there be a backup team standing by at the FAB, and reserve teams on the surface?
8. What are the team's objectives, and what is their time limit?
9. What conditions are known to exist underground?
10. Is the mine's communication system operating? Is it being monitored?
11. Is power to the affected area on or off?
12. Is there diesel or battery-powered equipment or a charging station in the affected area?
13. What type of equipment is in the area? Where is it located?
14. Where are air and/or water lines located? Are they in operation? Are valves known to be open or closed?
15. What type of firefighting equipment is located underground? Where is it?
16. What tools and supplies are available underground? Where are they?
17. Are there storage areas for oil or oxygen, acetylene tanks, or explosives in the area to be explored?

Visual 4: Briefing Questions

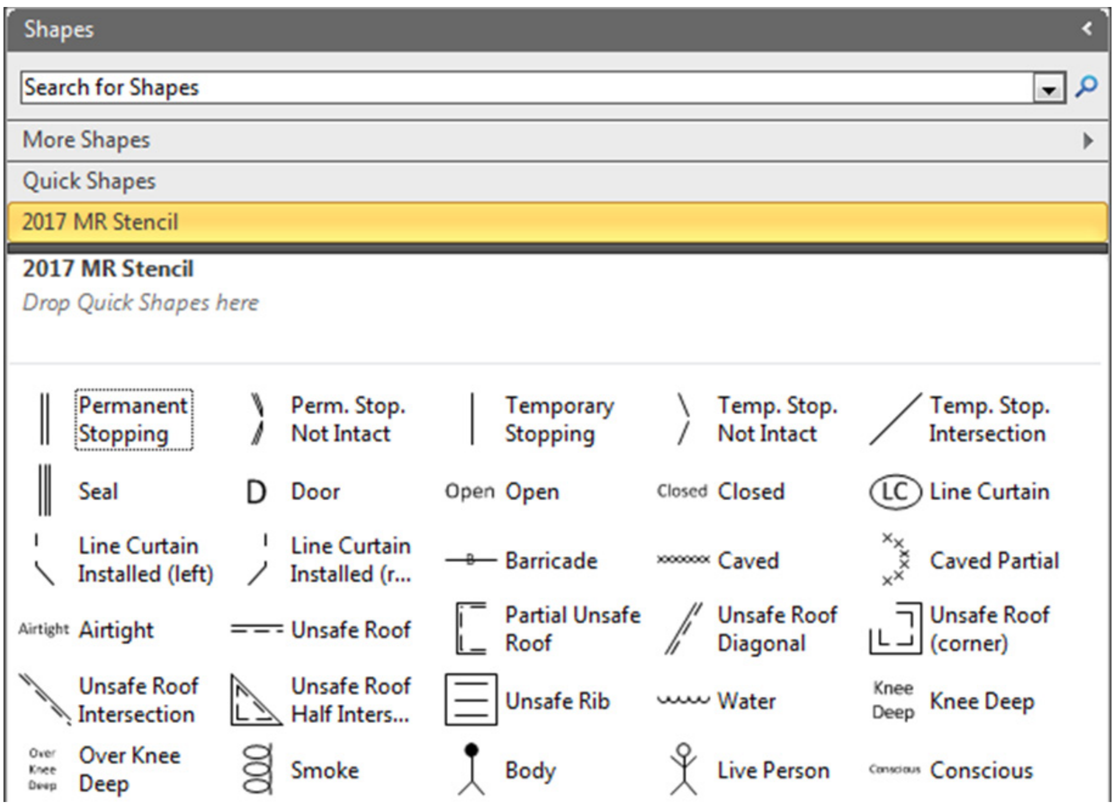


Visual 5: Marking the Mine Map

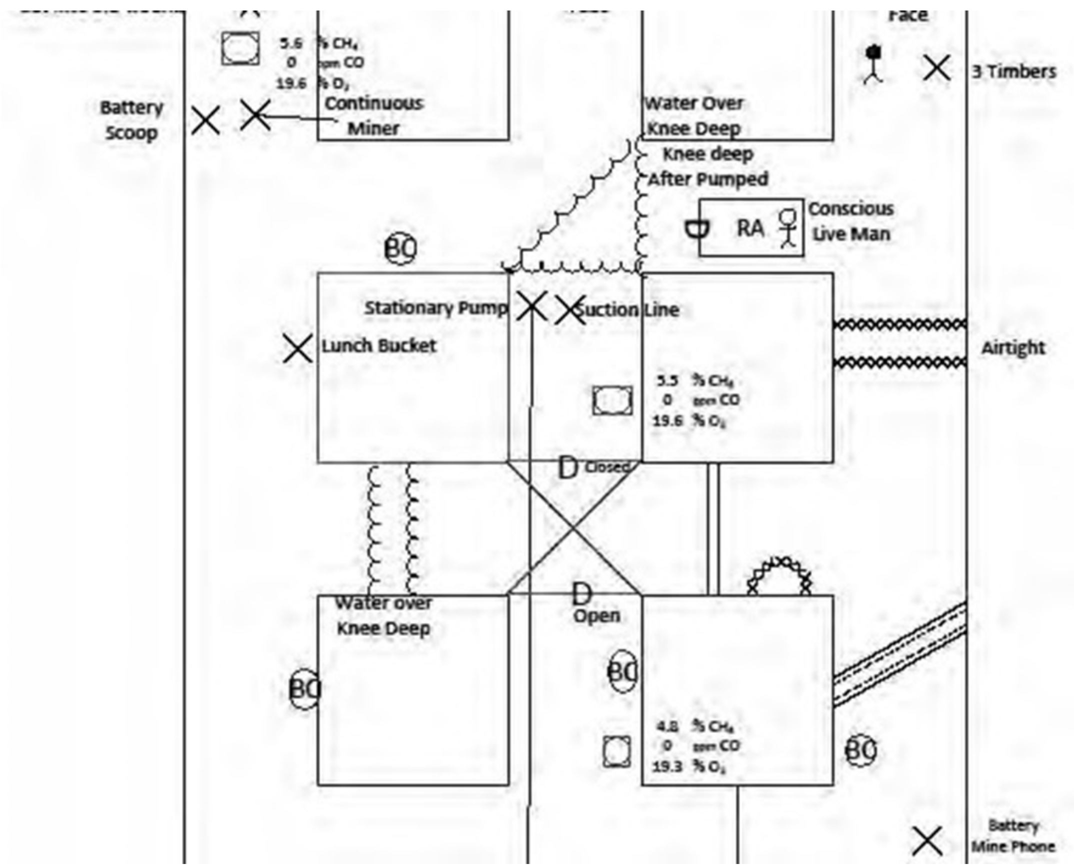
Microsoft® Visio® Mapping Software

For an actual mine emergency, an updated AutoCAD map should be supplied to MSHA's MEO, which they would use as a base map in their Underground Communication System (USC) software for mapping purposes.

This software allows for mapping functionality very similar to the click-and-drag method used in contests with Microsoft Visio®.



Visual 6: Click/Drag Mapping Symbols



Visual 7: Sample Map Using Mapping Software Symbols

MINE RESCUE TEAM SIGNALS

- ONE - STOP
- TWO - ADVANCE
- THREE - RETREAT
- FOUR - DISTRESS/EMERGENCY

Visual 8: Mine Rescue Team Signals

Underground Communication System Components

<u>ALWAYS</u> follow manufacturer's recommendations for care, maintenance, and use of any mine rescue communications system.

Equipment needed (pictured below):

- Gateway
- Yagi Antenna or Disc Antenna
- Fiber Switch
- Smart Battery
- Cable Set
- Fiber connection from a fiber reel
- IWT Radios (Minimum of 2)
- Portable MESH Node (PMN)

Visual 9: Underground Communication System Components

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 FAB.
    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 FAB is established.

5. In advancing a FAB, 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 FAB to ensure that all gases have been flushed from the area.
    c. Proceed inby the new FAB to explore and let other workers check for any gases outby the new FAB.
    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 behind which conditions are not definitely known, they should:
    a. Ask the FAB to send in the backup team.
    b. Erect an air lock to prevent the mixing of atmospheres.
    c. Open the door or stopping 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 FAB, the team member should:
    a. Be immediately sent back to the FAB.
    b. Be sent back to the FAB 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 FAB.

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

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

Glossary

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 FAB as a "backup" for the working team inby the FAB.

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 (FAB) – 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 FAB. It may be used as a manual communications system to the FAB [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 FAB 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.

Advanced
Mine Rescue Training - Coal

Module 5
Fires, Firefighting, and Explosions

Module 5 – Fires, Firefighting, and Explosions

Contents

Instructional Text

Course Objectives

The mine rescue team will be able to competently assess underground conditions during a mine fire and after an explosion, and be able to properly fight a fire.

Team members will:

- Describe the components of the fire tetrahedron.
- List and describe the 5 classifications of fires.
- Use firefighting equipment.
- Explain how to locate and assess a mine fire.
- Demonstrate the proper techniques for fighting a fire directly.
- Explain the proper techniques for sealing a mine fire.
- Explain and describe the causes and effects of explosions.
- Explain and demonstrate the proper procedures for assessing conditions following an explosion.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams

Suggested:

- Any firefighting equipment that the team will be using, or pictures or slides of the equipment if it is not available
- Chalkboard or flipchart
- PowerPoint program
- Laptop computer

NOTE: In addition to these materials, you are encouraged to incorporate any other up- to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction

II. Fires
   a. Fire Tetrahedron
   b. Classification of Fires

III. Firefighting Equipment
   a. Dry Chemical Extinguishers
      i. General Information
      ii. How to Use Hand-Held Extinguishers
      iii. Using Hand-Held Extinguishers on an Obstacle Fire
      iv. How to Use Wheeled Extinguishers
   b. Rock Dust
   c. Water
      i. Waterlines
      ii. Fire Cars
      iii. Fire Cars with Low Expansion Foam
      iv. Techniques of Applying Water to Fires
   d. High Expansion Foam
      i. Description
      ii. Foam Generators
         1. Description
         2. How to Use

IV. Firefighting
   a. Before Going Underground
   b. Locating Fires and Assessing Conditions
   c. Direct Firefighting
      i. General Procedures
      ii. Hazards
      iii. Electric Shock and Electrocution
      iv. Toxic and Asphyxiating Gases
      v. Oxygen Deficiency
      vi. Explosive Gases
      vii. Heat, Smoke, and Steam

V. Indirect Firefighting

a. Sealing Underground
    i. Planning
b. Temporary Seals
    ii. Types
        1. Brattice Cloth
        2. Concrete Block
        3. Wood
        4. Brick
c. Considerations While Building Temporary Seals
    i. Air Sampling Tubes
    ii. Ventilation
    iii. Explosions
    iv. Isolation
d. Permanent Seals
e. Types of Permanent Seals
f. Considerations While Building Permanent Seals
    i. Isolation
    ii. Air Sampling Tubes
    iii. Taking Air Samples
g. Sealing on the Surface
    i. Entire Mine
    ii. Remote Sealing
    iii. Foaming the Fire Area
    iv. Flooding the Mine

VI. Explosions

a. Causes and Effects
b. Before Going Underground
c. Exploration: Indications of Explosion and Assessment of Conditions

Instructional Text

Introduction

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 only because they produce toxic gases and heat, but also because they produce smoke, pose an explosion hazard, and create oxygen-deficient atmospheres.

In this module we will talk about fires and explosions in the mine - how they occur and how they affect your job as a mine rescue team.

Fires

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.

Fire Tetrahedron

Formerly, a fire triangle was used to represent the elements of a fire. This has been replaced by the fire tetrahedron.

The fire tetrahedron is a four-sided geometric representation of the four factors necessary for fire: fuel (any substance that can undergo combustion), heat (heat energy sufficient to release vapor from the fuel and cause ignition), oxidizing agent (air containing oxygen), and uninhibited chemical chain reaction (sufficient exothermic reaction energy to produce ignition).

The fuel/air ratio must be within the flammable limits, which describe the amount of vapor in air necessary to propagate flame. Removing any of these four factors will prevent, suppress, or control the fire.

NOTE: As you discuss the following information, refer to Visual 1 for an illustration of the fire tetrahedron.

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

NOTE: Refer to **Visual 1** for classification chart.

For firefighting purposes you should know the type of fire you are fighting.

The National Fire Protection Association classifies fires into the following four 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 Ashes.

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 Boil.

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 carbon 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 Current.

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.

NOTE: Class K fires are not frequently found in coal mines.

Firefighting Equipment

NOTE: See **30 CFR Part 75 Subpart L – Fire Protection** for further details regarding the Federal requirements on firefighting equipment.

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

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

NOTE: Material is provided below on each of these types of firefighting equipment. If the team uses other equipment, be sure to discuss that equipment also. ***IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams*** includes various activities for hose management and firefighting exercises.

Dry Chemical Extinguishers

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

NOTE: Refer to **Visual 3** for an illustration showing the proper way to use a hand-held extinguisher.

Before using any type of hand-held extinguisher, 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 manufacturer's 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 you will not put out the fire. It may waste both valuable time and the contents of the extinguisher.

To operate a hand-held extinguisher, you should grasp it firmly and approach the fire from the intake air side, holding the nozzle downward at a 45-degree angle. You should stay low to avoid any rollback of the flames and try to get within 6 to 8 feet of the fire before discharging the fire extinguisher.

The PASS System

One should remember the **PASS** system of operating a fire extinguisher. **P**ull the safety pin, **A**im the extinguisher hose/nozzle at the base of the fire, **S**queeze the operating/discharge handle, and **S**weep extinguisher nozzle/agent rapidly side to side to extinguish the fire. There should also be a second extinguisher nearby and you should never turn your back to the fire once it has been extinguished (possible re-ignition).

To effectively and quickly put out the fire, direct the stream of dry chemical to about 6 inches ahead of the flame edge. Begin far enough away to allow the discharge stream to fan out and you should use a deliberate side-to-side motion as you cover the fire with the dry chemical. Each sweep of the chemical should be slightly wider than the near edge of the fire.

As you put out the fire closest to you, you should advance slowly toward the fire, forcing it back. Always be on the alert for possible re-ignition of the fire even though it appears to have been extinguished. The discharge time of hand-held extinguishers varies from 8 to 60 seconds, depending on the size and type of fire extinguisher. A 30-pound extinguisher will normally last 18 to 25 seconds.

As a safeguard, be sure to maintain control of the extinguisher. If you lose control of the extinguisher, you could end up exposing other people to the dry chemical stream.

NOTE: At this point you may wish to supplement the material with more specific information on the type of hand-held extinguisher the team uses.

Using Extinguishers on an Obstacle Fire

If you encounter an obstacle fire with flaming equipment at its center, the fire should be fought by two people using hand-held extinguishers. It is difficult and sometimes impossible for one person to put out this type of fire.

The two firefighters should approach the fire together from the intake air side, holding the extinguisher nozzle downward at a 45-degree angle. Both streams of dry chemical should be directed to 6 inches ahead of the flame edge.

The two firefighters should split up and slowly advance around each side of the obstacle, trying to keep up with each other as much as possible. Each person should cover two-thirds of the fire area, using a side-to-side sweeping motion. When the fire appears to be extinguished, both firefighters should remain on the alert for a short time just in case the fire re-ignites.

How to Use Wheeled Extinguishers

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.

NOTE: At this point you may wish to supplement this material with more specific information on the type of wheeled extinguisher the team uses. **Always follow the manufacturer's recommendations.**

Rock Dust

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

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

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

NOTE: Refer to Visual 4 for an illustration of a fire car.

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

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.

NOTE: At this point you may wish to supplement the material with more specific information on the low expansion foam the team uses. Always follow the manufacturer's recommendations.

Techniques of Applying Water to Fires

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

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.

NOTE: Some foam generator manufacturers recommend that personnel should not travel through foam because hearing becomes difficult, vision is blocked, and breathing becomes uncomfortable. Also, there is the added hazard of slipping and falling in the foam. Some manufacturers also recommend that personnel do not wear self-contained breathing apparatus, gas masks, or other breathing apparatus into the foam. **However, if a team must travel through foam, it is essential that the team members use a linkline to ensure that no one gets lost in the foam. It is important that the team travel along the track or rib, where the best footing is most likely to be.**

Foam Generators

NOTE: Refer to **Visual 5** for an illustration of a foam generator.

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

NOTE: There are many different models of foam generators and each model has its own method of operation. This section on using a foam generator supplies general information only. If you wish to include more specific information on how to operate the model(s) that the team will be using, refer to the manufacturer's information. **Always follow the manufacturer's recommendations.**

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

Ask the team members the following questions and allow time for them to answer. Discuss the correct answers with the team so they fully understand the material covered.

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

2. Discuss each piece of equipment normally available to fight underground fires at the team's mine.

ANSWERS

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.
   - 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.
   - Class C fires are electrical fires. They are extinguished by non-conducting extinguishing agents such as carbon dioxide and certain dry chemicals.
   - 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.
   - 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.

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 use

Firefighting

Before Going Underground

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.

NOTE: This may be a good time to remind the team that no sudden changes should ever be made to the ventilation. If the main fan is off or destroyed, the Command Center will have to make careful plans before starting the fan. Everyone should be out of the mine before the fan is started.

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 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.

NOTE: For a more complete list of the information that should be covered in the briefing, refer to **Module 4 – Exploration.**

Prior to firefighting, and immediately after, each team member should have a carboxihemoglobin test to determine how much carbon monoxide (CO) is in his or her bloodstream.

Each team member's onsite CO rate should then be compared to his or her base rate obtained annually during their physical examination to see if dangerous levels are pre- sent. If a team member has absorbed too much CO, he or she should not be permitted to reenter the mine until the CO level is reduced.

NOTE: For this test, a small amount of blood is drawn and tested for the presence of carbon monoxide (CO).

Locating Fires and Assessing Conditions

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

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.

NOTE: Refer to **Visual 6** for an illustration of how to use a **transverse brattice** as you discuss it in the following section.

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

NOTE: Refer to Visual 7 for a list of the hazards of direct firefighting as you discuss the following section.

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

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

NOTE: Refer to **Visual 8** for a list of toxic gases produced from certain burning materials as you discuss them below.

The extremely toxic gas, carbon monoxide, is produced by all fires because of the incomplete 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 bloodstream 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.

NOTE: Refer to ***Module 2 – Mine Gases*** for further information on toxic and asphyxiating gases.

Oxygen Deficiency

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

NOTE: Refer to ***Module 2 – Mine Gases*** for further information on explosive gases.

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

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.

NOTE: You may wish to refer again to **Visual 6** as you discuss the following information about using **transverse brattice.**

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

Ask the team members the following questions and allow time for them to answer. Discuss the answers with them so they fully understand the material covered in the previous section.

1. Discuss why the fan should be kept running during underground firefighting.

2. Discuss a method of controlling the backup of a fire against the ventilating current (intake air) while fighting it directly.

3. Discuss why burning conveyor belts, cable insulation, and tires are particularly hazardous to firefighters.

4. Discuss other hazards that the rescue team should consider when fighting a mine fire directly.

REVIEW ANSWERS

1.

- 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.

- 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.

- 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.

- Electrocution
- Toxic and asphyxiating gases
- Oxygen deficiency
- Explosive gases
- Heat, smoke, and steam

Indirect Firefighting

Sometimes fighting a fire directly is ineffective or not possible because of certain hazards such as high temperatures, bad ground, or explosive gases. In these cases, it may be necessary to fight the fire from a distance, or “indirectly,” by sealing the fire or by filling the fire area with foam or water. The indirect methods work by excluding oxygen from the fire. The foam or flood of water also serves to cool the fire.

These indirect methods allow the firefighters to remain a safe distance from the fire while they work to control and fight a large or otherwise unapproachable fire.

Sealing Underground

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 map symbol for seal is three straight lines or two straight lines with the word “SEAL” printed after them:

||| SEAL   or || SEAL

NOTE: Draw these symbols on a chalkboard or flip-chart, if possible.

Temporary seals are built to be fairly airtight. They are usually constructed of brattice cloth, concrete blocks, metal panels or boards.

Permanent seals are built to specifications in the engineering design. They are designed to withstand either a minimum of 50psi or 120psi dynamic force resulting from an explosion.

A permanent seal can be constructed from a variety of materials. The most commonly used materials in approved seals are lightweight cementitious material, reinforced concrete, glued concrete blocks, or solid concrete plug.

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.

In short, the Command Center decides where, **approximately,** to build the seals, what materials to use, and in what order to build the seals if more than one is needed. As for the team's responsibilities in sealing, it's up to you to pick the **exact** site within the designated entry or heading for building each of the seals and to do a good job in constructing the seals.

When picking an exact site for temporary seals, you should look for (1) good roof and (2) even roof and rib surfaces. When building a temporary seal, it should always be built far enough into the entry or crosscut to allow enough room and good roof outby it for a permanent seal to be built. If the only site available for sealing has bad roof, you may have to bar it down and support it with posts before beginning to build the seal.

Temporary Seals

Temporary seals can be built using:

- Metal stoppings
- Brattice cloth
- Concrete blocks
- Wood

Metal Stoppings

Metal stoppings are easier to transport than block. They can be erected fairly quickly and used as temporary seals. Foam can be used to seal the perimeter and seams. The center panels of the final temporary seals to be built can be left out until the last minute, allowing the sealing of the area to be completed rapidly. Follow manufacturers' installation procedures.

Brattice Cloth Temporary Seals

Basically, there are three ways to erect brattice seals. With one method, the brattice, canvas, or plastic can be attached to the roof and ribs with spads.

The surplus brattice at the bottom is then weighted with timbers or other available loose material to keep the seal closed. The other two methods require nailing the brattice to a framework of posts and boards that are set in a solid and well-squared location. With one method, the brattice is cut and nailed to the framework and to the ribs, if possible.

To obtain maximum tightness, it may be necessary to foam the edges of the seal and to shovel loose material against and along the bottom. With reasonable care, a brattice cloth seal can be constructed that will allow only slight leakage of air.

Where time is not a serious factor and a fairly tight seal is required, a more substantial brattice cloth seal can be erected. To build this seal, set posts about one foot from each rib and one or more posts in between. Be sure to set the posts firmly on solid ground. Nail boards across the top, center, and bottom of the posts. The boards should extend from rib to rib and the top and bottom boards should be placed as near as possible to the roof and floor.

If the ribs are irregular, short boards extending from the top to the center boards and from the center to the bottom boards should be nailed along both sides of the framework. These boards should roughly follow the curvature of the ribs.

A piece of brattice cloth, canvas, or plastic should be nailed to the boards. The material should be cut large enough to cover the opening, with a small surplus on the sides, top, and bottom. It may be necessary to double or triple the thickness of the material in order to improve the air tightness of the seal.

To close small openings around the edges of the seal, small pieces of boards should be used to push the brattice cloth into all irregularities of the roof, ribs, and floor and should be nailed into place.

To obtain maximum tightness, it may be necessary to caulk the edges of the seal and to shovel loose material against and along the bottom. With reasonable care, a brattice cloth seal can be constructed that will allow only slight leakage of air.

Concrete Block Temporary Seals

Concrete block seals can be put up fairly rapidly especially if they are laid dry. To lay them dry, the blocks should be built up on a solid bottom, one layer at a time. The last layer of blocks should be wedged between the top of the seal and the roof. Caulk the edges of the seal with cement or other suitable caulking material. Seal the edges and plaster the seal with cement or other suitable sealing material to make it as airtight as possible.

Wood Temporary Seals

Various kinds of boards can be used to construct wood seals. Usually, rough boards of various widths and about one inch thick are used. However, if a tighter seal is desired, it is better to use tongue-and-groove boards or shiplap boards. The boards should be nailed horizontally on a framework of rib and center posts. The posts should be wedged inward and hitched in the bottom. Also, if possible, a shallow hitch should be dug in the roof, ribs, and floor. The boards should be fitted snugly into the hitch as the seal is erected.

The boards can be overlapped at the center of the seal if they are too long to fit perfectly. This will eliminate having to saw the boards and will, therefore, save time.

If you’re using ship-lap boards, you should nail them onto the framework, starting from the top and overlapping each board as you work your way down. After the boards have been nailed to the framework, the edges of the seal should be caulked with cement or other suitable caulking material.

If rough lumber is used and sufficient brattice cloth is available, the entire surface of the seal should be covered with a layer of the cloth. If brattice cloth is not available, seal the edges and plaster the seal with cement or other suitable sealing material to make it as airtight as possible.

Considerations for Temporary Seals

Air Sampling Tubes

When you build the temporary seals, you should include provisions in some of the seals for collecting air samples from within the sealed area. Non-metallic pipes or tubes with valves on them are used for this purpose—usually 3/8 inch tygon tubing because it is light and flexible.

This air sample tube can be placed anywhere in the seal and should extend at least to the second crosscut inby the seal in order to get a good representative sample of the air that is close to the fire. Depending on the situation, this can vary from about 40 to 100 feet.

The tube can be suspended from the roof by tying it to timbers or roof bolts. The number of seals in which air sampling tubes should be placed will depend on the sealed area, the number of seals used, and their positions.

Ventilation

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.

NOTE: Use **Visual 9** as an aid in describing the following procedure. Point out the steps on the visual as you discuss them.

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 FAB side of the curtain.

Posts can be set, framework nailed on, and double or triple thickness of brattice cloth cut to fit the framework. The cloth is then rolled up and nailed to the tops of the framework, not to be dropped until the very end of the temporary sealing operation. This work can be done by two team members at a time, with the other team members in fresh air only a few feet away.

When Entries 2, 3, and 5 are sealed, the last temporary seal in entry 4 can be built. While it is being built, only mine rescue members to construct the temporary seal should remain in the mine – all other personnel should evacuate the mine.

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

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, 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.

Isolation

It is also important to isolate the sealed area from the mine in as many ways as possible. This means that all power cables and water and/or air lines going into the sealed area should be removed or severed from the sealed area.

It is also advisable to remove a section from the track or any other conductors leading into the sealed area.

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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.

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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, 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.

Isolation

It is also important to isolate the sealed area from the mine in as many ways as possible. This means that all power cables and water and/or air lines going into the sealed area should be removed or severed from the sealed area.

It is also advisable to remove a section from the track or any other conductors leading into the sealed area.

Permanent Seals

A mine cannot be returned to production until the sealed area of the mine has been closed off with permanent seals. Usually, after temporary seals are erected, a waiting period of about 72 hours is recommended before beginning construction on permanent seals.

Permanent seals must be built according to an approved seal design with proper installation and certification. Seal designs are very specific and the Installation Guidelines for whichever seal is being built must be followed.

There are a myriad of approved permanent seals that are designed to withstand either a minimum of 50psi or 120psi dynamic force application from an explosion. The material with which these seals are built from include lightweight cementitious material, reinforced concrete, glued concrete blocks, and a solid concrete plug.

The specific construction techniques that are to be followed during the construction of a permanent seal will be prescribed in the approved Installation Guidelines. It is important that all aspects of these Guidelines are followed. Any deviation from these Guidelines may be cause for rebuilding the permanent seal.

Considerations for Permanent Seals

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 permanent seals.

Air Sampling Tubes

The permanent seals must also have provisions for collecting air samples from within the sealed area, just as the temporary seals do.

If air sample tubes were installed in the temporary seals, it will only be necessary to extend those tubes and valves to the permanent seals if they do not already reach.

Taking Air Samples

After the fire area is sealed, it may be necessary to take air samples of the air that is behind the seal so that the quality of the air can be assessed. The ideal time to collect an air sample is when the sealed area is under positive pressure or "breathing out."

Pressures within and without sealed areas generally will vary according to temperature and barometric changes. These differences in pressure are usually described as "breathing in" (negative pressure in sealed area), "breathing out (positive pressure in sealed area), or "neutral" (no difference in pressure).

When you collect an air sample, if the sealed area is breathing out, you should let the pressure evacuate the air from the sealed area for a while before getting the sample. This will ensure that you get a good representative sample of the air that's in the fire area, not the air that's right next to the seal.

If the sealed area is in-gassing or neutral, you should use a small permissible pump to evacuate enough air from the sealed area to ensure that you collect a good representative sample of the air that's in the sealed area.

Sometimes, however, seals are situated so far away from the fire that the air near the seals has an altogether different composition from the air near the fire. In these cases, air samples are usually not collected at the seals because they would not be accurate. Instead, a two-inch bore hole from the surface or another level to the fire area can be used to obtain air samples.

NOTE: If you need additional information on collecting air samples, refer to the "Air Sampling" section of ***Module 2 – Mine Gases.***

Sealing on the Surface

Although it may be possible to seal a fire in a gassy section of a mine without a subsequent explosion during or shortly after sealing operations, undoubtedly the safest method is to seal the mine openings at the surface. On these occasions, any mine openings to the surface are plugged up and sealed as best as possible.

Remote Sealing

Another method of sealing a fire from the surface is to pump sealing material down through boreholes to the fire area. This is usually done within a mine that has already been sealed on the surface, making it possible to establish effective temporary seals in a distant part of a large mine where a fire raged.

Remote sampling should be done to determine if the atmosphere in the temporarily sealed area is explosive. Inert gases can be added remotely if needed to make the area non-explosive. When the area is non-explosive, the mine can be safely re-entered and permanent seals erected if necessary.

By establishing these temporary seals, it may be possible to re-establish ventilation throughout the rest of the mine without disturbing the fire area during initial recovery of the mine.

Foaming the Fire Area

Foam can be used indirectly on a fire in an attempt to bring the fire under control so that more direct extinguishing methods can be used. In these instances, the foam generator is set up a distance from the fire. The foam is then pumped down to the fire to smother and cool it.

Sometimes it is necessary to construct a temporary stopping around the foam generator in order to create a confined area into which to pump the foam. Once conditions permit, the generator can be moved closer to the fire or the team members can move in to fight the fire directly.

Flooding the Mine

Another method of indirect firefighting is flooding the sealed fire area with water. This is not done very often and, when it is, it is used as a last resort because it makes any later recovery work difficult.

REVIEW QUESTIONS

Ask team members the following questions and allow time for them to answer. Discuss the answers with them so they fully understand the material covered thus far.

1. Discuss reasons why a mine fire would be sealed rather than fought directly.

2. Discuss why it is recommended that the last intake and return seals be erected and closed simultaneously.

3. Discuss why all waterlines, power cables, and track leading into a sealed area should be severed or removed before sealing a fire area.

ANSWER SHEET

1.
    - 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. It lessens the possibility of explosive gases building up in the fire area.

3. This practice ensures that the sealed area is completely isolated from the other areas of the mine and possible ignition sources.

Explosions

Causes and Effects

NOTE: Refer to **Visual 2** for an illustration of the fire triangle as you discuss the following section.

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

Before any team begins rescue work in a mine where an explosion has occurred or is suspected of having occurred, the Command Center will make sure that the mine is relatively safe to enter and that as many hazards as possible have been eliminated.

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

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.

NOTE: Refer to **Visual 10** for an illustration of a fan chart.

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:
    - o 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.
    - o 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.

However, in some situations it may be too hazardous for teams to explore and re- ventilate safely. In these situations, the team will usually be instructed to seal the area or the entire mine will be sealed.

NOTE: Information on re-ventilation and recovery after an explosion is covered in

Module 7 – Mine Recovery.

REVIEW QUESTIONS

Ask team members the following questions and allow time for them to answer. Discuss the answers with them so they fully understand the material covered thus far.

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

2. Discuss the chief concerns of a mine rescue team when exploring a mine following an explosion.

3. Discuss evidence that the exploring team might encounter that would indicate an explosion has occurred in the mine.

ANSWER SHEET

1.

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

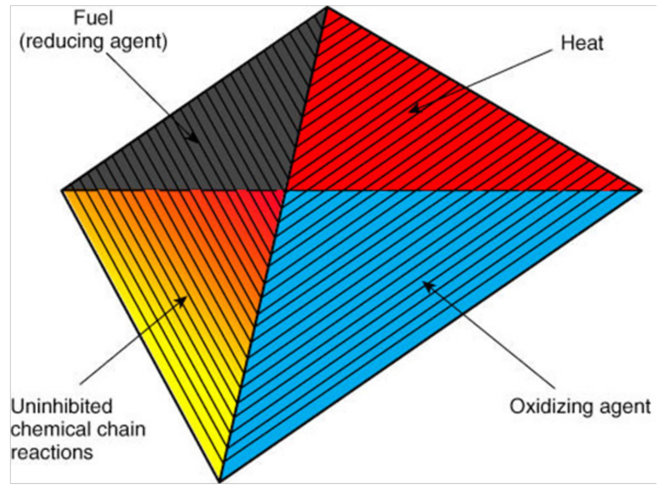
2.

- 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

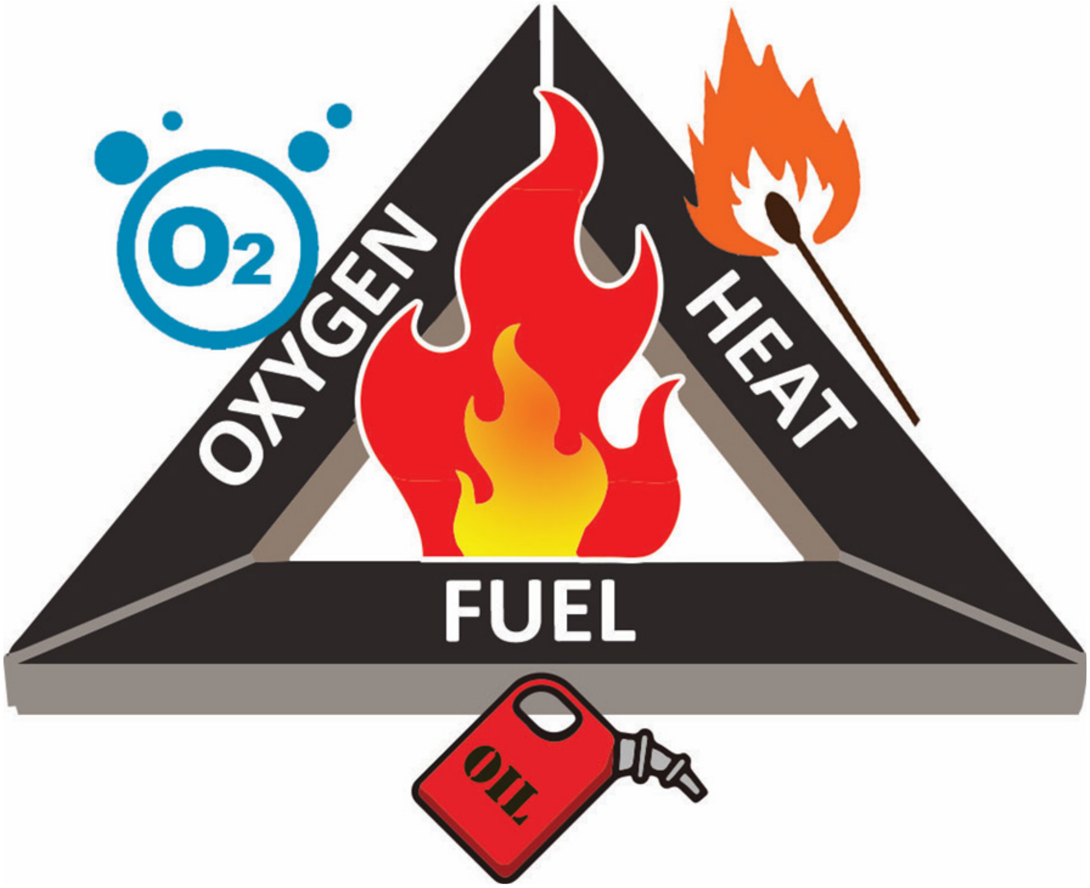
3.

- 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

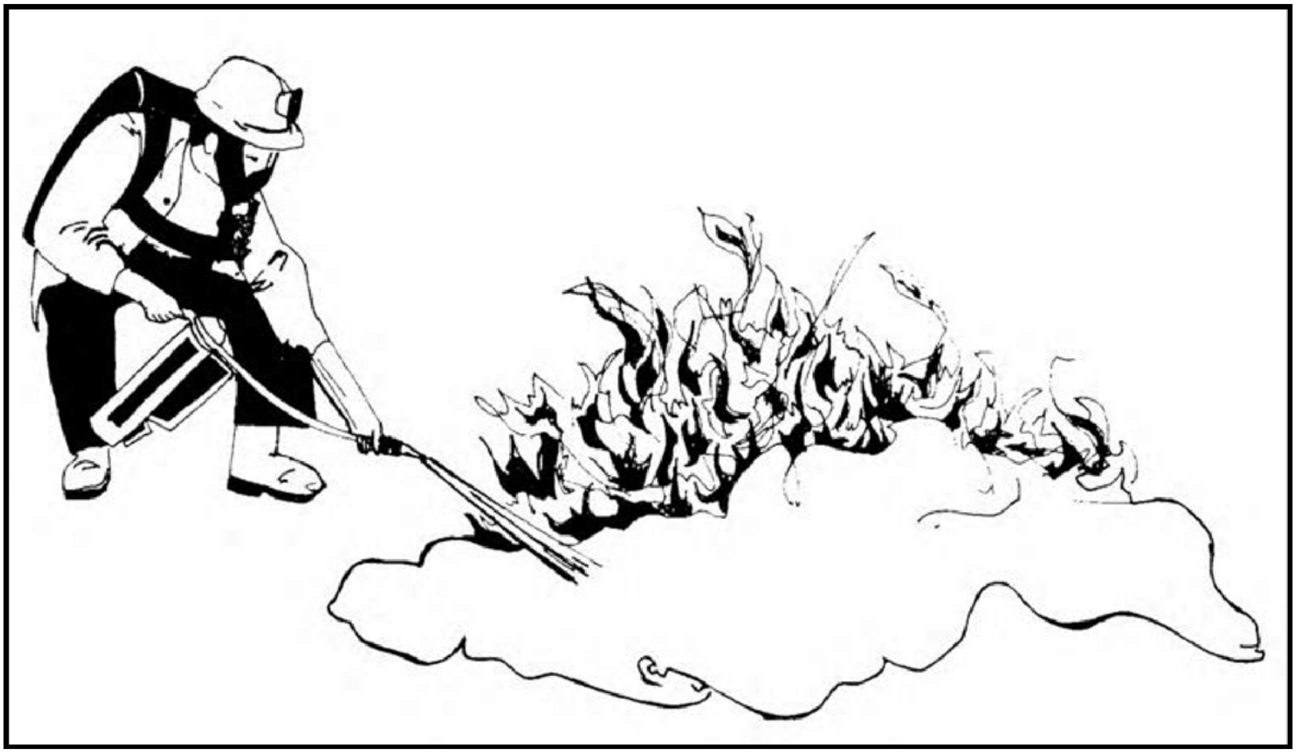
Visuals



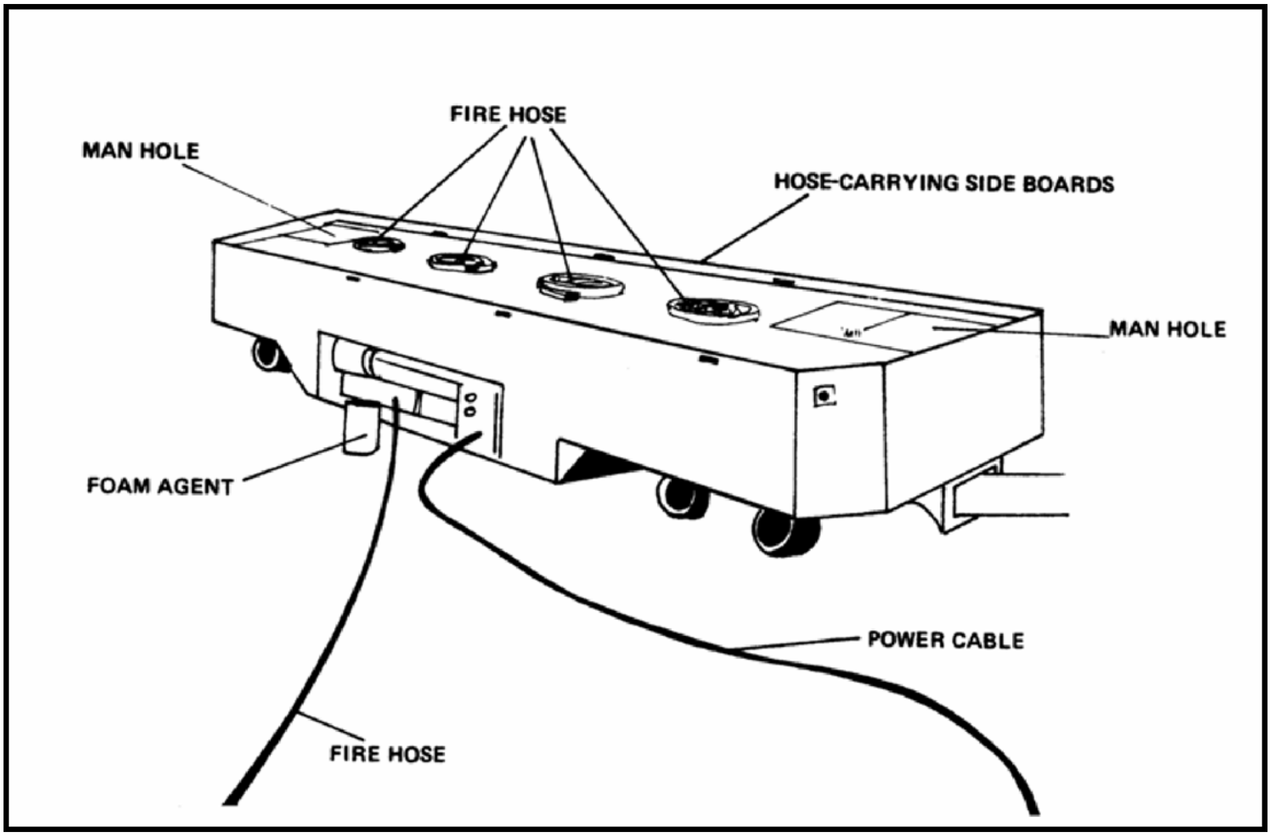
Visual 1: The Five Classes of Fire and the Fire Tetrahedron



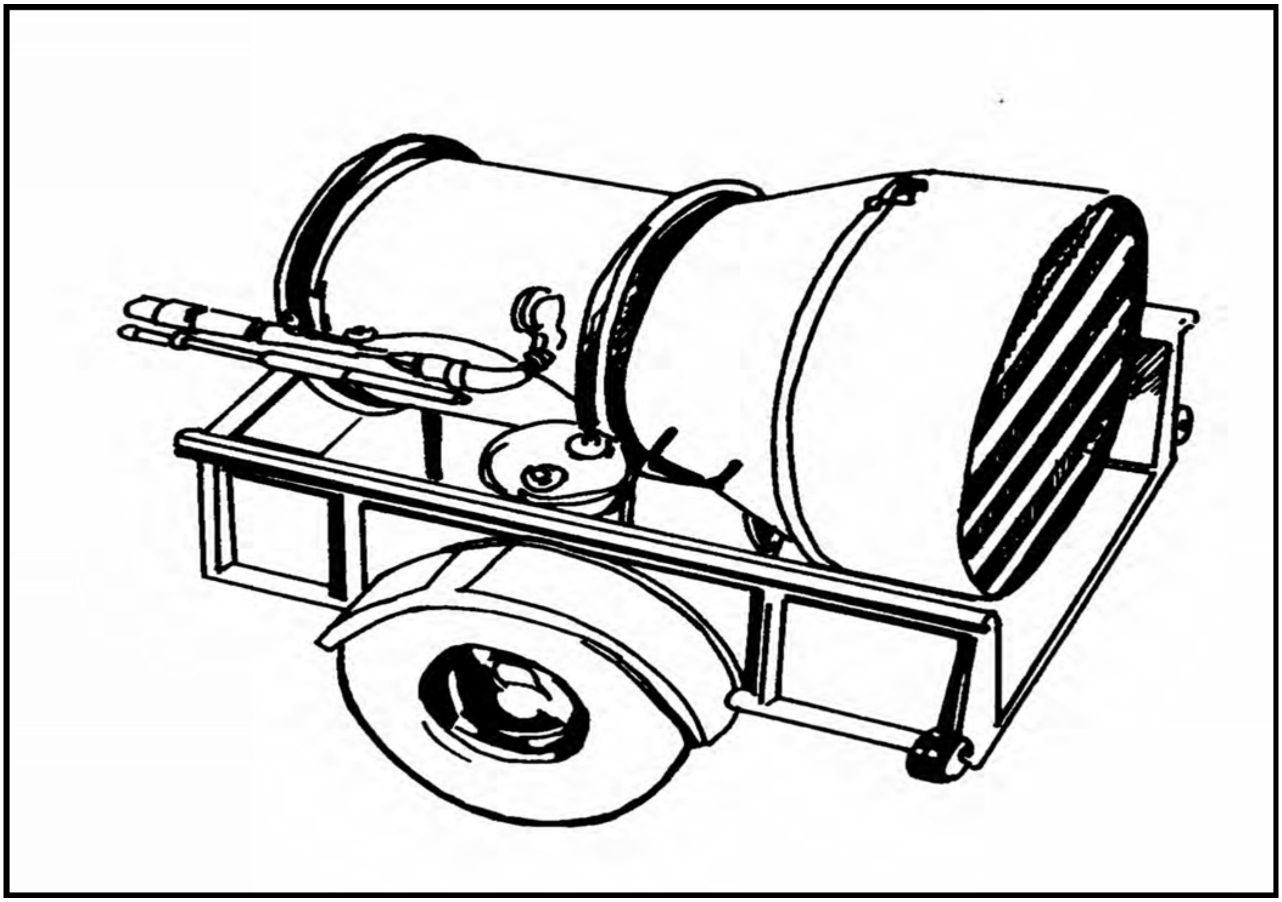
Visual 2: Fire Triangle



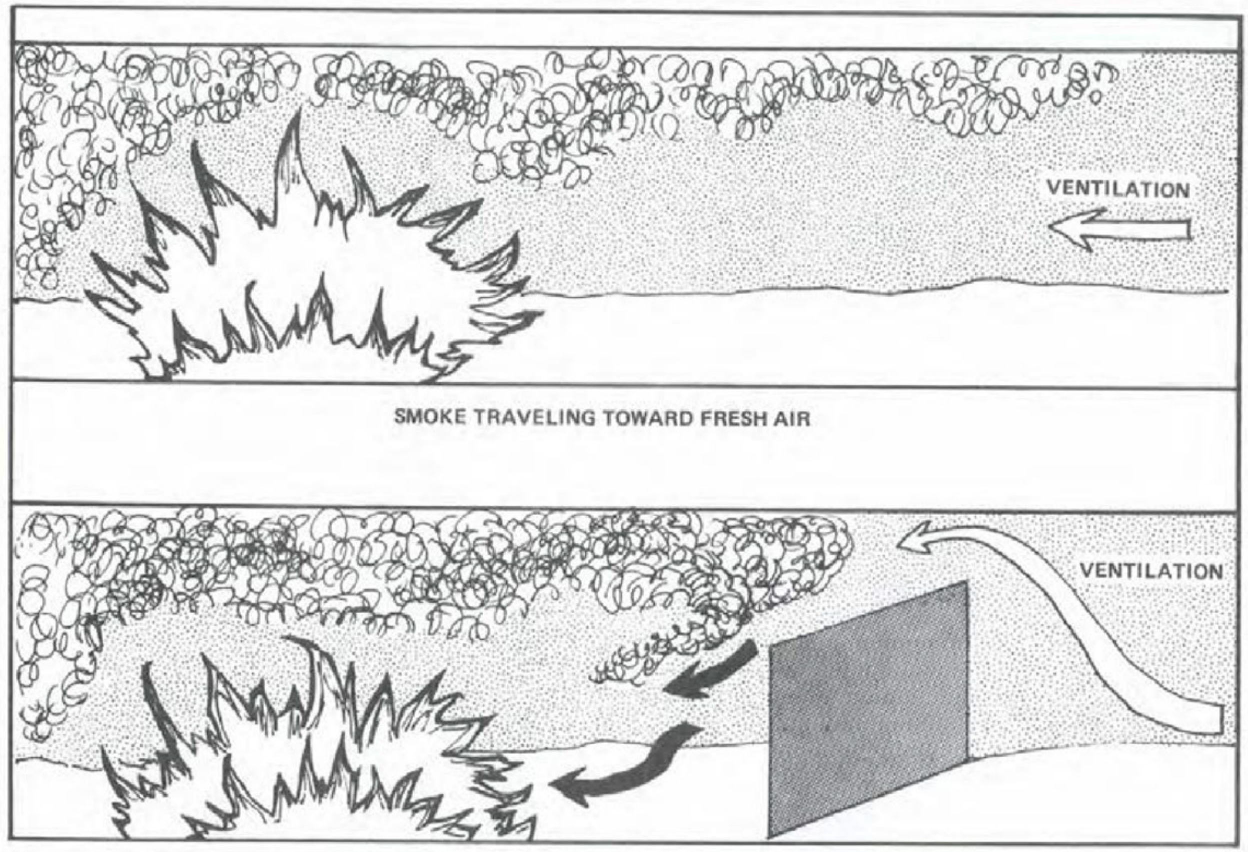
Visual 3: Using a Hand-Held Fire Extinguisher



Visual 4: Fire Car



Visual 5: Foam Generator



Visual 6: Transverse Brattice

Hazards of Direct Firefighting

- Electrocution
- Toxic and Asphyxiating Gases
- Oxygen Deficiency
- Explosive Gases
- Heat, Smoke, and Steam

Visual 7: Hazards of Direct Firefighting

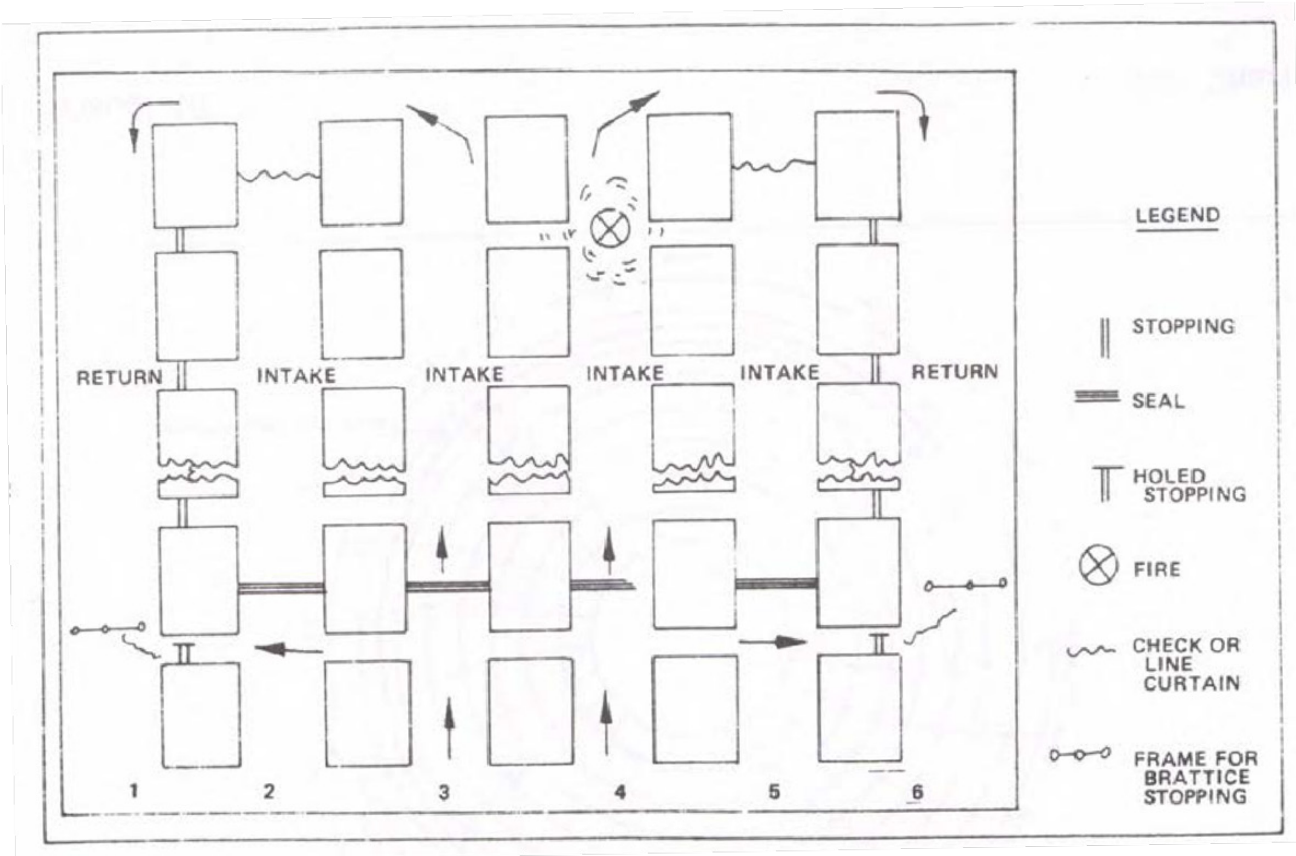
Gases Produced by Burning Rubber, Neoprene, and PVC	Maximum Allowable PPM	Percent
Carbon Monoxide	50	.005
Chlorine	1	.0001
Hydrogen Chloride	5	.0005
*Phosgene	0.1	.00001
Sulphur Dioxide	5	.0005
Hydrogen Sulfide	10	.001
Nitrogen Dioxide	5	.0005
Ammonia	50	.005
Hydrogen Cyanide	10	.001
*Arsine+	0.05	.000005
*Phosphine+	0.3	.00003

*Note the deadliness of these gases as compared to Carbon Monoxide.

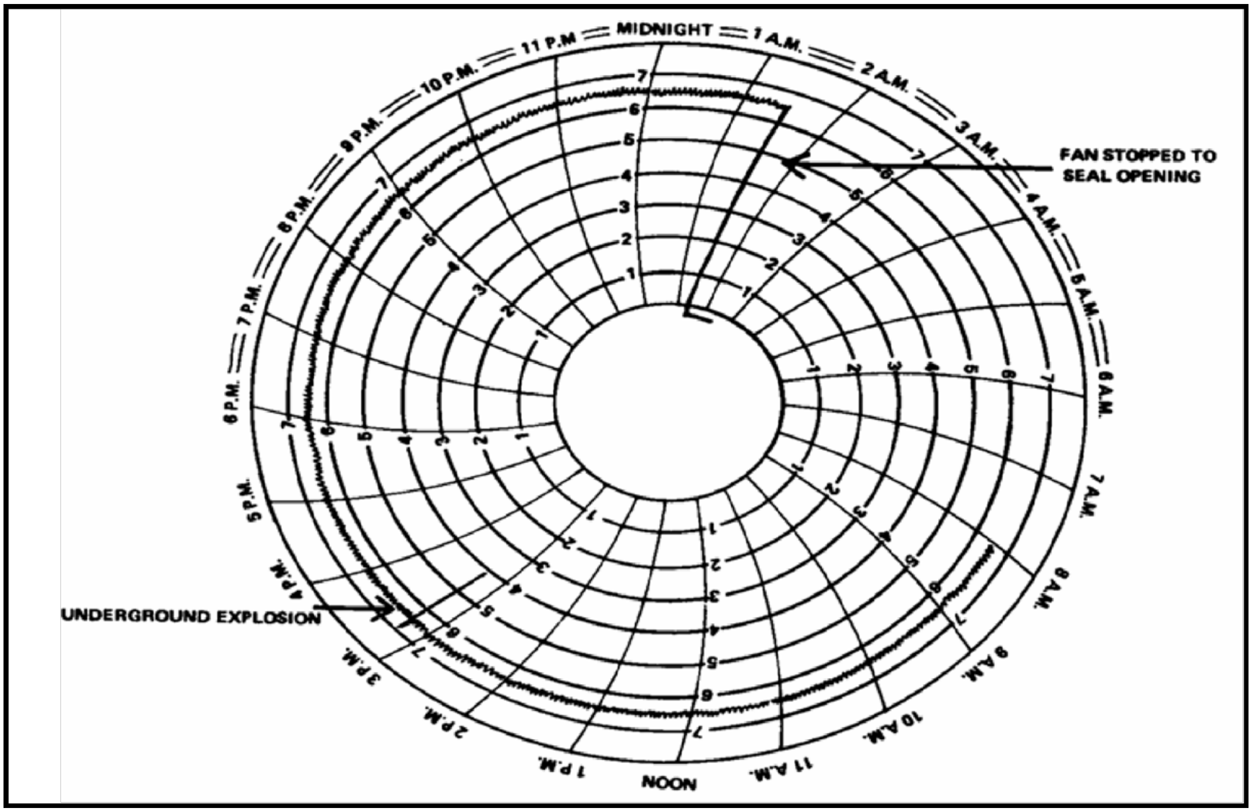
+These gases will be found only if the carcass (foundation) is impregnated with certain fungicidal or fire-retardant compositions.

Source: “Investigations into Underground Fires.” Safety in Mines Research Establishment, Buxton, England.

Visual 8: Toxic Gases



Visual 9: Sealing Procedure



Visual 10: Fan Chart

GENERAL REVIEW

Fires, Firefighting, and Explosions

Choose the correct answer for each of these questions.

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 stoppage
   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
   d. 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

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

Glossary

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.)

Advanced Mine Rescue Training - Coal

Module 6 Rescue of Survivors and Recovery of Bodies

Module 6 - Rescue of Survivors and Recovery of Bodies

Contents

Instructional Text

Course Objectives

The mine rescue team will follow the proper procedures for rescuing survivors and recovering bodies following a mine disaster.

The team members will:

- Describe the factors that help determine the location of possible survivors during a mine emergency.
- Describe the proper procedure for entering a refuge chamber or a barricade behind which survivors may be located.
- Describe the possible physical and psychological condition of survivors during a mine emergency.
- Describe the proper procedures for transporting survivors out of the mine.
- Describe the proper procedures for marking locations and identities of bodies that are found.
- Recognize the possible conditions encountered when recovering bodies following a mine disaster.
- Describe the correct procedures for extricating, disinfection, and tagging bodies, and placing bodies in body bags following a mine disaster.

Course Materials

Required:

- Pencil and paper for each team member
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams

Suggested:

- Any rescue or recovery equipment that the team will be using, or pictures or slides of the equipment if it is not available
- Chalkboard or flip-chart
- PowerPoint program
- Laptop computer

NOTE: In addition to these materials, you are encouraged to incorporate any other up- to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction

II. Rescuing Survivors
   a. Locating Survivors
   b. Opening Refuge Alternatives, Refuge Chambers, or Barricades
   c. Injured Survivors
   d. Triage System
   e. Psychological Factors for Survivors

III. Bringing Survivors Out
   a. Miners Found in Open Areas
   b. Miners Found in an RA, Barricaded Area, or Rescue Chamber

IV. Psychological Factors for Mine Rescue Workers
   a. Signs of Stress

V. Body Recovery
   a. Locating the Dead and Marking the Area
   b. Condition of Bodies
   c. Handling the Bodies
   d. Surviving Families

Instructional Text

Introduction

This training session is about how to rescue survivors and recover dead bodies from a mine in which a disaster has occurred. Rescuing survivors might very well be the most rewarding part of your job as a mine rescue team, while recovering bodies is a task everyone hopes they never have to face.

There's little that prepares you emotionally for these two tasks. However, by learning about what you might see and conditions you might encounter during this sort of work you should be better prepared to handle the situation.

Rescuing Survivors

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.

Opening Refuge Alternatives, Refuge Chambers, or Barricades

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 RA, chamber, or barricade by the quickest means possible. Once the fresh air is advanced, the RA, chamber, or barricade can be opened. Sometimes, however, it may be necessary to rescue the survivors before fresh air can be advanced to them.

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. Refuge alternatives will have an integral airlock built in.

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.

Injured Survivors

After survivors have been found in the mine, the next step is to get them to safety and fresh air as quickly as possible. In some cases, survivors may need emergency first aid treatment before they can be transported.

Caution should be utilized through the use of Body Substance Isolation (BSI) precautions. A simple and effective means of protection can be achieved through the use of protective gloves by the rescue workers. Gloves provide a barrier between the hand and contamination. Gloves are put on:

- Immediately before contact with any patient's mucous membranes.
- Immediately before contact with any patient's non-intact skin.
- When performing vascular access procedures.
- To avoid any contact with moist body substances.
- When handling or touching surfaces or items contaminated with body substances.

Effective infection control precautions provide protection to both patients and rescue workers. Whenever precautions are used to protect rescue workers (i.e., gloving for touching a patient's mucous membranes), the impact on the patient must be considered and protection of both accomplished (i.e., using fresh, clean sterile gloves immediately before touching the patient's mucous membranes). Latex-free personal protective equipment is available.

NOTE: First aid procedures are **not covered in this module**. There are a number of programs already available for teaching first aid. Refer to first aid training programs as needed.

Triage System

When several survivors suffering from physical and/or psychological trauma have been located, the accurate sorting of priority victims may mean the difference between life and death. This sorting of victims is commonly referred to as a “triage” system.

Survivors can be categorized into four priority groups according to the following patient assessment:

START Triage System				
	IMMEDIATE	**DELAYED**	**MINOR**	**DECEASED**
Respirations	>30 per minute	<30 per minute	<30 per minute	Absent
Perfusion	Capillary refill >2 seconds or radial pulse absent	Capillary refill <2 seconds or radial pulse present	Capillary refill <2 seconds or radial pulse present	Absent
Mental Status	Unable to follow commands	Able to follow commands	Able to follow commands (Can Walk)	Absent

Table Reference

Le Baudour, C., & Bergeron, J. D. (2019, 2016, 2011). *“The START Triage Algorithm”*, *Emergency Medical Responder : First on Scene, Page 559, Figure 27.5* (11th ed.). (K. Wesley, Ed.) London, England: Pearson Education, Inc.

It is recommended that an emergency medical technician (EMT) be a member of the rescue team, since he or she has the training to determine the extent of injuries, especially if there are several individuals injured.

Ideally, the emergency medical service established on the surface should include a physician above ground at the Command Center. This physician could communicate with the EMT or team member who is attending those injured. This is especially helpful for those victims who need immediate medical attention.

If you find a survivor who has heavy debris on the abdomen, pelvic area, or legs, you must be extremely cautious when you remove that debris. The rescuer must realize that the victim’s blood pressure to the critical area has been maintained by the pressure of the debris. Once the debris has been removed, the victim’s blood pressure may drop sharply and death could ensue very rapidly. If you encounter this type of injury, you should request directions from the surface on how to maintain the victim’s blood pressure. In all instances, whenever possible, victims should be stabilized before they are extricated.

One thing to remember when dealing with any injury is to stay as calm as possible. Sometimes when faced with a gruesome or unnerving sight, the best thing to do is to take a deep breath and continue to breathe fully and deeply until the job is finished. It helps also to try to concentrate on the fact that what you're doing is a "job" and that "job" is helping someone else to continue living.

Psychological Factors for Survivors

Psychologically, when survivors are found, their behavior may range from apprehension to uncontrollable hysteria.

The best way to relieve psychological stress in survivors is to try to communicate with them as soon as possible. **Most importantly, the communication MUST be continued.**

If a survivor loses this communication with the rescue team, they may feel abandoned and try to escape to fresh air even though it is unsafe. If you locate a survivor who is acting irrationally, it may be necessary to restrain him or her in order to protect the person from injury.

NOTE: There have been instances in the past where **survivors have tried to pull off a team member's facepiece.** Also, there have been cases where rescue team members have endangered themselves by unthinkingly pulling off their facepieces to give oxygen to a survivor while in bad air.

Whether survivors are showing signs of hysteria or not, they should never be left alone. You should make every effort to assure them that they will be helped. Survivors should never be allowed to walk out unaccompanied even if they appear to be physically able. They will need your assistance and support in leaving the mine.

Bringing Survivors Out

Miners Found in Open Areas

If survivors are found in contaminated or questionable air, they will need to be given breathing protection if they are to be transported to fresh air. If survivors are able to walk, they should be positioned between two rescue team members and assisted to fresh air. If the person is unable to walk, a stretcher will have to be used to bring that person out.

Miners Found in an RA, Barricaded Area, or a Rescue Chamber

The mine map, if accurate, will show the condition of the area **before** the event occurred. The extent of the barricaded area and other areas of access to the barricaded area may be indicated on the mine map. Persons utilizing the mine map must **remember that the preexisting mapped conditions may have changed** due to the event or alteration by miners after the event.

- Test the atmosphere in the affected area to determine if the atmosphere is respirable or irrespirable and report to the Fresh Air Base (FAB)/Command Center. The area surrounding the RA, barricaded area, or rescue chamber may have to be cleared of noxious gases such as carbon monoxide or low oxygen content before a person without breathing protection can be removed from the RA, barricaded area, or rescue chamber.

- Determine, if possible, the condition of the person or persons located within an RA, barricaded area, or a rescue chamber, and report to the FAB/Command Center. The Command Center may dictate the means of communicating this type of information and the team should adhere to this means of communication.

- It is recommended that the conditions (location of live persons, bodies, etc.) within a barricade be accurately mapped and any potential evidence should be left as undisturbed as possible.

If survivors found in an RA, barricaded area, or a rescue chamber can walk, they should be provided with the necessary breathing apparatus and assisted to fresh air. If they are unable to walk, they will have to be carried out on stretchers.

When a large number of survivors are found in an RA, barricaded area, or a rescue chamber, all resources should be considered to expedite the rescue effort.

The procedure for bringing out survivors one at a time is as follows:

- The stretcher should be brought into the RA, barricaded area, or rescue chamber and checked to be sure that it will bear the weight of a person.
- The individual chosen to be brought out first should be given the necessary breathing protection and carefully loaded onto the stretcher.
- The rescue team should then carry the stretcher through the air lock and proceed to fresh air by the shortest and quickest route.
- Every effort should be made during this process to prevent irrespirable air from entering the barricade.

This procedure for bringing out survivors should be repeated until all miners are brought to fresh air.

NOTE: Refer also to **IG 7a - *Advanced Skills Training Activities for Coal Mine Rescue Teams*** for activities related to rescuing survivors.

Psychological Factors for Mine Rescue Workers

Working through a mine emergency situation can pose substantial psychological and emotional difficulties for the responders, their families, and other persons assigned to the operation.

Remember:

- No one who sees a disaster is untouched by it.
- It is normal to feel anxious about your safety.
- Profound sadness, grief, and anger are normal reactions to an abnormal event.
- Acknowledging our feelings helps us recover.
- Focusing on our strengths and abilities will help you to heal.
- Accepting help from community programs and resources is healthy.
- We each have different needs and different ways of coping.

Persons in charge of mine rescue teams should consider providing critical incident stress debriefing throughout and after the emergency situation. Many mine rescue team members probably suffer from some form(s) of post-traumatic stress during and after responding to mine emergencies and are hesitant to seek help or counseling.

As team trainers, it is imperative to be familiar with the signs and symptoms of stress-related illness and advise any team member who they feel may be affected to seek assistance.

Signs of Stress

- Difficulty communicating thoughts
- Difficulty sleeping
- Difficulty maintaining balance
- Easily frustrated
- Increased use of drugs/alcohol
- Limited attention span
- Poor work performance
- Headaches/stomach problems
- Tunnel vision/muffled hearing
- Colds or flu-like symptoms
- Disorientation or confusion
- Difficulty concentrating
- Reluctance to leave home
- Depression, sadness
- Feelings of hopelessness
- Mood swings
- Crying easily
- Overwhelming guilt and self-doubt
- Fear of crowds, strangers, or being alone

NOTE: It is important to recognize these symptomatic behavioral signs; however, very few mine rescue trainers are trained and qualified counselors. You may seek additional assistance from your local EMS Management Agency or the local Red Cross. Keep in mind that survivors of emergency situations will have been through a traumatic situation and may need counseling as well.

Body Recovery

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.

Condition of Bodies

Recovering bodies is a somber and difficult task for rescue workers, and even worse when there had been some hope of finding the miners alive.

Recovering bodies is a job everyone hopes they never have to face. Unfortunately, there's little that prepares rescue teams for what they will be encountering. In some cases, bodies will have no obvious injuries, while others may be badly burned or disfigured, or even dismembered.

If the bodies are not recovered soon after death, they will begin to decompose. In addition to the gruesomeness of a decomposed body, there will also be a stench from the rotting flesh and other body parts. In past recovery operations, teams have chosen to use breathing apparatus even when they were working in good air in order to avoid the odor.

After death, the body goes through various changes and stages of decay.

Some of the factors that influence body deterioration and the changes that occur are:

1. **Air temperature** – A body at freezing temperatures can be preserved for weeks. A body at 70o F (21o C) or higher will decay very rapidly. How quickly the body begins to decay will depend on the temperature in the area.

   The temperature in a coal mine is usually 50 to 60 degrees F (10 to 15.5 degrees C). Therefore, putrefaction (decay) may not begin for 10 or 12 hours after death.

   The parts of a body that are exposed to air will decay faster than the parts that are covered, for instance by clothing. You may find a body lying face up where the face is badly decomposed, but the back of the head which was against the ground still has hair on it.

2. **Body size** – The more muscular the individual, the sooner rigor mortis (rigidity of skeletal muscles) will develop, probably within 4 to 8 hours. The more obese the individual, the longer it will be before rigor mortis will develop, probably within 6 to 10 hours. However, an obese individual will begin the putrefaction (decay) process sooner than a muscular individual.

3. **Body Fluid** – The body is 80 percent liquid. During decomposition, the fluid breaks down and creates gas pressure. Fluid may be forced out of the mouth, nose, ears, or other orifices. Blisters will form under the skin and cause the body to swell. Some bodies retrieved after a mine disaster have been so swollen that the clothing begins to split.

   The body must be handled very carefully or the skin could rupture. If the rescuer is not careful when handling a body, the skin will pull off. In some cases, the skin has actually been pulled off the hand and resembles a hand-like glove, complete with fingernails and creases at the knuckles.

4. **Smell** – There will probably be no decay odor for the first 4 to 8 hours following death. Once the putrefaction process begins, so does the smell. The smell is the result of decay and the gases escaping from the body. When a body is moved, the smell becomes stronger. When the body is brought out of the mine in dry, warm air, the smell is overwhelming.

   In general, a body that suffered a great deal of physical trauma, such as a rock fall, will decay faster and have a much worse odor than the body of a person who died from poisonous gases. Further, a body that suffered abdominal or genital injuries will smell worse than the body of a person who had only head injuries.

As long as you wear your self-contained breathing apparatus while recovering the bodies, you will not be affected by the odors. Wearing a handkerchief around your face will not keep out the strong decaying smell.

5. **Body color** – The dead body will turn dark where the blood pools. If the victim is lying face down, the front of the body will be dark. However, if the mine accident is the result of an explosion, the victim may be covered with soot and the discoloration may not be too apparent.

6. **Water, drowning** – If a body is in cold water, it will remain in almost perfect condition for 2 or 3 days. Then it may begin to swell. After taking the body out of the water and exposing it to air, it will begin to decay almost immediately.

   Most of the time the body will remain under the water for the first 2 days and then it will float. The body floats because of the gases that build up within the body.

These are all very unpleasant things that the team may have to deal with. Some team members will probably be better able to cope with recovering bodies than others. Often in the past, teams composed of volunteers were sent in to do body recovery work. The volunteer crew may be one particular team or it may be made up of team members from different teams.

Rescue workers, especially those recovering bodies for the first time, may very well begin to feel sick or apprehensive. The best advice for you is to try to work with a businesslike and professional attitude. Most of your reactions to the situation will be from your senses of sight and smell. Try to overcome these sensory reactions.

One reaction, however, that may help you is your body's production of adrenaline. Adrenaline is a hormone that is part of the body's natural defense system. It can be produced on a split second's notice and helps one to cope amazingly well with traumatic or frightening situations. Adrenaline stimulates the heart and increases muscular strength and endurance. So, if you've got a lot of adrenaline flowing, you may find yourself with more strength and courage than you thought you were capable of having.

If you know you can't take it, don't try to bluff your way through. Feeling nauseous with your apparatus on is just not safe. If you are in irrespirable atmosphere and you vomit into your facepiece, you will not be able to take off your facepiece. So, be honest and let your team captain know if you are experiencing nausea which you cannot control.

Keep in mind that even some of the best rescue team members in the past have had difficulty dealing with dead bodies. If you pass out or go down, you become a detriment to your team.

Handling the Bodies

Normally, when bodies are brought out of a mine, they are placed in rubber body bags and brought out on stretchers. If body bags are not available, the bodies can be wrapped in brattice cloth or canvas.

Don't examine the victim's clothing for personal possessions unless you have the team captain's approval. Nothing should be removed from a body except in the presence of witnesses and after a written record is made of the material removed.

Usually, all personal belongings such as a lunch bucket, cap lamp, and self-rescuer, are brought out along with the body. This is important, since miners, especially those who barricaded themselves, may have written notes to their loved ones on or in their lunch buckets or other personal items.

The location of these items should be marked on the mine map and on the roof or rib. Also, if the location and position of the body and the identifying number have not already been marked in the mine and on the mine map, this should be done by the body recovery crew before they remove the body. A tag listing the identifying number and the location where each body was found should be attached to each body bag.

When dealing with bodies that have been underground awhile, be sure to wear rubber gloves. Also, the bodies should be sprayed well with a disinfectant before you touch or handle them. This disinfectant will usually be provided for the teams.

One of your main concerns in body recovery work is not to cause further damage to a body in the process of bringing it out of the mine. Bodies recovered shortly after death will not present too many problems because they may not have begun to decompose. Rescuers can lift the bodies by the shoes and armpits and place the victims in body bags. But, with bodies that have begun to decompose, you will have to be extra careful. Trying to put these bodies into body bags will be more difficult.

One of the best methods for transferring a decomposed body into a body bag is to gently roll the body onto a sheet of brattice or plastic which is placed next to the body. You can roll the body by using either your hands or a board or something similar. Once the body is on the brattice or plastic, you can easily lift the four corners of the sheet and place the body, along with the sheet, into the body bag.

If you have to straighten limbs that are stiffened by rigor mortis in order to get the body into a body bag, you will have to use some force. Nevertheless, just be careful not to cause unnecessary damage to the body.

In cases where bodies are entangled in debris or buried under falls, the bodies will have to be extricated slowly. Any extrication work that is in close proximity to body parts should be done by hand to ensure that the body is not damaged any further. If you ever find an extra limb or part of a body by itself, put that part in a body bag and mark the bag with what it contains so that it can later be matched with the correct body.

After recovery of victims of a mine event, the team must decontaminate their clothing, boots and other equipment. Both boot wash and decontamination disposal facilities need to be available. This can be critical if bodily fluids are contacted.

Surviving Families

Recovering the bodies of the dead provides some emotional closure to the stress of the family members. It allows for a funeral, through which there can be communal recognition of the passing of a loved one.

It is important also for legal and insurance reasons. Without a body, a family would have to petition the court to have the person declared dead so that any necessary legal or insurance proceedings could go forward. To this extent, then, teams involved in body recovery can feel that their efforts help to ease the suffering and pain of the waiting families.

REVIEW QUESTIONS

Discuss the following questions with the team members. After you have discussed the questions, allow some time for the team to ask questions or just vent feelings and apprehensions about rescuing survivors or recovering bodies from the mine.

1. Discuss 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, discuss the critical information that your team will need during the briefing.

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

4. Discuss the usual procedure when a body is encountered during exploration.

ANSWER SHEET

1.
   - 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.
   - Number of missing miners.
   - Section or sections where they were working.
   - Escape routes used from those sections.
   - Likely places where miners would erect barricade.
   - Location of any ventilation boreholes where miners could obtain fresh air.

3.
   - 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.
   - 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.

Glossary

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 alternatives – Structures intended to provide a life-sustaining environment for persons trapped underground when escape is impossible.

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.

Advanced Mine Rescue Training - Coal

Module 7
Mine Recovery

Module 7 – Mine Recovery

Contents

Instructional Text

Course Objectives

The mine rescue team will be able to effectively participate in a recovery operation after a mine disaster.

The team members will:

- Explain and demonstrate the steps for re-establishing ventilation after a fire or explosion.
- Explain and describe supplementary work necessary to restore the affected areas to normal operations.

Course Materials

Required:

- Visuals/handouts from the back of this module
- Pencil and paper for each team member
- IG 7a – Advanced Skills Training Activities for Coal Mine Rescue Teams

Suggested:

- Chalkboard or flipchart
- PowerPoint Program
- Laptop Computer

NOTE: In addition to these materials, you are encouraged to incorporate any other up- to-date supplemental mine rescue instructional materials, handouts, and/or methods that will increase the effectiveness and retention of the training.

Course Outline

I. Introduction

II. Assessing Conditions

III. Re-establishing Ventilation After a Fire or Explosion

   a. Unsealing a Fire Area
   b. When to Unseal
   c. Preconditions for Opening a Sealed Fire Area
   d. Preparations for Opening a Sealed Fire Area
   e. Re-ventilation Methods Used for Unsealing a Fire Area
      i. Progressive Ventilation
      ii. Direct Ventilation
      iii. Preventing a Buildup of Gases in the Fan House
   f. Re-establishing Ventilation After a Fire or Explosion
      i. Considerations
      ii. Using Progressive Ventilation
      iii. Dealing with Obstructed Passageways

IV. Clearing and Rehabilitating the Affected Area

   a. Roof and Rib Control
   b. Pumping Water
   c. Clearing Roadways and Track
   d. Loading Out Falls and Hot Debris
   e. Restoring Power
   f. Re-establishing the Communication System

Instructional Text

Introduction

Specific procedures and methods of mine recovery are determined by the needs of an actual recovery operation. This module gives mine rescue team members a general overview of what those methods and procedures are, and a basic explanation of what a recovery operation involves.

The main objective of recovery work is to put the mine or affected area of the mine back in operation as soon as conditions permit after a mine disaster. Depending on the conditions, recovery operations can range from a few days' work re-establishing ventilation on a section to many months of costly re-ventilation and rehabilitation work throughout an entire mine.

Your role as a mine rescue team member in recovery work varies as the operation progresses and conditions change. Until ventilation is re-established in the affected area, apparatus crews will be needed to assess conditions, rebuild stoppings, and, where necessary, clear debris and stabilize roof and ribs.

Once ventilation has been re-established and fresh air is advanced, non-apparatus crews can take over the rehabilitation and clean-up effort.

Assessing Conditions

In order to plan a recovery operation, there must be an initial assessment of underground conditions. Then, as the work progresses, rescue teams will be making updated reports on the conditions and damages they encounter. Assessment of conditions is necessary for your team's safety and also to determine how much rehabilitation work is needed to recover the affected area.

NOTE: You may want to list the topics covered in an assessment on a chalkboard or flipchart so the team members can follow along with your discussion.

One of the main things your team will be checking is the extent of damage to the ventilation system. This includes checking the condition of each of the ventilation controls and any auxiliary fans and tubing.

As your team explores and re-ventilates an area, you should be checking gas conditions and roof and rib conditions. You should also check the condition of the track, waterlines, power lines, and phone line, and look for evidence of flooding, flood damage, and smoldering debris or hot spots in a fire area.

Re-establishing Ventilation After a Fire or Explosion

Re-establishing ventilation and bringing fresh air to an area damaged by fire or explosion is the main task of mine rescue teams in a recovery operation. Once this is done, regular work crews can help with the recovery effort.

In a fire area that has been sealed, this means unsealing the area, assessing the damage, and repairing and rebuilding the ventilation system. If the area has not been sealed, re-establishing ventilation is a little easier. It involves simply assessing the damage and making the necessary repairs to re-establish normal ventilation.

In an area damaged by an explosion, the task is the same: assessing damages and repairing ventilation controls. After an explosion, though, a great deal of construction work is usually needed to restore ventilation to proper functioning.

Unsealing a Fire Area

Unsealing a fire area requires careful planning. Opening seals prematurely can cause a re-ignition of the fire or set off an explosion. Normally, a step-by-step plan for unsealing a fire area is drawn up by company mine officials with the advice of Federal and, where applicable, state and union representatives.

While mine rescue team members do not plan the unsealing operation, it is important that you know what the considerations and potential problems are in such an operation.

When to Unseal

Determining the exact time to unseal a fire area is based on the laws of physics and chemistry, as well as on experience and sound judgment. A reasonably accurate analysis and interpretation of the gases present in a sealed area is possible through proper sampling techniques and with the aid of a chemist experienced in this work. In addition to the gas conditions, other factors must be taken into consideration when choosing the safest time to unseal a fire area.

NOTE: Refer to Visual 1 for a list of the following factors as you discuss them.

The main factors governing the time for unsealing a fire area are:

1. Extent and intensity of the fire at the time of sealing
2. Characteristics of the burning material and surrounding strata
3. Tightness of the seals
4. Effect of barometric pressure on the enclosed area
5. Effect of temperature on the enclosed area
6. Location of the fire area with respect to ventilation

7. Gas conditions as indicated by analysis of air samples taken from behind the seals. (Usually, the gases analyzed are oxygen, carbon dioxide, carbon monoxide, methane, hydrogen, and nitrogen.)

In addition to analysis of these factors, local conditions, such as the proximity of gas wells to the fire area and the extent of the region under seal, must be considered.

Ordinarily, more time will be needed before unsealing a large area than a small area.

Preconditions for Opening a Sealed Fire Area

NOTE: Refer to Visual 2 for a list of the preconditions for unsealing a 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

NOTE: Refer to Visual 3 for a list of the necessary 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 de-energized, grounded, locked-out, and tagged-out. 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.

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 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 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. With direct ventilation, 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.

Progressive Ventilation

Progressive ventilation is the usual method when the sealed area is large, the fire is extensive, or bodies must be removed.

With this method, the sealed area is explored and re-ventilated in successive blocks by the use of air locks. As long as conditions remain favorable, the work continues and the entire area can eventually be recovered.

NOTE: Remind the team that an air lock is made by building two stoppings 10 to 15 feet apart. Each stopping should have a door or flap in it so that teams can enter and exit the sealed area. One opening in an air lock must be kept closed while the other is open to prevent mixing of the two atmospheres.

Ten to fifteen feet is an **approximate** figure. The distance should be small to limit the amount of air that could enter the sealed area. However, there must be enough room in the air lock to accommodate the team members and their equipment.

NOTE: Air-locking operations should NEVER be undertaken until the oxygen content of the atmosphere behind the sealed area has been reduced to a maximum of two percent.

During progressive ventilation, a certain amount of air will unavoidably enter the area behind the seals. As the work continues, oxygen and explosive gas levels must be carefully monitored, and the operation halted if conditions become dangerous.

Recovery by progressive ventilation is very similar to advancing a Fresh Air Base (FAB). But it is usually an even slower operation because of the damage that is normally found in a sealed area. The first step in progressive ventilation is to build a stopping at one of the seals on the intake side of the fire area to create an air lock.

NOTE: Refer to **Visual 4** for a map showing a sealed area and the first air lock for progressive ventilation.

Air locking operations should always begin on the intake side of the fire. Once the air lock is completed and conditions are right for entering the sealed area, a team with apparatus can enter the air lock and break out an opening in the seal.

You may have to wait after removing the first few blocks from a seal for the pressure to stabilize. After the seal is opened, an apparatus team or, if necessary, a rotation of teams can enter the sealed area and explore and assess conditions to the point where the next air lock will be built.

The distance between air locks is usually between 200 and 500 feet. It depends on the conditions encountered and the amount of construction work that is needed to prepare an area for re-ventilation.

During exploration, the team should note conditions in general. They should take temperature readings and make the necessary tests for oxygen, carbon dioxide, carbon monoxide, and methane. When requested, they should collect air samples.

They should also take measurements for the new air lock that will be built and any additional stoppings that will be needed in parallel entries to seal the area.

NOTE: For the following discussion, refer to **Visual 5.**

Once the exploration and assessment is complete, a team or teams can be sent in to construct the first stopping of the new air lock and put up any additional stoppings needed in parallel entries to reseal the area.

Also, the team will have to prepare the area between the two air locks for re-ventilation. This involves repairing ventilation controls and making the necessary changes to direct the air to a return airway.

Before the team leaves the area being prepared for re-ventilation, a final check should be made for any possible fires. Once the team is out of the area, it can be re-ventilated. Generally, a seal on the return side is opened first, followed by one of the seals on the intake side.

The return air should be kept below the lowest explosive limit of methane and oxygen. If conditions are good, the rest of the original seals can then be opened. This process of putting up air locks and working through them to explore and re-ventilate an area can be continued until the entire area is recovered.

As the work progresses, frequent tests should be made to determine gas conditions in the sealed area and at the returns of the areas being recovered. The main concern is the possibility of an explosion or the rekindling of the fire.

After the work has progressed close to the seat of the fire, it may be decided to load out heated materials through the air lock before attempting re-ventilation.

As long as there is every indication that the fire has been extinguished, the final sealed area can be re-ventilated. The gases from this area should be removed as quickly as possible.

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.**

The first step is to build an air lock at an intake seal. Then an apparatus team or, if necessary, a rotation of teams will take temperature readings and test for oxygen, carbon monoxide, carbon dioxide, and methane. The team will probably be asked to collect air samples as well.

After completing their testing and observation of the area, the team will return to the FAB. If the conditions are favorable, the unsealing can begin. A seal on the return side should be broken open and the air lock opened to admit air. The area can then be ventilated. Any combustible gases in the main exhaust should, if feasible, be kept below the lowest explosive limit.

NOTE: When using direct ventilation, be sure that all unnecessary personnel are out of the mine before air is actually directed into the sealed area. The remaining personnel needed to open the seals should then come out as quickly as possible once the seals are opened.

The time for persons to re-enter the mine is governed by the quality of the return air, as indicated by periodic sampling and analysis. The Command Center will determine when conditions appear safe to reenter the mine. If the sealed area is extensive, it's advisable that a rescue team wearing apparatus be the first to reenter. The team should check for and flush out any standing gases from the fire area.

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.

Preventing a Buildup of Gases in the Fan House

If the mine is using an exhausting fan, some provision should be made to prevent the buildup of explosive gases in the fan house. One technique is to ventilate the fan house. An auxiliary fan can be set up a short distance from the fan house with tubing extending into the fan house.

Another technique is to control the volume of air being drawn from the mine. This can be done by using the explosion doors as a regulator.

Re-establishing Ventilation after an Explosion

The objective of re-establishing ventilation after an explosion is to rid the mine of explosive or potentially explosive gas mixtures and restore normal ventilation and normal amounts of oxygen to all workings without propagating another explosion.

Considerations

NOTE: Refer to Visual 6 for a list of the following considerations, as you discuss them.

Areas of concern to you, as rescue team members are:

1. Concentrations of explosive gases: Are they below, within, or above the explosive ranges?
2. Percent of oxygen present: Will it support life? Is it low enough to prevent another explosion?
3. Are possible sources of ignition being considered and eliminated—electrical power, battery-powered equipment, possible fires and hot spots, sparks from tools and team equipment, etc.?

During re-ventilation work, an observer should be stationed at the main fan to ensure it is operating correctly and to warn the team in case of any malfunction. Also, someone should be monitoring gas levels at the main returns.

Using Progressive Ventilation

Re-ventilation after an explosion is usually accomplished by progressive ventilation. A FAB is set up and stoppings are built in parallel entries to isolate the affected area. Then, an apparatus team can enter the affected area through an air lock (the FAB) to explore and assess conditions. The procedure is basically the same as unsealing a fire area by progressive ventilation.

As long as conditions remain favorable, teams can go in and build a new air lock inby the old one, build any other stoppings needed in parallel entries, and prepare the area being recovered for re-ventilation. The teams should be sure to make the necessary adjustments to direct air from the re-ventilated area to a return.

NOTE: While exploring and preparing an area for re-ventilation, teams should be on the alert for and eliminate any possible sources of ignition.

Once the new air lock is put up and gas conditions are checked, normal ventilation can be advanced to that point by taking down the old air lock and opening an airway to the return so that air can circulate through the area. Teams can continue this procedure until the entire area is re-ventilated.

The size of the area re-ventilated each time will depend on the conditions the teams encounter. Where damage is slight, a team will be able to re-ventilate a large area.

However, a team may only be able to do two or three blocks at a time when the damage is extensive and much work must be done to repair ventilation controls.

The re-ventilation process will also be slower where travel is difficult, or where roof and rib conditions are hazardous and require timbering and other support.

Once an area is re-ventilated, labor crews working barefaced can normally do any further rehabilitation work that is needed in that area. This frees the apparatus teams to prepare the next area for re-ventilation.

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

Ask team members the following questions and allow time for them to answer. Discuss the correct answers with them so they fully understand the material covered.

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

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

3. What preparations should be made before opening a sealed area?

4. Discuss three possible methods of recovering an area of the mine that has obstructed entries.

ANSWER SHEET

1.

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.

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.

3.

1) Adjustments in the ventilation system are needed so that toxic and explosive gases released from the sealed area are directed into the main returns.
2) Someone should be observing the operation of the main fan and alert the people working underground if the fan slows down or malfunctions. Also, someone should be monitoring gas levels from the main returns.
3) All electrical power in the sealed area should be cut off, as well as the power in the return airways near the sealed area.
4) In bituminous coal mines, all entries and crosscuts leading to and from the sealed area should be well rock dusted.
5) All unnecessary personnel should be withdrawn from the mine.

4.

1) Bypass the entry and come in behind it.
2) Re-ventilate as close as possible and then clear the obstruction with permissible machinery and tools. While this is being done, line brattice can be used to ventilate the area.
3) Mine through the solid almost to the point of breaking through; then, build an air lock. A team with apparatus can go through the air lock and hand mine the last little bit.

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 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 and Rib Control

Fires, explosions, and other disasters frequently result in weakened roof and rib conditions. Rescue teams will have to carefully assess roof 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 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

Ask the team members the following questions. Allow time for them to answer and then discuss the correct answers with them so they fully understand the material covered.

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

1.

- 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.

- 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.

NOTE: Refer to **IG 7a –** ***Advanced Skills Training Activities for Coal Mine Rescue Teams*** for training related to recovery procedures.

Visuals

Factors Governing When to Unseal

1. Extent and intensity of fire
2. Characteristics of burning material and surrounding area
3. Tightness of seals
4. Effect of barometric pressure
5. Effect of temperature
6. Location of fire area
7. Gas conditions

Visual 1: When to Unseal

Preconditions for Unsealing

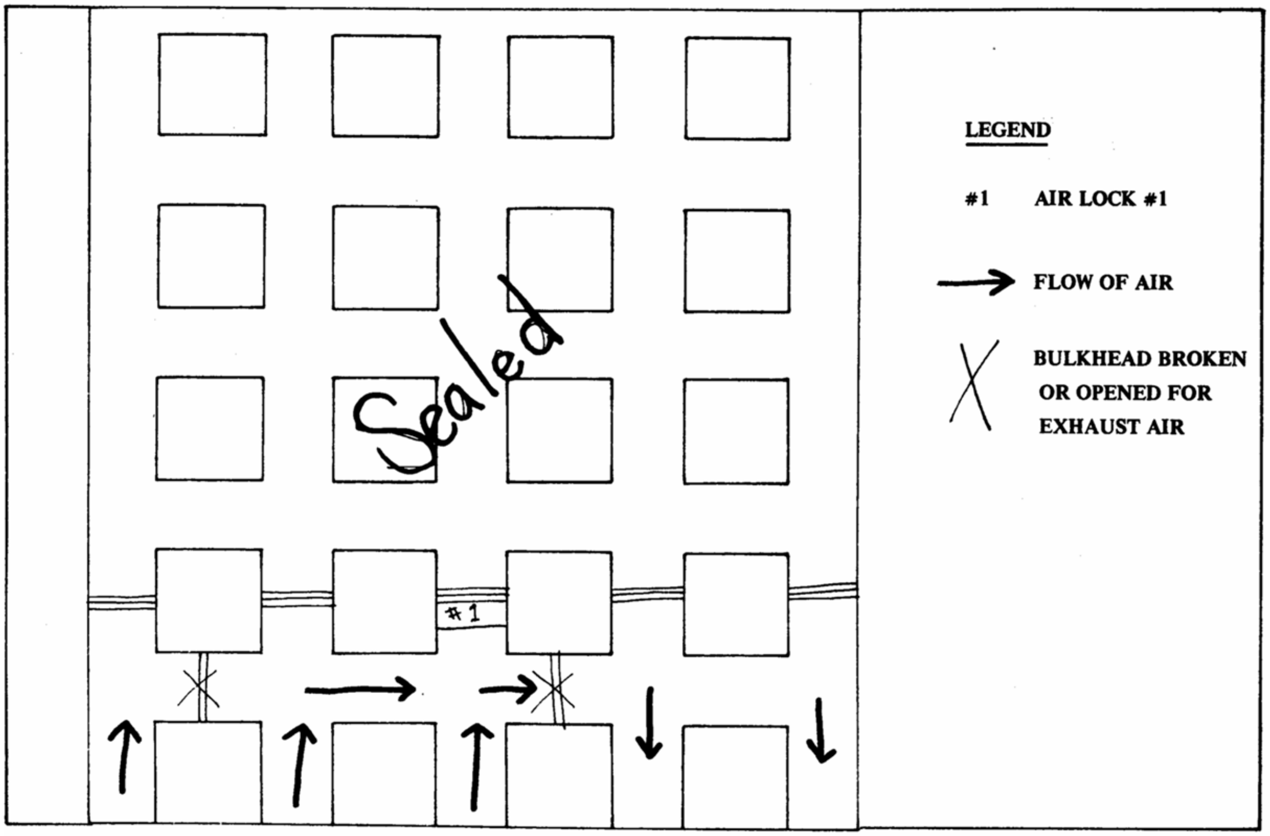
- **The oxygen content of the atmosphere in the sealed area is low enough to make it inert**
- **Carbon monoxide <u>not present</u> behind seal**
- **Area behind seal has had sufficient cooling time**

Visual 2: Preconditions for Unsealing a Fire Area

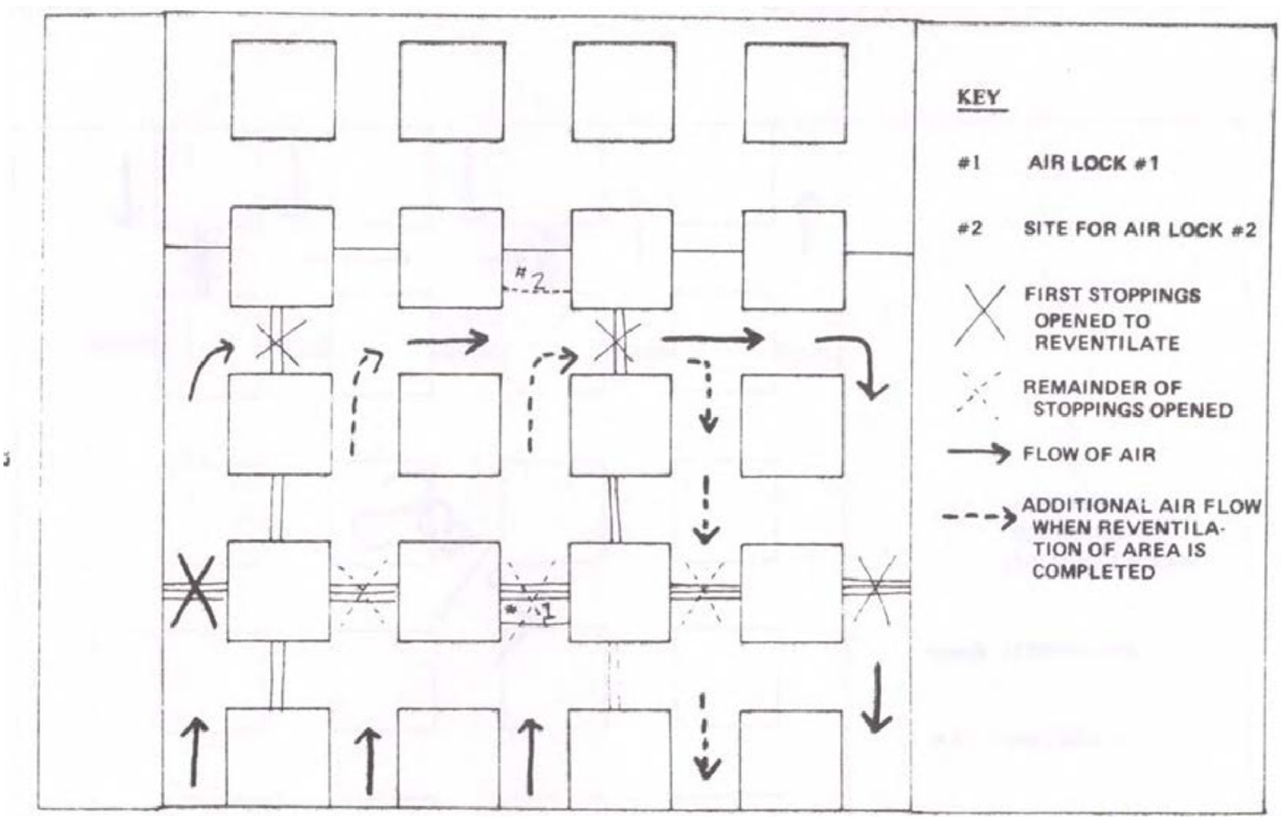
Preparations for Opening a Sealed Fire Area

1. **Adjust ventilation so toxic and/or explosive gases released from the sealed area are directed into main returns.**
2. **An observer should be stationed at the main fan to warn the rescue team of any fan malfunctions. Also, someone should be stationed in the main exhausts to monitor gas levels.**
3. **Cut off all electrical power to the sealed area.**
4. **In bituminous mines, heavily rock dust all entries and crosscuts leading to and from the sealed area.**
5. **Withdraw all unnecessary personnel from the mine.**

Visual 3: Preparations for Opening a Sealed Fire Area



Visual 4: Sealed Area and First Air Lock

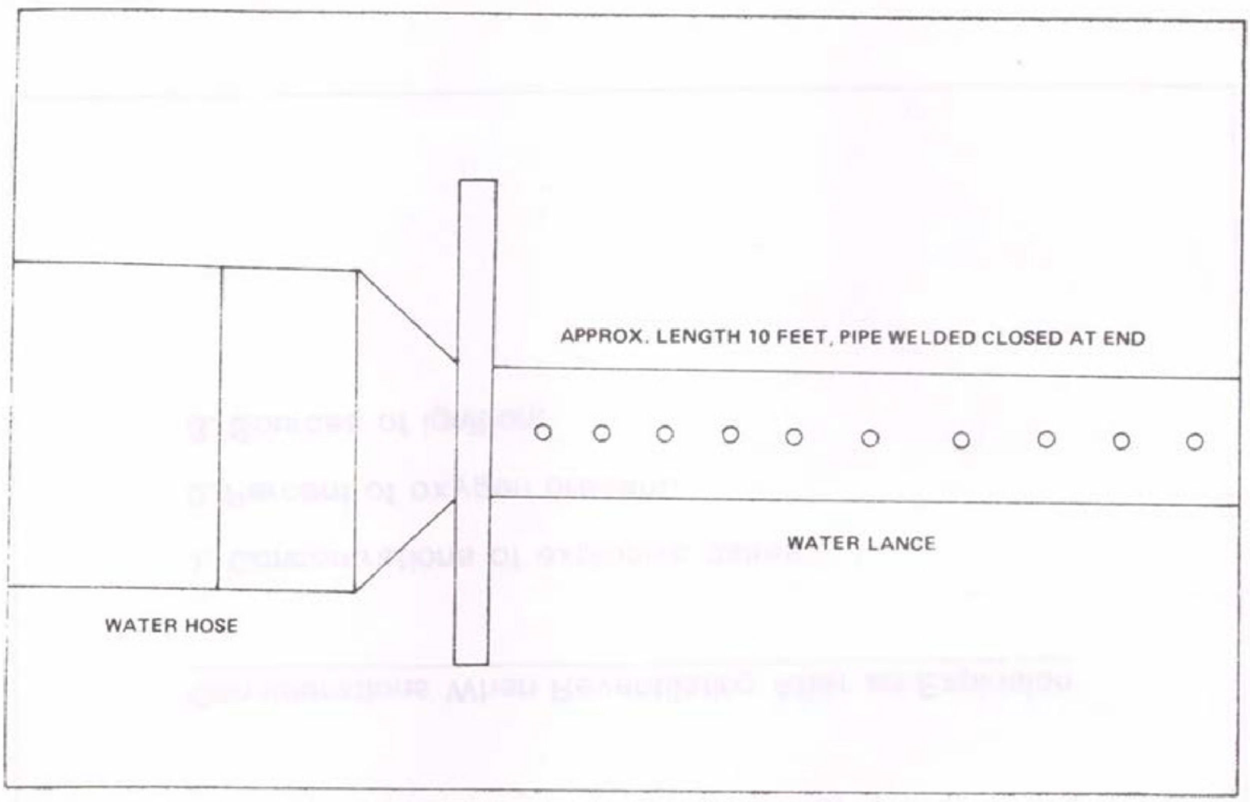


Visual 5: Re-ventilation of an Area

Considerations When Re-ventilating After an Explosion

1. Concentrations of explosive gases
2. Percent of oxygen present
3. Sources of ignition

Visual 6: Re-ventilation After an Explosion



Visual 7: Water Lance

Glossary

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.

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.