Saskatchewan
Labour

Occupational Health
and Safety

Saskatchewan Mine Emergency Response Program

Mine Rescue Manual

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SAFETY

It's in your hands

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Chapter One - Mine Gases

Introduction

It is generally assumed when referring to gases in the mining environment that the interest is in toxic gases, however, the concentration of nontoxic gases, such as oxygen, can be of importance.

Gases in the mine environment come from different sources. The major concern about most gases is their toxicity to workers. If the concentration of and exposure time to a gas are sufficient, illness or death may result.

Saskatchewan Labour's Occupational Health & Safety Division is responsible for setting allowable levels of exposure to gases in the workplace. The regulation of the workplace environment is a well-accepted process and serves to protect mine employees in their daily work. The concepts of the "8-Hour Average Contamination Limit" and the "15-Minute Average Contamination Limit" in Saskatchewan's occupational health and safety legislation, and Threshold Limit Value (TLV), Time Weighted Average (TWA), and Short-Term Exposure Limit (STEL) are commonly referred to as standards. These limits set levels of contaminants that should not be exceeded in order to protect workers from either adverse long-term or acute (short-term) health effects. Refer to material safety data sheets (MSDSs), for contamination limits and other hazard information.

During an emergency when a toxic gas or gases are released into the workplace, the concentration of the toxins can exceed normal workplace standards. This situation may pose a short-term or acute risk because of the increased toxicity of the higher concentration. As well, the reduction of oxygen in the air may also pose a risk to life because oxygen is needed to sustain life.

General properties of gases

The term gas refers to the physical state of a substance at room temperature and normal atmospheric pressure that, when unconfined, expands to fill the space it occupies. At reduced temperatures or high pressures, a gaseous substance can exist in a different physical state. Examples include the liquid propane gas (LPG) and the solid dry ice that, at room temperature would be gaseous propane and carbon dioxide.

Traditionally, mine rescue teaching about gas properties focused on the density of pure gases. However, gases in a workplace in emergency situations are often not pure, but are mixed with air and other gases. Pure gases seldom exist in the workplace. When they do, it is likely that the gas was released from a pressurized vessel discharging uncontrollably. Even a leak of pure, pressurized gas will not perform like a pure gas as the distance from the leaking vessel and turbulence increases. Eventually, the leaking gas will mix with the surrounding air as it moves away from the source of the leak.

Stratification of gases does occur where the gas mixture has a significant difference in density from the surrounding air. A good example is the gases produced during a fire. Because of the heat of combustion, the gases that are released from burning material are hot and less dense than air at normal conditions. As a result, combustion gases generally rise. This mass of hot gas, or package, has a diffuse boundary and is lighter than the surrounding air. The fact that heated gas responds as an unconfined mass is readily visible from chimney smoke in cooler weather. The smoke has buoyancy and rises until the package of gas has mixed and cooled to the same point as the surrounding air. Because of turbulence and diffusion, the package of gas is diluted to the point where it differs little from air alone.

There are other physical properties of gases, such as taste, colour, and odour, that may or may not be helpful as warning properties. For example, the property of colour is often best observed with pure gases. Workers may or may not be able to smell a gas (depending on its concentration). Therefore, in an emergency, these properties may serve little purpose in understanding the toxic nature of a gas when it has been mixed with mine air.

Effects of dilution

Air is primarily composed of oxygen (O) and nitrogen (N). If another gas is evenly mixed with air, as
happens given a sufficient amount of time, the concentration of oxygen and nitrogen will be proportionally reduced.

For example, assume that a gas is introduced into a confined space containing air and that there is no chemical reaction consuming the oxygen. The resulting effect is simply dilution. If the introduced gas is measured at 10 percent, the oxygen and nitrogen in the air will be diluted by 10 percent.

The reduction in O and N concentrations can be determined by the following formulas.

Note: For simplicity, the actual concentrations of oxygen and nitrogen have been rounded off to 21% and 78% respectively.

- The actual O concentration has been diluted by 10% and so is 0.9 X 21% = 18.9%
- The actual N concentration has also been diluted by 10% and so is 0.9 X 78% = 70.2%

Adding up the concentrations of the introduced gas (10%), O (18.9%) and N (70.2%) equals 99.1%. If you apply the above concept to the original air which contained 1% other gases, the missing 0.9% is accounted for.

In the above example, if the oxygen had been diluted by 20%, the actual O concentration would be 0.8 X 21% = 16.8%. If the nitrogen had been diluted by 20%, the actual N concentration would be 0.8 X 78% = 62.4%.

Such calculations are not intended to be a substitute for air monitoring. They serve only to explain the principle of dilution, and the effect of dilution on the concentration of the individual components of air.

Gas accumulation and stratification

Gases can collect in pockets separate from the rest of the mine air. This is especially true where mines lack adequate ventilation. Hot gases from a fire (see General properties of gases, P.1) will rise to the back and remain there until the smoke has time to cool and mix with the air. Therefore, expect the smoke near a fire to be denser at the back. The smoke will be more uniformly distributed in a drift once it moves away from the fire and is mixed with the mine air by ventilation flows and turbulence.

A second example of gas stratification is the distribution of methane in a coal mine. Pure methane has a relative density about one-half that of air and can be produced in massive quantities in an underground coal mine. Such large amounts of methane will physically displace the other mine air. Because of its low density, there may be pockets of methane that will tend to accumulate near the back.

Small differences between the density of a gas and of air will not cause stratification. For example, oxygen is ten percent more dense than air. However, the oxygen will not be more concentrated near the floor in a room or a stope. It remains thoroughly mixed with the rest of the mine air.

Gases derived from combustion processes

Burning organic material and hydrocarbon fuel results in the formation of carbon monoxide and carbon dioxide. Generally, carbon dioxide (CO_2) is produced in larger quantities while carbon monoxide(CO) is produced in smaller amounts where combustion is not 100 percent efficient.

Nitrogen dioxide (NO_2) and other oxides of nitrogen, sulphur dioxide (SO_2), hydrogen cyanide (HCN) and phosgene ($COCI_2$) may be produced by combustion. Burning various plastic or synthetic materials will result in some production of these gases. Base metal mines, such as those that produce copper or zinc, get the metals from sulfide ores. In cases where sulphide ore catches fire after a production blast, a large quantity of sulphur dioxide will be produced.

Industrial gases

An industrial gas is produced for a commercial application. Some of the most common industrial gases found in the mining industry are natural gas or methane (CH_4), propane (C_3H_8) and acetylene (C_2H_2). Some are burned to provide thermal comfort or to do work involving high heat such as cutting metals or brazing. These industrial gases are derived from fossil fuels and are composed of carbon (C) and hydrogen (H). When burned they produce carbon dioxide, water vapour and carbon monoxide. The most well known danger from the combustion of these gases is carbon monoxide poisoning, even though the carbon monoxide is generally produced in small concentrations. Carbon monoxide is a dangerous gas because it readily binds to hemoglobin in red blood cells, even at low concentrations of several hundred parts per million (ppm).

Industrial gases released into the workplace pose additional concerns. When released into an enclosed area, the air concentration may be sufficiently diluted to asphyxiate anyone in the space. An explosive hazard will be produced if the concentration of the gas approaches its lower explosive limit (LEL). For example, the effects of low oxygen content are discernible at 17 percent (not asphyxia), or approximately four percent lower than the normal concentration in air. If air is diluted by methane to an oxygen concentration of 17 percent, the actual concentration of methane is approximately 20 percent. Methane at this concentration is theoretically above its upper explosive limit. However, there will be areas where methane is explosive because of its uneven distribution in the air. For other combustible gases, try calculating the concentrations of a mixture with air and determine if the result is an explosive atmosphere.

An industrial gas released quickly and in sufficient volume from a pressure vessel will produce a cold mass of gas that may be stratified or distinctly layered near the point of its release. Whether the release occurs outdoors or indoors does not reduce the danger of a moving plume or cloud of concentrated combustible gas. The boundary of the gas plume has a concentration gradient that varies from pure air to an increasingly richer mixture in air. The plume, or body of gas, constantly expands until it makes contact with an ignition source. At some point, the gas concentration in the plume will be at or above its lower explosive limit.

Gases used in industrial processes

Nitrogen gas comprises 78.09 percent of pure, dry air at sea level. Nitrogen does not contribute materially to the body’s functioning or the combustion process. Because of this, nitrogen is often used to inert vessels that can not be exposed to oxygen during maintenance.

In the absence of oxygen, nitrogen becomes a lethal asphyxiant. Conversely, air that is oxygen enriched will support rapid burning that can be extremely dangerous.

Ammonia gas is caustic and breathing its vapours in sufficient quantities can damage lung tissue and impair breathing. When released from a pressurized vessel, the extreme cooling effect of the expanding gas will cause skin to freeze.

Gases from explosives

The detonation of commercial explosives creates the same gases found from burning fuel. The presence of carbon and nitrogen in commercial explosives makes it likely that carbon monoxide, carbon dioxide and nitrogen oxides will be produced from a blast.

Natural occurrences of gases

***Hydrogen sulfide (H_2S)*:** Hydrogen sulfide in the mining environment is derived from water. In the Saskatchewan potash mining industry, hydrogen sulfide is derived from water entering mined areas from either the Dawson Bay Formation or the Winnipegosis Formation. The hydrogen sulfide dissolved in the water originates from bacterial decomposition of soluble sulfate in the water. Once the water enters the mine, hydrogen sulfide is released into the mine air in the absence of hydrostatic pressure. The solubility of hydrogen sulfide in water is relatively low at mine atmospheric pressures.

When the water inflow area has restricted ventilation, hydrogen sulfide will build up in the area of the inflow. Levels of 100 ppm are rare in unventilated caverns with water inflows. Although 100 ppm is not an immediately lethal concentration, extended and unprotected exposure beyond one-half hour can lead to unconsciousness and, ultimately, death.

Decomposition of organic material such as sewage can lead to the formation of hydrogen sulfide if sulphur compounds are in the decaying material. Water wells with intakes at the bottom of the reservoir have brought hydrogen sulfide into the pump house with deadly results for workers.

***Carbon dioxide ($C0_2$)*:** Carbon dioxide is a natural metabolite produced in the human body and exhaled in the respiratory process. In sufficient concentration, naturally exhaled carbon dioxide is hazardous. The exhalation of carbon dioxide by workers in refuge stations can create hazards. A dead air space is commonly employed for refuge in underground potash mines. Hardrock mines commonly use much smaller refuge stations supplied with compressed air. (see also Gas in enclosed areas, P.9).

Methane (CH_4) or natural gas: Methane is produced when organic matter decomposes. Methane is also produced when sewage or other organic matter is subject to stagnant conditions and bacterial action. Coal beds may also contain methane and release the gas when the bed is exposed during mining. Methane is very dangerous in underground coal mines where inadequate ventilation can result in concentrations of the gas building to explosive levels.

Oxygen deficiency/depletion

The biological effect of oxygen depletion is similar to asphyxiation. However, the physical processes leading to oxygen depletion are different. Oxygen depletion requires two factors to produce a hazardous condition. A chemical reaction called oxidation is necessary to consume oxygen from the surrounding air and there must be limited incoming fresh air to replace the oxygen that has been consumed. Oxygen deficiency can be produced by displacement from another gas.

Some base metal mines, such as those found in northern Saskatchewan and Manitoba, produce copper and zinc sulfide minerals. These minerals contain iron sulfides such as pyrrhotite which have high oxidation rates. Workers have been killed after entering a stope with mill tailings that have undergone oxidation. Oxygen depletion from coal storage bins has also been reported. Such depletion likely originated from iron sulfides found in the coal.

Measuring gas concentrations

The measurement of gases has always been an important component of mine rescue.

One of the common questions asked of instructors today is “where to measure?” for a toxic or explosive gas. Typically, the instructor will refer to the specific gravity of a pure gas, and state that sampling should be done high or low because gases find elevations relative to their specific gravity. In general, this approach does not yield accurate evaluations. As discussed, the behaviour of gases is much more complex.

In most emergencies where a toxic gas is encountered, it is already mixed with the mine air. Even a very toxic mixture of H_2S at 1000 ppm is virtually the same density as air alone. There is no density stratification of the H_2S because, at 1000 ppm, the mixture is still 99.9 percent air. There may be a concentration gradient near the source depending on the extent of mixing from turbulence and diffusion.

Gases respond to thermal differences. For example, hot combustion gas is largely composed of CO_2 and some CO, and represents a package of gas that is heavier than air. However, because these gases are hot, they tend to be buoyant relative to the surrounding cooler air. The smoke containing these gases will rise, dilute, mix, and cool, becoming indistinguishable from air.

Conversely, cold gas formed during release from a compressed cylinder will be dense and tend to gravitate close to the ground surface or in a pit. Such a cold air mass could flow into a nearby sump and remain there for some time in the absence of good mixing. Cold gas will normally mix with mine air due to turbulence, dilution and warming, and will eventually be uniformly distributed throughout the mine atmosphere.

The best place to take gas samples is where the gas could be harmful. This would be in the breathing zone and in any area where people may be present. Samples might also be taken along the potential mixing front of a gas. However, a mine rescue team taking the samples should remain alert to the possibility of gas stratification as discussed in the previous section.

Monitoring equipment

Equipment to measure the concentration of gases comes in two types: the colourimetric or length-of-stain tube system, and the electronic gas detector.

Important: Refer to the manufacturer's instructions for use of gas detecting equipment.

Colourimetric (length-of-stain) tube system: This method of gas detection is comprised of a glass tube and pump. Although there are several different designs for the stain tube system, they all work on the same principle. In each case, the manufacturer has developed a tube that changes colour along the length of the tube in proportion to the concentration of the gas in the air. A known quantity of air, usually in multiples of 100 cm^3, is pulled through the tube after the two glass ends have been broken and the tube is inserted properly into the pump. Drawing 100 cm^3 of air with the pump is termed a stroke. Most pumps are designed to draw 100 cm^3 of air per stroke but some pumps are capable of pulling a half stroke or 50 cm^3.

The stain tube detection system has several advantages. The system is relatively accurate (usually + or – 25%) if the user follows the manufacturer's recommendations and precautions. Numerous gases can be monitored relatively inexpensively, but a large inventory of tubes is required to provide the flexibility to monitor several gases at different concentrations. The system does not require calibration. One disadvantage of the detector tube is its limited shelf life, which requires paying close attention to the expiry date. Another disadvantage is that several strokes and minutes are required to obtain a reading.

The basic rules to follow when measuring gas levels with a detector tube system include:

- Become familiar with and use the fact sheet provided with each box of tubes. It contains important information on the effects of humidity and interference, to name just a few points.
- Conduct a leak test to check the state of the bellows or piston, and tube seats.
- Break off ends of gas tubes.
- Ensure gas tubes are firmly seated in the pump and placed with the arrow pointing towards the pump.
- Determine the appropriate number of strokes for the tube, especially if the tube is a multi-stroke tube and has two scales.
- Check that sufficient time has elapsed for the sample.
- Allow bellows to fully deploy and, with piston pumps, be sure that the vacuum has returned to atmospheric pressure.
- Check the detector tube fact sheet for possible interference or cross-sensitivity from other gases. Cross-sensitivity can have positive or negative results.
- Read the tube where there is a colour change; take the reading as soon as the sample is taken and before bleeding of the colour interface has occurred.

Electronic gas detectors: Electronic gas detectors have come a long way in reliability, cost and gas detection capability. However, these devices remain an expensive alternative to length-of-stain systems and the costs are higher with each detector the unit is fitted with. Electronic gas detectors are generally fitted with an audio alarm that can be set to sound at certain concentrations. Changing contamination levels are assessed almost instantaneously.

Electronic gas detectors have limitations. Typically, these detectors function at the lower ranges of gas concentrations with levels mostly associated with normal industrial hygiene surveys and concerns. Of course, there are exceptions. Oxygen and combustibles in the acutely hazardous range can be adequately assessed with an electronic gas detector. Regular monthly calibration is necessary, but for critical circumstances, it is recommended that the unit be calibrated prior to its use. Testing or bumping with a test gas may be used to test the instrument’s response. Although gas detection instruments are shielded from radio frequencies by metal or metal impregnated cases, the instrument may be affected when a radio is keyed with the instrument close by.

In spite of these limitations, an electronic gas detector is a very valuable piece of equipment for measuring the preliminary concentration of a gas in an emergency and for giving an “all clear” to workers after an emergency.

Flame safety lamp: The flame safety lamp has been used in mine rescue operations for more than 100 years. With the introduction of electronic gas detecting instruments, the flame safety lamp has been relegated to a piece of backup equipment.

Measurement

Gases are commonly measured in percentage (%) by volume and ppm. Since both of these units of measurement are volume relationships, they are easily converted to one another by using the following basic formula.

$$\% \times 10000 = \text{ppm, and conversely ppm} \div 10000 = \%$$

Contamination limits are only quoted in milligrams per cubic metre (mg/m^3). The following formula is used to convert concentrations from ppm at 20°C to mg/m^3. "M" refers to the molecular weight of the gas. 24.04 is a constant.

$$mg/m^3 = (ppm \times M) \div 24.04$$

To calculate the equivalent Saskatchewan 8-hour contamination limit in ppm use the following formula:

$$ppm = (mg/m3 \times 24.04) \div M$$

Molecular weights for some common gases are provided in Figure 1-1.

Acetylene	26.0	Hydrogen sulfide	33.1
Ammonia	17.0	Methane	16.0
Carbon dioxide	44.0	Nitrogen	4.0
Carbon monoxide	28.0	Nitrogen dioxide	46.0
Chlorine	70.9	Nitric oxide	30.0
Hydrogen	2.0	Propane	44.1
Hydrogen cyanide	27.0	Sulphur dioxide	64.1

Figure 1-1: Molecular weights for some common gases

Gas in enclosed areas

During an emergency, workers may have to seal themselves into a heading to create a cocoon of breathable air around them, or they may seek refuge in a mine refuge station. When brattice is used, there is no replenishment of the oxygen consumed nor is there dilution of the expired carbon dioxide. The same situation occurs in potash mines where the volume of the dead air space in a refuge centre provides breathable air for workers. For a short period of time and a small number of workers, elevated carbon dioxide is not a major concern.

It has been generally assumed that the provision of oxygen or air from pressurized cylinders is sufficient to maintain an adequate supply of breathable air. Given sufficient time and number of workers, the expiration of carbon dioxide can create a toxic environment in the occupied air space.

Although existing provincial regulations do not address the time and capacity of mine refuge stations, some basic design rules-of-thump have been used. A maximum design concentration of three percent carbon dioxide with a minimum of 16.25 percent oxygen at eight to 24 hours is recommended by MASHA* in their "Guidelines for Mine Rescue Refuge Stations". MASHA summarized the various models for dead air space design. All models produce similar results of 5.7 to 6.2 m^3 of dead air space per person to limit the CO_2 concentration to three percent after eight hours. To maintain the same upper limit of three percent CO_2 for a 24-hour period would require three times the dead air space volume (~18 m^3 per person).

For refuge stations equipped with compressed air, such as those commonly found in hard rock operations, design flows should maintain an adequate oxygen supply. It is critical that sufficient air be provided to dilute the CO_2 exhaled in the worker's breath. MASHA says that flow rates of 50 to 100 scfm (standard cubic feet per minute) per person are required to keep CO_2 levels to less than 5000 ppm. The use of standard sized (300 ft^3) cylinders is impractical for providing extended protection because of the large volume of compressed air required for dilution.

Mine rescue personnel should be acquainted with basic design considerations for the capacity of a refuge station. Refuge stations should be designed to handle the required number of workers who could be sent to them.

Mine clearance

Following a toxic gas release, one of the main tasks of the mine rescue team is to determine if it is safe for other workers to return to the mine.

If the gas concentration is below a recognized workplace contamination limit established for extended exposure, it should be safe to return to normal operations. Remember that the basic assumption of the threshold limit concept is that below the TLV, a person should not experience ill health from exposure at that concentration for a working lifetime. It is important to have calibrated electronic gas detection equipment or low concentration gas tubes available for evaluating the air.

Summary

The most serious emergencies underground originate from fire. Surface emergencies may involve process gases as well.

The gases carbon monoxide and carbon dioxide produced by fire are a major concern. Although other gases may form when synthetic materials are burned, their effects may be of lesser importance than the effects of exposure to carbon monoxide and carbon dioxide, and the depletion of oxygen.

* MASHA, Mines and Aggregates Safety and Health Association, Ontario, Canada

Gas properties and characteristics

This section provides detailed information on gases that may exist in a mine and its surface operations due to an unusual condition or emergency. However, other gases not discussed in this chapter may exist in small quantities.

Except for the section on air, most gas descriptions here are broken down into six subsections. The first subsection presents the health effects for acute exposure through inhalation, ingestion or absorption. Acute exposure refers to the severe and often dangerous effects from exposure to high concentrations of a gas for a short period of time.

The second subsection identifies the Saskatchewan workplace contamination limit. This value can be used to establish clearance after an emergency. Workplace contamination limits are based on the concept of long-term exposure that should not produce any health effects.

The remaining subsections include physical properties, known origins of the gas, with special emphasis on occurrences in Saskatchewan and neighbouring provinces, methods of detection, and treatment of workers who have been acutely exposed.

Each gas title is followed (in brackets) by its chemical formula. The formula identifies the elements that the gas is composed of. Below is a list of the elements and their chemical symbols that form the gases discussed in this chapter.

- (C) - carbon
- (Cl) - chlorine
- (H) - hydrogen
- (N) - nitrogen
- (O) - oxygen
- (Rn) - radon
- (S) - sulphur

Air

Normal air is a mixture of gases. Air is colourless, tasteless and odourless. It supplies the oxygen necessary for life. Pure, dry air at sea level is 78.09% nitrogen, 20.94% oxygen, 0.94% argon, 0.03% carbon dioxide, and contains trace amounts of other gases.

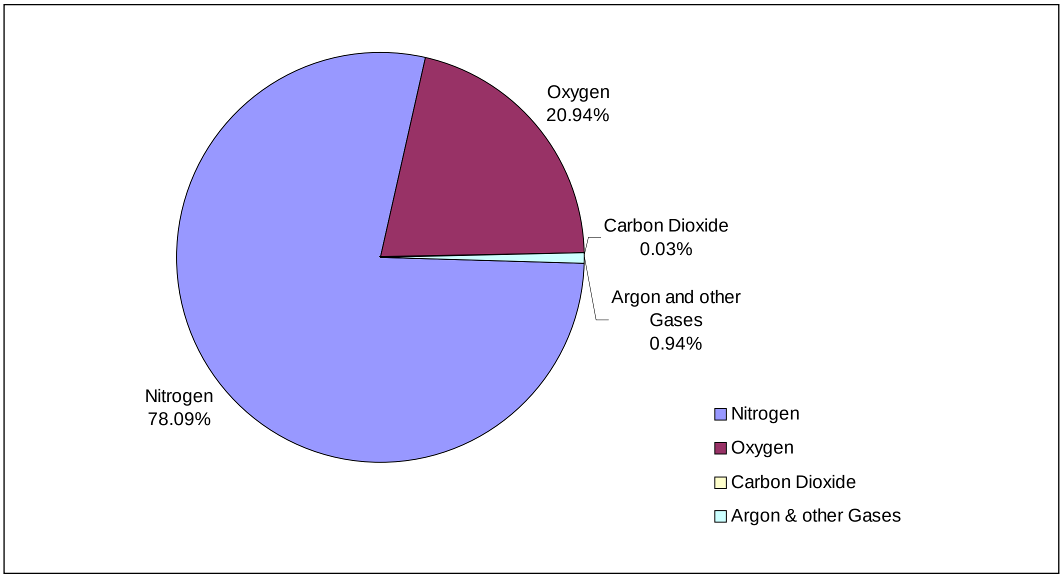


Figure 1-2: Percentage of gases in normal air

Ammonia (NH_3)

Health effects: Ammonia is an alkaline chemical that is irritating to the eyes and moist skin. Severe irritation of the respiratory tract can lead to respiratory arrest. After an acute exposure, bronchitis or pneumonia may develop. Contact with ammonium hydroxide can cause extensive eye damage resulting in blindness. As with other compressed gases, there is a danger of frostbite from contact with the discharged gas near the point of discharge.

Some health effects of exposure to ammonia include:

- 20-25 ppm: maximum concentration that does not produce severe complaints
- 25-100 ppm: nasal irritation develops with several hours of exposure
- 500 ppm: upper respiratory irritation after 30 minutes
- 700 ppm: immediate upper respiratory irritation
- 1500-10000 ppm: convulsive coughing, chest pain, and pulmonary edema; potentially fatal

***Contamination limits*:** The 8-hour average limit for ammonia is 17 mg/m^3 or 24 ppm (*The Occupational Health and Safety Regulations, 1996*).

***Properties*:** Ammonia is flammable and colourless. It has a sharp or pungent, intensely irritating odour that is described as suffocating. The odour is detectable below 5 ppm. Ammonia has an explosive range of 16 to 25 percent. In water, ammonia is known as ammonium hydroxide.

Origin: Ammonia is used as a chemical feed stock for fertilizer production, in large air cooling units at some mines, and is also a primary ingredient in blasting agents like ANFO. Processing of uranium into yellow cake uses ammonia. Ammonia is found in US trona deposits, but the extent of the health risk is not known.

Detection methods: The simplest way to determine ammonia concentration is with a direct reading colourimetric tube. Electronic gas detectors are available for the detection of ammonia.

Treatment of affected persons: Take the victim to fresh air and seek medical help.

Carbon dioxide (CO_2)

Health effects: In spite of being a human metabolite, carbon dioxide causes physiological responses at elevated concentrations. Elevated concentrations can produce narcotic effects, stimulate respiration, and result in asphyxiation depending on the concentration and exposure time.

Health effects of exposure to carbon dioxide include:

- at five percent, respiration is stimulated
- at seven to 10 percent carbon dioxide, unconsciousness results after a few minutes; a high carbon dioxide concentration will eventually cause death

Contamination limits: The 8-hour average limit for carbon dioxide is 9000 mg/m^3 or 4920 ppm (*The Occupational Health and Safety Regulations, 1996*). For underground operations, the limit is 5000 ppm (*The Saskatchewan Mines Regulations*).

Properties: Carbon dioxide is colourless and odourless. High concentrations may produce an acid taste. Carbon dioxide does not burn.

Origin: Carbon dioxide is a normal component of air (~0.03 percent). There are no toxic effects at normal background. Although internal combustion engines produce carbon dioxide, workplace concentrations are generally controlled through ventilation.

Elevated concentrations of carbon dioxide are produced from combustion and blasting operations. However, combustion is not a chemically clean process and is accompanied by carbon monoxide in sufficient quantities to be toxic. The breathing process could produce dangerous levels of carbon dioxide given sufficient time and a lack of ventilation. Biological oxidation, such as rotting, will elevate the concentration of carbon dioxide in a confined area while lowering the oxygen concentration to potentially dangerous levels.

Detection methods: Electronic detection devices and direct reading colourimetric tubes are available to measure carbon dioxide levels. Electronic detectors are more suitable for concentrations below 5000 ppm.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and artificial respiration if breathing has stopped and seek medical help.

Carbon monoxide (CO)

Health effects: Carbon monoxide is highly toxic. Inhaled carbon monoxide readily binds to blood hemoglobin reducing the blood's oxygen carrying capacity (carboxyhemoglobin). As with other toxic gases, the level and duration of exposure determines the severity of the effects. (see Figure 1-3).

Health effects of exposure to carbon monoxide include:

- 400 ppm: temporal headache develops after two to three hours of exposure
- 1600 ppm: headache, dizziness and nausea in 20 minutes; collapse and death in two hours
- 2000-2500 ppm: unconsciousness in about 30 minutes
- high concentrations may provide little or no warning before collapse; deafness has been reported after severe CO intoxication

Contamination limits: The 8-hour average limit for carbon monoxide is 29 mg/m^3 or 25 ppm (*The Occupational Health and Safety Regulations, 1996*). For underground operations, the limit for carbon monoxide is 25 ppm (*The Saskatchewan Mines Regulations*).

Properties: Carbon monoxide is flammable, colourless, tasteless and odourless. It has an explosive range of 12.5 to 74 percent. Such concentrations are unlikely to result from a mine fire unless the fire is confined and is oxygen starved. High concentrations of carbon monoxide may be partially responsible for the event known as backdraft.

Origin: Carbon monoxide is a product of incomplete combustion of carbon based materials. The burning or detonation of explosives also produces carbon monoxide, and it is emitted from the exhaust of internal combustion engines.

Detection methods: Electronic gas detectors and direct reading colourimetric tubes are available for carbon monoxide. Electronic gas detectors are better for the lower concentrations experienced in the normal working environment.

Treatment of affected persons: Take victim to fresh air and, if possible, give oxygen immediately to lessen the severity of the carbon monoxide poisoning. If artificial respiration is necessary, oxygen should be given as soon as possible. CPR may also be required. The victim should be kept at rest and provided with medical attention as soon as practicable.

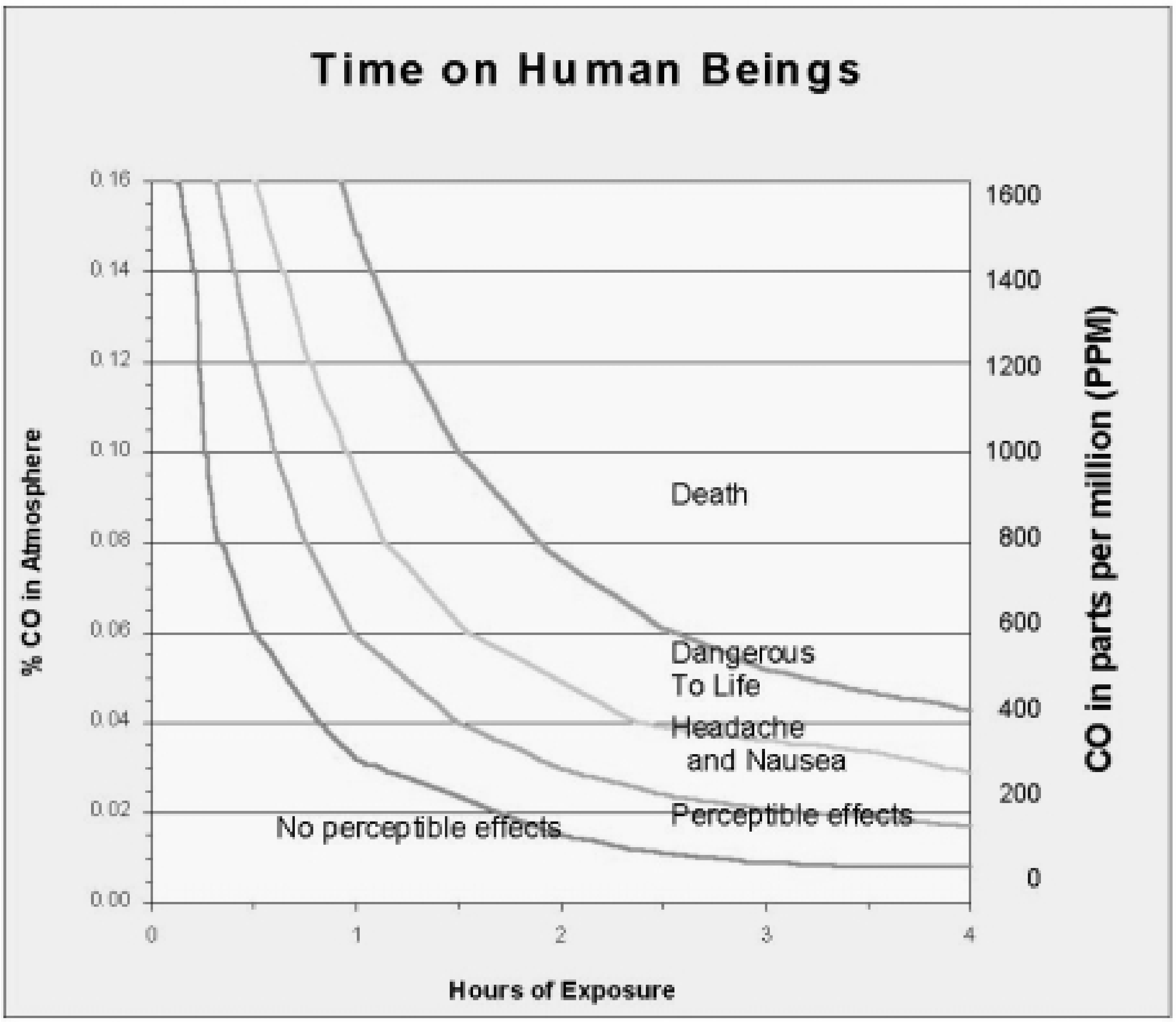


Figure 1-3: Physiological effects of exposure to carbon monoxide (CO)

Chlorine (Cl)

Health effects: Chlorine is a severe irritant for the skin, eyes and the upper respiratory tract. The inhalation of sufficient quantities of chlorine can cause bronchitis, fluid buildup in your lungs (pulmonary edema) and congestion. High doses of chlorine gas can cause rapid death. Exposure of the skin to chlorine leaking from compressed lines or cylinders can cause frostbite.

Health effects from exposure to chlorine gas include:

- 1-2 ppm: itching and burning of the nose and eyes
- 5 ppm: chlorine is severely irritating; cannot be tolerated for more than a few minutes
- 15-60 ppm: bronchitis and severe pulmonary damage after 30 minutes
- 35-50 ppm: death in 1 to 1.5 hours
- 430 ppm: death in 30 minutes

Contamination limits: The 8-hour average limit for chlorine is 1.5 mg/m^3 or 0.5 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Chlorine does not burn. It has a greenish yellow colour, and a distinct odour that smells like household bleach. The odour of chlorine can be perceived at 0.3 ppm.

Chlorine is an oxidizing agent and will react explosively or form an explosive compound when combined with substances like acetylene, ether, turpentine, ammonia, hydrogen and fuel gas. Chlorine gas is heavier than air and can collect in low lying areas when released into stagnant air. Chlorine gas released from a compressed gas cylinder or line is usually cold and thus is more likely to collect in low lying areas.

Origin: Chlorine is commonly used to treat potable water. In some cases, it may be used to treat effluent at a sewage treatment facility. Leaks can occur if piping or cylinders are damaged or if valves are improperly secured on a compressed gas cylinder.

Detection methods: Direct reading colourimetric tubes are commonly employed to measure chlorine concentrations. Electronic gas detectors are also commercially available. However, some electronic chlorine detectors may require weekly maintenance to function properly.

Treatment of affected persons: Take the victim to fresh air, keep quiet and immediately seek medical attention. Give oxygen and provide artificial respiration as necessary.

Combustible gases

Specific compounds: Several gases are used in Saskatchewan mining operations that are hydrocarbon fuels. The more common of these gases are methane (CH_4), propane (C_3H_8) and acetylene (C_2H_2). Methane is also found in coal beds where it is formed by the decomposition of organic material.

Health effects: The combustible gases referred to in this section are considered nontoxic. However, they act as simple asphyxiants. (See the Health effects for oxygen P.24). These gases may also be explosive, depending on their concentrations in the atmosphere.

Contamination limits: There are no limits established for the combustible gases of acetylene, methane and propane. Because these gases are explosive, the lower explosive limit should not be exceeded.

Phosphine occurs in commercial grade acetylene. Therefore, acetylene should be limited to 3160 ppm to limit phosphine to 0.42 mg/m^3 or 0.3 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Methane, propane and acetylene are flammable and colourless. Methane is the major component of natural gas. Propane and natural gas sold commercially have an odourant added to make the gases easy to smell. Acetylene has a garlic-like odour.

The explosive ranges are (see additional gases Figure 1-4):

- Acetylene 2.5% to 93%
- Methane 5.3% to 15%
- Propane 2.2% to 9.5%

Origin: Leaks from compressed gas vessels or their piping network are the most likely sources of combustible gas. Methane can be produced when organic material rots in stagnant water. Methane occurs as free gas in coal beds. Its presence is a particular concern in underground coal operations. If gas concentrations and sources of ignition are not controlled, disasters, such as the Westray explosion, can occur.

Detection methods: Electronic gas monitors with combustible gas detectors are most commonly employed to evaluate these gases. Combustible gas detectors are not gas specific and have different sensitivities to various combustible gases. Ensure that the appropriate manufacturer’s conversion factor is applied and the instrument is appropriately calibrated. Direct reading colourimetric tubes are also available for these gases.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and provide artificial respiration as necessary. Seek medical help.

Examples of Flammable Ranges		
Fuel	Lower Limit (%)	Upper Limit (%)
Gasoline Vapour	1.4	7.6
Methane (Natural Gas)	5.3	15.0
Propane	2.2	9.5
Hydrogen	4.0	75.0
Acetylene	2.5	93.0

Figure 1-4: Examples of flammable ranges

Hydrogen (H)

Health effects: In high concentrations, hydrogen acts as a simple asphyxiant. The limiting factor is the available oxygen.

Contamination limits: There is no limit established for hydrogen. Because this gas is explosive, the lower explosive limit should not be exceeded.

Properties: Hydrogen is colourless, odourless and tasteless. It is very flammable and explosive when exposed to heat or flame or when mixed with chlorine, air, oxygen, or other highly oxidizing or flammable materials. The explosive range is four to 75 percent.

Origin: Hydrogen gas may be released during a fire. However, such a release is rare. For example, it could occur during a steam explosion when molten metal causes water to break down into its elements of oxygen and hydrogen, or when combustible metals, such as magnesium, burn. Ultimately, hydrogen is very combustible and would be easily consumed by the blaze.

Detection methods: Electronic gas monitors with a combustible gas detector can be used to measure the concentration of hydrogen. Combustible gas detectors (catalytic diffusion sensors) are not gas specific and have different sensitivities to the various combustible gases. Ensure that the instrument is calibrated using the appropriate manufacturer’s conversion. Direct reading colourimetric tubes are also available for hydrogen.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and provide artificial respiration as necessary. Seek medical help.

Nitrogen (N)

Health effects: Nitrogen is nontoxic. At concentrations above 78 percent, nitrogen is probably displacing oxygen. A lack of oxygen can result in asphyxiation.

Contamination limits: There is no provincial standard. The oxygen concentration should not be lower than 19 percent by volume (*The Saskatchewan Mines Regulations*).

Properties: Nitrogen is colourless, odourless and tasteless. Nitrogen is not an explosive gas and it will not burn.

Origin: Nitrogen is the largest component of normal air. Pure dry air at sea level contains 78.09 percent nitrogen.

Detection methods: Monitors and direct reading colourimetric tubes are not available. The relevant measurement method is to test for oxygen concentration.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and artificial respiration if breathing has stopped. Seek medical help.

Hydrogen cyanide (HCN)

Health effects: Cyanide is highly toxic when inhaled as hydrogen cyanide gas or ingested as dissolved cyanide. Lethal amounts of cyanide can also be absorbed through the skin. The toxic effect is caused from interference with cellular metabolism. Cyanide in the blood blocks the use of oxygen by the body's cells (cytotoxic anoxia).

Health effects from acute exposure to hydrogen cyanide include:

- 18 to 39 ppm: Some symptoms may result after exposure of several hours. Symptoms such as light-headedness, breathlessness, feeling shaky, headache and nausea have resulted from accidental exposure.
- 45 to 54 ppm: Exposure at this concentration can be tolerated for 30 to 60 minutes without immediate or delayed effects.
- 110 ppm: fatal after 60 minutes
- 135 ppm: fatal after 30 minutes
- 181 ppm: fatal after 10 minutes
- 270 ppm: immediately fatal

Contamination limits: The ceiling limit for hydrogen cyanide is 5 mg/m^3 or 4.5 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Hydrogen cyanide is flammable and colourless. It has a faint odour of bitter almonds that may not be perceived by 20 to 40 percent of the population. Its explosive range is 5.6 to 40 percent.

Origin: Cyanide compounds are commonly used in the recovery of gold. When cyanide is in a solution at a high pH, very small amounts of HCN are released. However, large amounts of HCN are released if the solution becomes acidic.

Detection methods: Electronic gas detectors and direct reading colourimetric tubes are available for testing for hydrogen cyanide.

Treatment of affected persons: Exposure to hydrogen cyanide requires prompt treatment with antidotes and oxygen. This is administered by specially trained personnel in consultation with health care providers.

Nitric oxide (NO)

Health effects: There are few reports on the health effects of inhaling nitric oxide. Since nitric oxide spontaneously oxidizes in air and becomes nitrogen dioxide, the reported health effects are attributed to a mixture of nitrogen oxides that also includes nitrogen dioxide. However, based on animal studies, it appears that nitrogen oxide is much less toxic than nitrogen dioxide.

Contamination limits: The 8-hour average limit for nitric oxide is 31 mg/m^3 or 25 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Nitric oxide is colourless and has an odour threshold of 0.3 to 1 ppm. Nitric oxide has a slightly sweet odour.

Origin: Nitric oxide is produced by burning or detonating nitrogen based explosives and by running diesel engines. Electric arc and oxy-gas welding will generate nitric oxide. Nitric oxide is also generated from an oxyacetylene torch because of the elevated operating temperature of 3093 to 3316^{o}C (5600-6000^{o}F). Most of these sources of nitric oxide are workplace generated and do not generally cause mine emergencies.

Detection methods: Direct reading colourimetric tubes and electronic gas detection equipment are available for determining the nitric oxide concentration.

Treatment of affected persons: Take the victim to fresh air and seek medical help.

Nitrogen dioxide (NO_2)

Health effects: Many deaths from fluid buildup in the lungs (pulmonary edema) have occurred from exposure to high concentrations of nitrogen dioxide. Nitrogen dioxide is relatively insoluble and that permits it to penetrate to the lower respiratory tract where it may cause death. There is a latent period of three to 30 hours from the time of initial exposure to the onset of potentially fatal pulmonary symptoms.

Health effects from exposure to nitrogen dioxide include:

- 1-13 ppm: irritation of the nose and throat
- 10-20 ppm: mild irritation of the eyes, nose and upper respiratory tract
- 80 ppm: tightness in the chest after three to five minutes
- 90 ppm: Pulmonary edema has been reported after a 30-minute exposure. Therefore, levels above 100 ppm may be dangerous for even a short exposure.

Contamination limits: The 8-hour average limit for nitrogen dioxide is 5.6 mg/m^3 or 3.0 ppm (*The Occupational Health and Safety Regulations, 1996*). The limit when operating diesel engines underground is 2.0 ppm (*The Saskatchewan Mines Regulations*).

Properties: In its purest form, it is a reddish-brown gas with a pungent, acrid odour. The odour of nitrogen dioxide has been described as “sweetish and acrid” and “bleach-like”. It is detectable at 0.04 to 5 ppm. Nitrogen dioxide does not burn or explode.

Origin: Burning or detonating of nitrate explosives produces nitrogen dioxide. Nitrogen dioxide is in the exhaust of diesel engines. However, diesel emissions are unlikely to create an emergency.

Detection methods: Direct reading colourimetric tubes and electronic gas detectors provide good detection for nitrogen dioxide.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and complete rest. Seek medical help.

Hydrogen sulfide (H_2S)

Health effects: Hydrogen sulfide is highly toxic because it interferes with cellular metabolism. It blocks the use of oxygen by your body's cells (cytotoxic anoxia). Tissues that require a lot of oxygen, such as your nervous system and heart, are particularly affected.

Health effects from exposure to hydrogen sulfide include:

- 30 ppm: eye irritation
- 50 ppm: prolonged exposure can result in pulmonary edema
- 50 to 500 ppm: hydrogen sulfide irritates the eyes and respiratory tract, leading to nausea, vomiting and headaches.
- 150 to 200 ppm: olfactory (sense of smell) fatigue occurs
- 250 to 600 ppm: prolonged exposure commonly results in pulmonary edema and unconsciousness
- 1000 to 2000 ppm: unconsciousness, stopped breathing, and death after a few breaths due to paralysis of the respiratory centre; death may occur even if an individual is removed to fresh air at once

Contamination limits: The 8-hour average limit for hydrogen sulfide is 14 mg/m^3 or 10 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Hydrogen sulfide is colourless and has the odour of rotten eggs. The odour may be perceived at 0.003 ppm. At higher concentrations, the odour may not be detected due to olfactory fatigue. Hydrogen sulfide is explosive in the range from 4.3 to 46 percent.

Origin: Hydrogen sulfide is produced when sulfur compounds are chemically reduced or decompose. It is found in some oil and gas fields and in some gypsum mines. It may also be released from methane feeders in mines with methane. Hydrogen sulfide is often created when acid mine water corrodes metallic sulfides. It can also be released from water that contains the gas or sulfides in solution. Heating sulfides in the presence of moisture (as in mine fires) may produce hydrogen sulfide gas. Blasting in sulfide ores can also create and release hydrogen sulfide.

Detection methods: Electronic gas detectors and direct reading colourimetric tubes are the standard test methods for hydrogen sulfide.

Treatment of affected persons: Exposure to H_2S requires prompt treatment with antidotes and oxygen. This is administered by specially trained personnel in consultation with health care providers.

Oxygen (O)

Health effects: Oxygen is essential for life. It is harmful to breathe air that is low in oxygen. Such air is known as an oxygen deficient atmosphere.

Health effects and physiological responses from oxygen deficiency include:

- 17%: breathing is faster and deeper; impaired judgement may result
- 16%: the first signs of anoxia appear
- 15%: dizziness, buzzing noise, headache and blurred vision may develop
- 12-16%: breathing and pulse rate increases; muscular coordination is slightly impaired
- 10-12%: emotional upset and abnormal fatigue on exertion are evident; a person may remain conscious
- 6-10%: nausea and vomiting may occur; victims are unable to move freely and may lose consciousness
- < 6%: convulsive movements and gasping respiration occurs; respiration stops and soon after the heart also stops

Contamination limits: Oxygen should not be less than 19 percent by volume (*The Saskatchewan Mines Regulations*). For hazardous confined spaces, oxygen must not be less than 19.5 percent or more than 23 percent (*The Occupational Health and Safety Regulations, 1996*).

Properties: Oxygen is colourless, odourless and tasteless. Oxygen is not an explosive gas, but it does support combustion. In concentrations above 21 percent, oxygen will produce accelerated combustion.

Origin: Potential causes of an oxygen deficient atmosphere include displacement by a gas other than air, and consumption of oxygen in a fire, explosion, or a chemical reaction. The rotting of organic material is a biological oxidation process that could lead to an oxygen deficient atmosphere by building up carbon dioxide. In the case of fires and explosions, there may be other toxic gases that will be harmful before the environment becomes dangerous due to oxygen deficiency.

Detection methods: Electronic gas detection is a reliable detection method. Historically, oxygen deficiency was detected with a safety lamp. The flame of a candle or safety lamp is extinguished at approximately 16 percent.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and artificial respiration if breathing has stopped. Seek medical help.

Radon (Rn)

Health effects: Radon is not chemically toxic. However, radon and radon progeny (decay products of radon) are radioactive and emit radiation. Radon gas is not immediately life threatening, but will deliver radiation exposure to people when air containing radon is breathed. Continued exposure to high levels of these gases has been linked to lung cancer.

Contamination limits: Mines are required to keep exposure to radiation below 2 WLM (working levels) per quarter.

Properties: Radon is colourless, odourless, and tasteless. Radon is not flammable. It is soluble in water and can be found at higher concentrations near water inflows or at sumps.

Origin: Radon is a gaseous decay product of the uranium series and is found in all uranium mines. As radon is released into a mine's atmosphere, it continues to decay and forms airborne radioactive atoms (radon progeny). Workers get a radiation dose from inhaling radon progeny sticking to dust that is deposited in the lungs, where it continues to decay and damage lung tissue. If the radon level in an area is very high, breathing protection may be required to reduce radiation exposures.

Stagnant air in a mine has the highest concentration of radon. Pooled water will release radon. Radon levels in the mine air will rise when ventilation is disrupted.

Detection methods: Air samplers are used to measure radon progeny in the air. Dosimeters can be used to monitor an individual's exposure.

Treatment of affected persons: Individuals should continue to have annual medical examinations by their physician.

Phosgene ($COCl_2$)

Health effects: Phosgene is very irritating to the entire respiratory tract. A single shallow breath of a moderately high concentration causes a rasping, burning sensation in the nose, pharynx and larynx. The most serious effect of phosgene is lung irritation causing increasing edema until as much as 30 percent to 50 percent of the total blood plasma has accumulated in the lungs, causing "dry land drowning." High concentrations of phosgene are immediately corrosive to lung tissue and result in sudden death by suffocation.

Health effects of exposure to phosgene include:

- 1 ppm: maximum amount for prolonged exposure
- 1.25-2.5 ppm: dangerous to life, for prolonged exposure
- 5 ppm: cough or other subjective symptoms within one minute
- 10 ppm: irritation of eyes and respiratory tract in less than one minute
- 12.5 ppm: dangerous to life in 30-60 minutes
- 20 ppm: severe lung injury within one to two minutes
- 25 ppm: dangerous to life after as little as 30 minutes
- 90 ppm: rapidly fatal (30 minutes or less)

Splashes of phosgene in the eye will produce severe irritation, and phosgene on the skin can cause severe burns.

Contamination limits: The threshold limit value established by the ACGIH designed to prevent the occurrence of pulmonary edema is 0.1 ppm.

Properties: Phosgene is a colourless gas that decomposes in water. It has a suffocating musty hay odour.

Origin: Phosgene is used in the manufacture of a wide variety of organic chemicals. It is also used in metallurgy to separate ores by chlorination of the oxides and volatilization. Its chief importance, however, lies in its occurrence as one of the products of combustion whenever a volatile chlorine compound, such as chlorinated solvent or its vapour, comes in contact with a flame or very hot metal. This can produce a serious threat where ventilation is inadequate, the area is confined, or considerable quantities of chlorinated vapours are involved.

Detection methods: Direct reading colourimetric tubes are available for phosgene.

Treatment of affected persons: The person should be removed from the contaminated atmosphere and given oxygen. Any exposure must be treated as life threatening. The person should be kept at rest and delivered to medical aid as soon as possible.

Sulphur dioxide (SO_2)

Health effects: The major effects of Sulphur dioxide are on the upper respiratory tract. It also irritates the eyes. In high concentrations, edema of the lungs or glottis and respiratory paralysis can also occur.

Health effects from exposure to sulphur dioxide include:

- 6-12 ppm: nose and throat irritation occur
- 20 ppm: chronic respiratory symptoms occur
- 100 ppm: coughing, irritation to the eyes, nose and throat; maximum concentration
- 150 ppm: may be endured for several minutes
- 400-500 ppm: life threatening

Contamination limits: The 8-hour average limit for sulphur dioxide is 5.2 mg/m^3 or 2 ppm (*The Occupational Health and Safety Regulations, 1996*).

Properties: Sulphur dioxide is colourless with an irritating, pungent, strong suffocating odour. The threshold for smell or taste is 0.3 to 1 ppm.

Origin: Sulphur dioxide may be produced when blasting sulfide ores. It is the main gas released from conventional copper and zinc refineries that use oxide roasters and reverberatory furnaces.

Detection Methods: An electronic gas detector or direct reading colourimetric tube can be used to measure the concentration of sulphur dioxide.

Treatment of affected persons: Take the victim to fresh air. Give oxygen and artificial respiration if breathing has stopped. Seek medical help.

Gas	Chemical Symbol	Specific Gravity	Explosive Range (%)	Colour	Odour	Taste
Acetylene	C_2H_2	0.9	2.5 to 93	None	Garlic	None
Air	-	1	Non-flammable	None	None	None
Ammonia	NH_3	0.6	16 to 25	None	Pungent	None
Carbon Dioxide	CO_2	1.5	Non-flammable	None	None	Acidic
Carbon Monoxide	CO	1	12.5 to 74	None	None	None
Chlorine	Cl_2	2.5	Non-flammable	Greenish yellow	Bleach-like	None
Gasoline	-	-	1.4 to 7.6	None	Gassy	Yes
Hydrogen	H	0.07	4 to 75	None	None	None
Hydrogen Cyanide	HCN	0.69	5.6 to 40	None	Bitter almonds	None
Hydrogen Sulfide	H_2S	1.2	4.3 to 46	None	Rotten eggs	Sweetish
Methane	CH_4	0.6	5.3 to 15	None	None	None
Nitric Oxide	NO	1.04	Non-flammable	None	Sweet	None
Nitrogen	N	1	Non-flammable	None	None	None
Nitrogen Dioxide	NO_2	1.6	Non-flammable	Reddish brown	Pungent Acrid	Blasting fumes
Oxygen	O	1.1	Supports combustion	None	None	None
Phosgene	$COCl_2$	3.48	Non-flammable	None	Musty hay	None
Propane	C_3H_8	1.5	2.2 to 9.5	None	Gassy	None
Radon	Rn	7.5	Non-flammable	None	None	None
Sulphur Dioxide	SO_2	2.2	Non-flammable	None	Pungent	Acid (bitter)

Figure 1-5 Characteristics of Mine Gases

Gas	8-Hour Average Contamination Limit mg/m3	8-Hour Average Contamination Limit ppm	15-Minute Contamination Limit ppm	IDHL ppm	TLV-STEL ppm
Ammonia	17	24	35	300	35
Butane	1900	845			-
Carbon dioxide	9000	5000	30,000	40,000	30,000
Carbon monoxide	29	25	190	1200	-
Chlorine	1.5	0.5	1	10	1
Gasoline	890	300	500		500
Hydrogen chloride	Ceiling 7.5	Ceiling 5		50	Ceiling 5
Hydrogen cyanide	Ceiling 5	Ceiling 4.5		50	Ceiling 4.7 (skin)
Hydrogen sulfide	14	10	15	100	15
Nitrogen dioxide	5.6	2.0 Sask. Mines Reg's	5	20	5
Nitric oxide	31	25	38	100	-
Oxygen	260,000	195,000			-
Phosgene	0.4	0.1		2	-
Phosphine	0.42	0.3	1	50	1
Sulphur dioxide	5.2	2	5	100	5

Figure 1-6 Saskatchewan contamination limits

Chapter Two - Breathing Apparatus and Auxiliary Equipment

Respiratory Protection

The Occupational Health and Safety Regulations, 1996, Part VII, Personal Protective Equipment, Regulations 88, 89 and 90 cover respiratory protective devices and working in dangerous atmospheres.

Limitations

Chemicals that can penetrate the skin are not normally found underground, but the Mine Rescue Team must know what the dangers are at a specific site. Respiratory protective equipment will not protect people from gases that can enter the body by means other than the respiratory tract.

An oxygen supplying apparatus is the most important piece of equipment that mine rescue personnel will use. An inadequate face to facepiece seal needlessly exposes the wearer to toxic gases in the environment. One of the common causes of inadequate face seals is facial hair. Therefore, persons wearing full facepiece, self-contained respirators **must be clean-shaven**.

Respirators have limited space for eye glasses. The use of prescription lenses in frames fitted inside the facepiece is recommended for workers needing corrective lenses. The use of contact lenses inside a self-contained breathing apparatus (SCBA) facepiece is not recommended.

Respiratory Hazards

The three most common ways poisons enter the body are through the:

- digestive system (ingestion)
- skin (absorption)
- respiratory system (inhalation)

The respiratory system is the quickest and most direct way for poisons to enter the body because it is closely associated with the circulatory system and is constantly supplying oxygen to every cell in the body.

Respiratory hazards can be classified as follows:

- oxygen deficiency
- gas and vapour contaminants
- immediately dangerous to life and health (IDLH)
- not immediately dangerous to life and health
- particulate contaminants (aerosols, including dust, fog, fumes, mist, smoke and spray)
- a combination of gas, vapour and particulate contaminants

General respiratory protective device classifications

Respiratory protection devices fall into three classes:

- air-purifying
- air-supplied
- self-contained breathing apparatus

Non-self-contained or air purifying respirators remove contaminants from the air before they are inhaled. These devices do not supply oxygen to the user and cannot be used in oxygen deficient atmospheres. Air purifying respirators use cartridges or filters that remove particulates, vapours or gases from the inhaled air.

Self-contained Breathing Apparatus (SCBA): open-circuit SCBA provide breathing air through the use of compressed air cylinders or an attached airline. The exhaled air is exhausted to the outside atmosphere.

Closed-circuit SCBA (re-breathers): a closed system that removes the carbon dioxide from the circulatory system of the apparatus and provides fresh oxygen to the air before it is re-breathed. This respirator is totally independent of the outside atmosphere.

Breathing Techniques

Value of slow, deep breathing when wearing apparatus

To use respirators or other breathing devices properly, the art of deep breathing should be practiced until it becomes a habit. The value of slow, deep breathing at all times can be demonstrated by doing an exercise that causes panting or quick breathing. Draw in several deep, controlled breaths, slowly and evenly, inhaling as much air as possible. The normal rate of breathing can be resumed quickly and easily this way without panting.

When breathing devices are worn, heat and breathing resistance must be expected. The heat may vary from normal to an intolerable temperature, depending upon the type of apparatus and local conditions. The resistance can vary from slight to as much as three or four psi, and must be overcome.

If the wearer is breathing fast, he will be unable to overcome the resistance and get enough air before exhaling. When this happens, the wearer gets “air hunger.” This causes a feeling of suffocating, and an urge to remove the breathing device at all costs.

It is essential to breathe deeply and slowly when wearing any breathing device. This habit can only be acquired by continual practice.

Self-contained breathing apparatus (SCBA)

Physiological effects of breathing pure oxygen

The quantity of oxygen consumed by the body varies with the amount of energy expended (see Figure 2-1). A person at rest uses approximately one cubic metre of air per hour (m^3/hr).

During strenuous exercise, the consumption of air may increase to more than 8 m^3/hr, but the body uses no more oxygen than it requires.

Pure oxygen breathed by someone wearing a self-contained breathing apparatus causes no noticeable ill effects, even after several successive periods of use. The only exception to this rule is if the wearer is subjected to air pressures greater than the normal atmospheric pressure of 1.01 bar (14.7 psi) (e.g., caisson work) or for continuous exposure for 24 to 48 hours.

The human body uses the following approximate amounts of oxygen in litres per minute (lpm) based on various work loads	
Rest	0.2 to 0.5 lpm
Light work	0.75 to 1.0 lpm
Moderate work	1.0 to 1.5 lpm
Heavy work	1.5 to 2.0 lpm
Extremely heavy work	2.0 to 3.0 lpm

Figure 2-1: Human metabolic oxygen requirements

Elimination of dangerous amounts of carbon dioxide in apparatus

One of the most important functions of any closed-circuit, self-contained breathing apparatus is the elimination of carbon dioxide in the apparatus.

In a self-contained, open-circuit, pressure-demand type of apparatus using compressed breathing air, the exhaled air passes through a valve to the outside atmosphere.

A self-contained, closed-circuit breathing apparatus removes carbon dioxide using:

- a disposable alkaline cartridge, or
- a refillable canister that uses a soda lime compound

The CO_2 absorption process produces heat that raises the temperature of the canister and the air flowing through it.

A self-contained, closed-circuit oxygen-producing (chemical) apparatus removes carbon dioxide by a chemical reaction with potassium dioxide (KO_2) that consumes the carbon dioxide and produces oxygen.

Closed-circuit self-contained breathing apparatus

The two primary SCBAs used in Saskatchewan mine rescue are the Dräger BG-174 and the Biomarine BIO-Pak 240. Both units are service rated for 4 hours (240 minutes) of operation. The Bio-Pak 240 is a positive pressure, closed-circuit respirator. A new SCBA on the market is the Dräger BG-4. This is also a 4-hour breathing apparatus and is a positive pressure unit.

Dräger BG-174; General description

Follow the manufacturer's instructions for use of the Dräger BG-174.

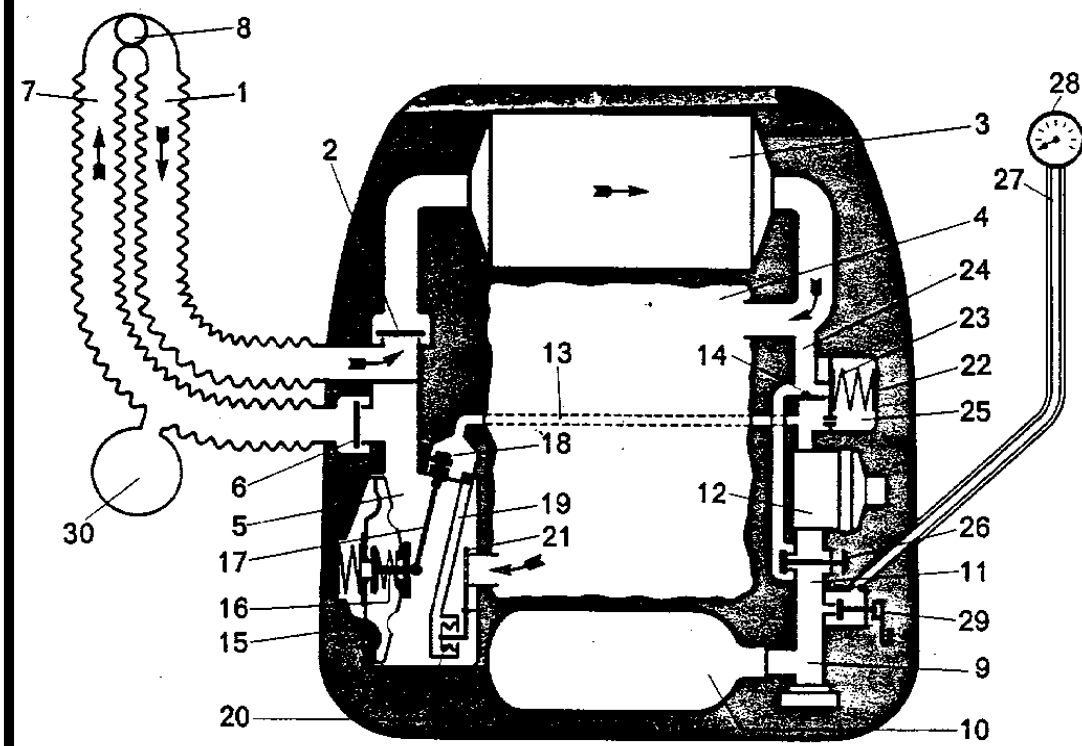
The Dräger self-contained, closed-circuit breathing apparatus enables the mine rescue worker to enter unbreathable and toxic atmospheres. The apparatus permits the wearer to breathe independently of the atmosphere and enables him to effect rescues and recoveries under extremely arduous conditions.

Since this respirator operates with negative pressures in the facepiece compared to the atmosphere, the seal of the facepiece to the wearer's face is critical.

The apparatus is light in weight (12.3 kg or 28 lbs.), but its construction is rugged and highly resistant to mechanical shock. Exhaled air is freed of its carbon dioxide in a regenerative canister and passed into a breathing bag. The air, purified in this way, is withdrawn from the breathing bag during inhalation.

The oxygen consumed during respiration is replaced from a cylinder of compressed oxygen through a constant flow-metering opening at the rate of 1.5 litres per minute (lpm). If this amount of oxygen is not sufficient due to strenuous exertion, additional oxygen is provided by an automatic demand valve controlled by the user's lungs.

When the apparatus is first turned on, the circuit is automatically flushed with approximately six litres of oxygen. Other than occasionally checking the oxygen supply by observing the pressure gauge, the apparatus requires no further attention during use.



1 Exhalation hose
2 Exhalation valve
3 Regenerating cartridge
4 Breathing bag
5 Valve box
6 Inhalation valve
7 Inhalation hose
8 Apparatus connector
9 Cylinder valve
10 Oxygen cylinder
11 Oxygen distributor
12 Pressure reducer
13 Oxygen line
14 Dosage nozzle
15 Control diaphragm
16 Cotter pin with sealing plate
17 Lung demand regulator lever
18 Lung demand valve
19 Control line
20 Warning signal control bellows
21 Warning signal flap
22 Preflushing device
23 Preflushing valve
24 Preflushing line
25 Control chamber
26 Manual booster valve
27 High-pressure line
28 Pressure gauge
29 Pressure gauge shut-off valve
30 Saliva trap

Figure 2-2: Dräger BG-174 oxygen breathing apparatus

Biomarine BIO-Pak 240; General description

Follow the manufacturer's instructions for using the Bio-Pak 240.

The Bio-Pak 240 is a closed-circuit SCBA for use in contaminated or oxygen deficient atmospheres. The Bio-Pak 240 can be used in atmospheres with no oxygen and provides positive pressure in the facepiece. This unit can also be used in atmospheres that contain toxic gases or vapours.

The Bio-Pak 240 is a closed-circuit breathing apparatus. It recycles the user's exhaled breath. The unit is rated at four hours of duration.

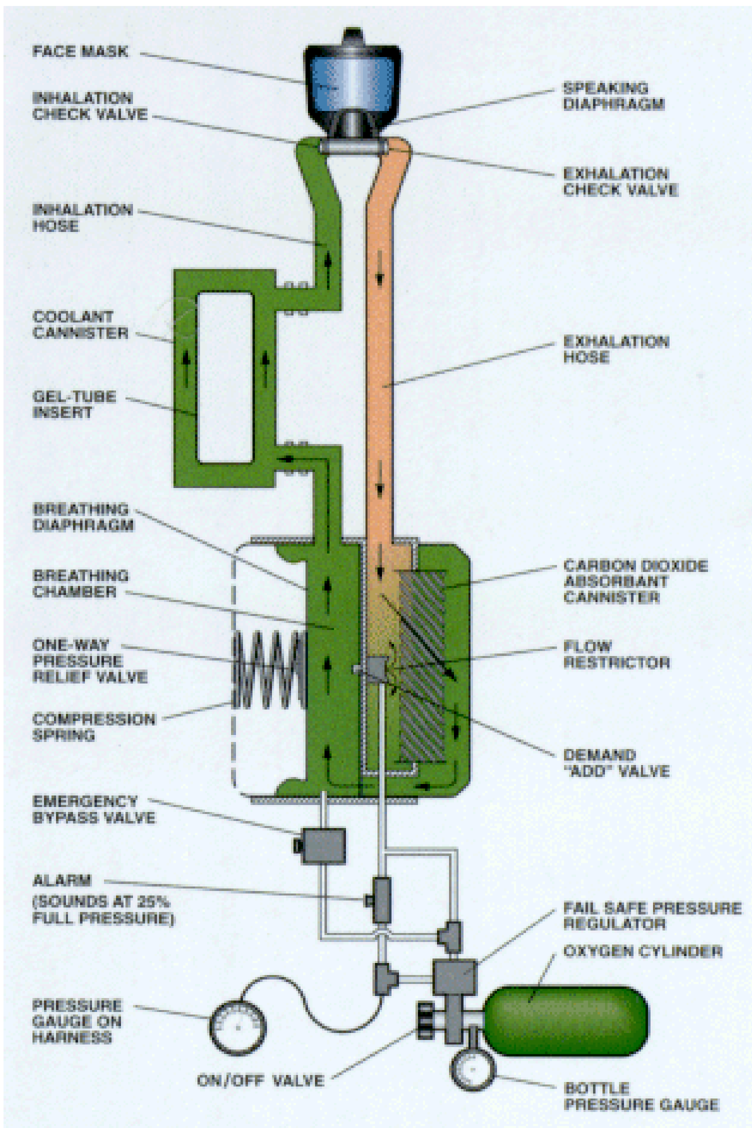


Figure 2-3: Biomarine BIO-Pak 240

Donning bench and bench tests of breathing apparatus

Immediately before using the Dräger BG-174 breathing apparatus, the wearer must do a bench test. If the maintenance tag is in place on the Bio-Pak 240 and the monthly check has been completed, a donning bench test may be conducted. This assures the wearer that the apparatus is safe. If the wearer is not satisfied that the apparatus is working properly, he should report to the person in charge for repair or replacement of the apparatus.

Station checks of breathing apparatus

Self-contained breathing apparatuses must be thoroughly station tested every month, and after every use and rough transport, to ensure their readiness for use in an emergency.

The main tests performed to ensure the safe operation of a breathing apparatus are for air lightness and function of the working parts.

Any malfunctions or deficiencies found on any apparatus must be repaired immediately. The unit must be taken out of service until repaired. The results of the station checks must be recorded in a logbook.

Other regular inspections of the apparatus should be done according to the manufacturer’s recommendations.

Maintenance and storage of apparatus

Regular maintenance and storage of breathing apparatus should be done according to the manufacturer’s recommendations.

Important: Oil or other petroleum based lubricants must not be used on any oxygen apparatus, particularly on the high-pressure connections or the cylinder valve. Breaking this rule may cause an explosion.

Care must be taken to ensure that when the apparatus is stored, it is protected against dust, sunlight, heat, extreme cold, excessive moisture, damaging chemicals and mechanical damage. Do not store rubber, neoprene or silicone parts under fluorescent lights.

Face masks should be stored in a normal position so that the sealing edge is not distorted.

Reference dates of canisters and soda lime should be checked and recorded to make sure their shelf life is not exceeded.

Refillable canisters must be emptied after each use.

Auxiliary Equipment

Universal Tester: Drager Model Rz 25

The Universal Tester (Figure 2-4) is a multipurpose unit for use in testing primary SCBAs. The tester can also be used for other self-contained respirators on site, including specialized, single use respirators (self-contained self-rescuers) reserved for use by underground personnel in an emergency exit from a mine or retreat to a refuge station. Follow the manufacturer's instructions.

Figure 2-4: Universal Tester: Drager Model Rz 25

Negative Leak Tester: Dräger Model Rz 35/40, Croeseler

These are compact units that may be used to test the negative pressure of breathing apparatuses. It is a precision measuring instrument and should be handled and used with care. Careful handling will assure a proper test and a minimum of maintenance problems.

An aspirator bulb with rubber tubing attached is used to get the air out of the apparatus during the test.

Charging oxygen bottles

Cascade system: Wherever oxygen breathing equipment is used, the empty oxygen cylinders have to be recharged. The obvious method is to pass oxygen from one cylinder to the other through a pressure-tight tube or cascading. A system has been adopted that enables the small apparatus cylinders to be recharged by equalizing their pressure with that of large cylinders. This “cascade” system incorporates a specially designed manifold that is connected to a series of three or more large cylinders. Cylinders should be secured to prevent their falling. A cascade system may also be used with a high pressure oxygen booster pump.

Recharging instructions: Arrange the three cylinders so that the one with the lowest pressure is to the right as you are facing them, and the one with the highest pressure is on the left. Connect cascade fittings to the cylinder outlets. To recharge the small cylinder, the following procedure should be used:

1. Connect the small cylinder to the adapter and open the small cylinder valve; be sure the bleeder valve is closed before the small cylinder valve is opened. Open the adapter valve.
2. Slowly open the valve on the right-hand cylinder, and close it again as soon as all sound of the flow has stopped.
3. Repeat with the valve on the centre cylinder.
4. If necessary, repeat with the valve on the left-hand cylinder; close the valve on the small cylinder then the adapter valve.
5. Open the bleeder valve.
6. Disconnect small cylinder.
7. Mark with chalk or masking tape the pressure of the cylinder and the time it was filled.

Important: Open all valves slowly to prevent excessive heat generation.

High pressure oxygen booster pumps

With the cascade system, it is difficult to attain the desired charging pressure of more than 150 atmospheres. This can best be achieved by compressing oxygen and transferring it from one cylinder to another at the desired higher pressure with multi-valve piston-type pumps. These pumps are available in either hand-operated or power-driven models.

Note: Follow the complete operating and maintenance instructions in the manuals supplied with the booster pumps.

Important: No oil or grease of any kind should be used in any type of high-pressure oxygen pump. A chemical reaction between the oil or grease and any oxygen is very likely to result in a violent explosion.

Use lubricant according to the manufacturer's instructions. The lubricant that can safely be used in these pumps is a mixture of one part glycerin and four parts water.

Dräger high pressure oxygen pump

This unit is a two-cylinder pump capable of boosting the pressure in the BG-174 or OXY SR cylinders being charged to either 2000 psi or 3000 psi. Always following manufacturer instructions. This is a complete stationary unit with all component parts enclosed in a sheet steel housing. The multiple outlets in the pump enable the filling of several cylinders at one time. The pressure in the supply cylinders can be used down to approximately 300 psi. It cannot be used for compressing gases from atmospheric pressure to any higher pressure.

Dräger oxygen booster pump: Model UH 2-T

This is a manually operated, single stage, double acting plunger pump with a maximum charging pressure of 220 kPa/cm^3 (3234 psi). The pump is housed in a compact wooden carrying case to allow for transportation to a fresh air base. It can also be wall-mounted. A number of UH 2-T pumps have been converted to automatic pumping by installing electric motors and bell cranks. The pump eliminates any water in the oxygen supply through a water trap and incorporates a high pressure oxygen dryer with an interchangeable cartridge. This cartridge must be replaced annually or after 200 bottles are refilled.

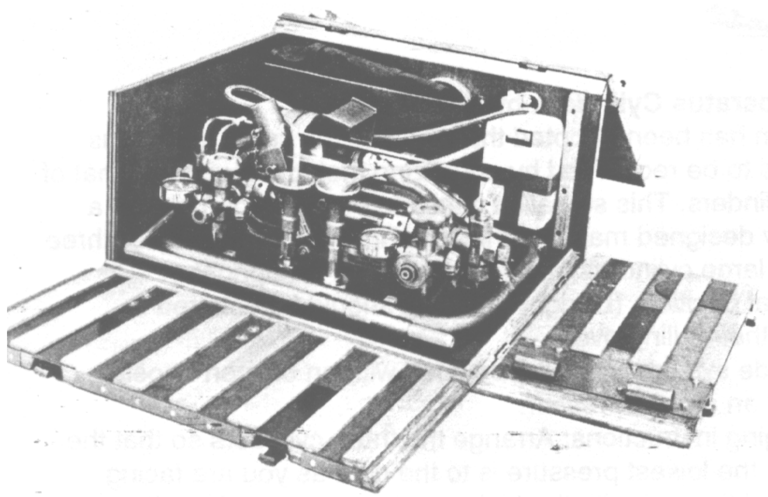
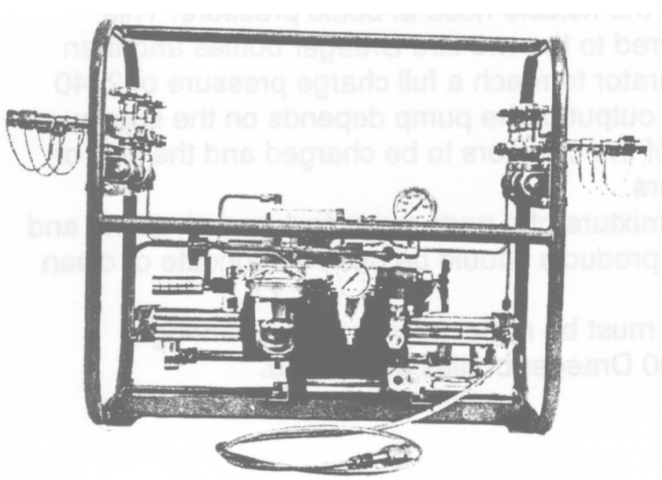


Figure 2-5: Manual oxygen booster pump UH 2-T (PN 200)

Haskel high pressure oxygen booster pump

The Haskel booster pump is designed to direct fill one to six cylinders at a time. It consists of two stages of compression which permits pumping from the supply cylinders as low as 150 psi, while boosting output pressures to as high as 4450 psi. This eliminates the need to cascade or the use of more than one cylinder. The pump can be driven by air or electricity.

It is recommended that guarding be installed around the pump to protect workers in the event a pressure oxygen booster pump explodes.



Benefits:

- No electrical hazard
- No high pressure diaphragms (boost sections operate hydrocarbon free)
- Portable by one man
- Self-cooling without fans or water connections
- Eliminates “cascading”

Figure 2-6: Haskel high pressure oxygen booster pump

Gas Cylinders

Oxygen supply and oxygen cylinders

To identify their contents, compressed air cylinders are distinctively coloured and marked. Breathing air cylinders are painted various colours and have the words “pure breathing air” stenciled on them. Oxygen cylinders are usually green, white or silver and are marked “oxygen.”

The purity of the oxygen used in rescue apparatus is very important because impurities tend to accumulate in the circulatory system of the apparatus. **The CSA Standard Z94-4-93 section 6.2** specifies that compressed breathing oxygen shall meet the purity requirements of Canadian Military Standard D22-003-002/SF-000.

Chemically generated oxygen shall meet the purity requirements of US Department of Defence Military Specification MIL-E-93252(2).

MSHA (Mine Safety and Health Administration) specifies that oxygen for use in rescue apparatus shall contain at least 98 percent oxygen, no hydrogen, and not more than two percent nitrogen, with traces of argon. Oxygen made by liquefaction processes conforms to this standard and contains no impurities other than nitrogen, with traces of the rare, inert gases.

The use of medical grade oxygen is recommended due to its lower moisture content. In addition, compliance with the CSA Standard requires that compressed oxygen not be used in supplied air respirators or in open-circuit, self-contained breathing apparatuses that have previously used compressed air. As well, oxygen must never be used with air line respirators.

All cylinders used to transport oxygen and other non-liquefied gases whose pressure exceeds 29 kPa at 21^{o}C must comply with the strength requirements of the Ministry of Transport Canada. All such cylinders exceeding 30 cm in length must also have valves equipped with an approved safety device (bursting disc).

All cylinders that have an outside diameter of five centimetres or more must be retested by hydrostatic pressure at least once every five years. The date of retesting must be marked on the cylinder.

Deterioration of air or oxygen cylinders

Air and oxygen contain small amounts of moisture that are generally transferred from large cylinders to small cylinders during refilling. The moisture hastens oxidation of the metal of the cylinder, causing scale, sediment, rust and pitting, and eventually weakens the walls of the cylinder. These changes occur with no visible sign on the outside of the cylinder. Hydrostatic pressure is the only means by which the condition of the cylinder can be determined. When the cylinder is subjected to a hydrostatic pressure, the “elastic expansion” (total expansion minus permanent expansion) is determined.

Oxygen cylinders which are usually charged to 204 atmosphere (20675 kPa) (3000 psi) are tested to 30345 kPa (4400 psi).

Safe practices with oxygen cylinders

All tanks should be held securely in the apparatus. The constant motion of an emergency vehicle during calls will create a dangerous situation if oxygen tanks are not held in place by straps, tank wells, blocks, or some other fixture.

Summary of Do’s and Don’ts when working with oxygen cylinders

Do:

- wear appropriate PPE
- “crack” cylinder valve prior to attaching regulator by opening slightly and then closing again; this procedure blows dust and debris out of the cylinder valve opening
- open cylinder valves slowly
- keep regulator inlet filter clean and intact to prevent lint from collecting on the valve seat; replace as required
- replace worn or frayed valve seat inserts; they are much more likely to catch fire
- have repairs done by qualified personnel
- keep soap away from high pressure connections because it is flammable
- pressure test (hydrostatic test) all steel oxygen tanks over a certain size at least once every five years; all tested tanks have the date stamped on them
- test all composite wrapped tanks once every three years

Do Not:

- disconnect the cylinder before depressurizing the system
- use oil or grease on oxygen equipment; an explosion may occur
- smoke or use open flame near oxygen (oxygen vigorously supports combustion)
- use regulators and equipment that have been used with other gases; flammable residues may remain in these regulators
- use cylinders for hat trees or clothes racks; if there is a leaky connection, hanging clothes may easily ignite

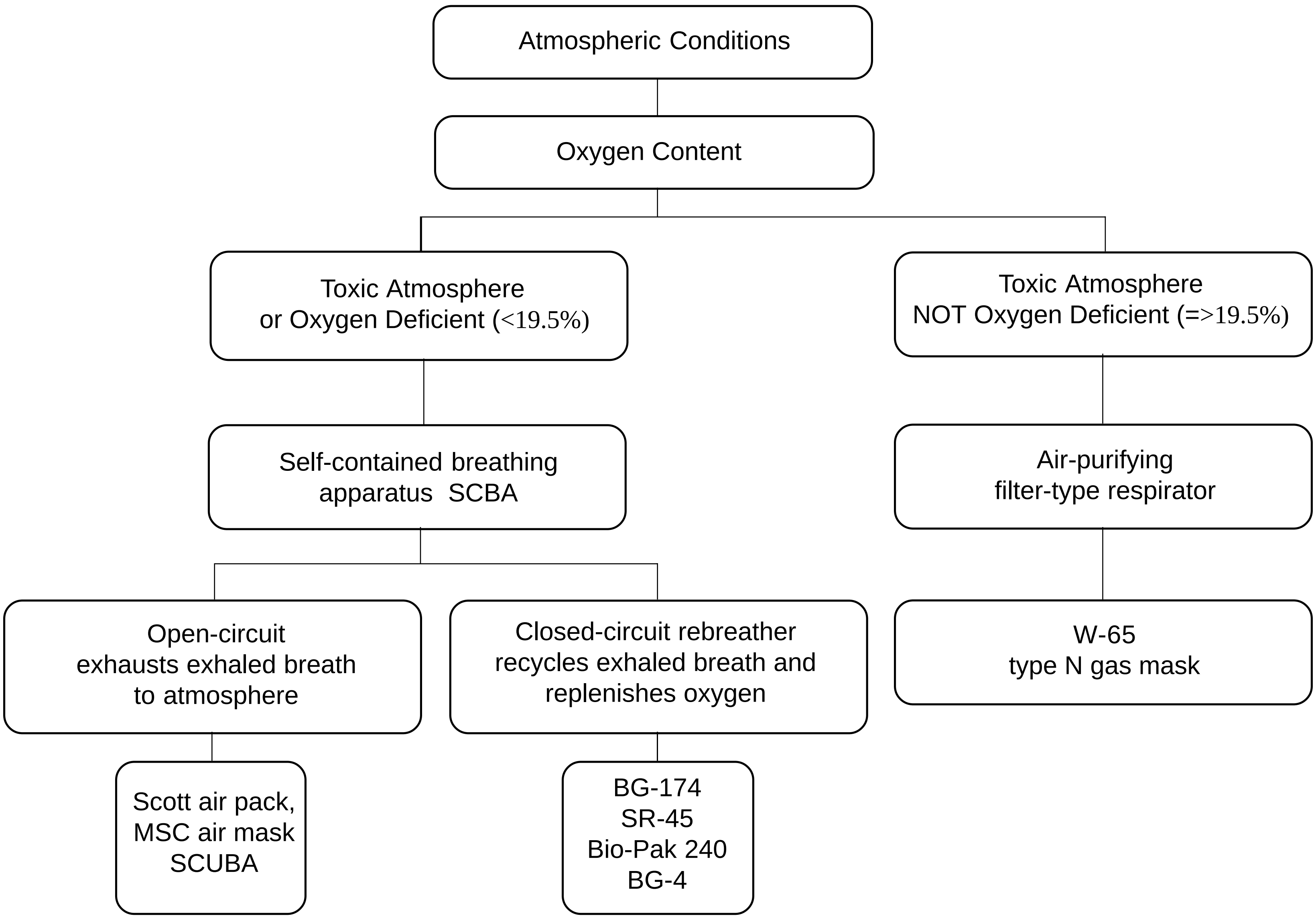


Figure 2-7: Respirators

Chapter Three - Mine Ventilation

General Information

Mine ventilation systems are unique in that the ventilation is needed at continually changing work faces that are gradually moving away from the source of fresh air. This requires continuous changes to mining ventilation systems.

Purpose and Principles of Ventilation

A typical ventilation system is designed to supply, by mechanical means, enough fresh air to the mining faces, shops, warehouses and all other work areas in the mine.

The ventilation system must reduce or control the working temperature, the level of dust, and diesel emissions in the air to provide adequate working conditions. The ventilation system must also maintain the temperature in the shafts above freezing.

The condition and performance of the ventilation system must be constantly assessed and recorded. Regulations require an adequate quantity of good air to be supplied in a mine.

Workplace air must contain at least 19.5 percent oxygen (*The Saskatchewan Mines Regulations*).

The ventilation system must exhaust contaminants and harmful gases and/or dilute them to acceptable limits. Large quantities of air are required to dilute carbon monoxide and other gases given off by diesel engines underground. Concentrations of diesel gases must not exceed 25 ppm for carbon monoxide, 5000 ppm for carbon dioxide, and 2 ppm for nitrogen dioxide.

Any diesel engine used underground must have at least 3.8 m^3 of ventilation air per minute for each rated kilowatt (100 f^3/m per horsepower).

The ventilation system must supply enough air flow to cool workers and prevent heat stress. Heat from engines, motors, equipment, lighting, etc. must be carried away from the work areas.

The rate of ventilation, conveniently measured in cubic metres of air per second (m^3/sec), should meet three requirements:

- sufficient air movement throughout the mine to prevent the formation of pockets of stale, stagnant air
- sufficient fresh air to limit the level of air pollution from all sources in the mine, and
- lower air temperature and humidity to limit heat stress

Ventilation Conditions

Mine ventilation can be further examined in two forms.

Mechanical ventilation

In mechanical ventilation, air is supplied and controlled through fans and ducting.

Generally, most underground mines in Saskatchewan have similar ventilation systems. These systems use:

- ➢ low pressure, high volume supply fans located on the surface
- ➢ mine air heaters for winter conditions
- ➢ distribution fans located underground to direct and distribute air to all work areas, and
- ➢ low pressure, high volume fans on the surface to exhaust mine air and contamination from the mine

Natural ventilation

In this form, air flow assumes a natural circuit, which may be determined through air temperatures, air pressures, and elevation.

Effects of fires on ventilation

Fires may interrupt the use of mechanical ventilation. Air flow through mechanical or natural ventilation may be affected by a fire. Ventilation reversals and unpredictable ventilation effects may occur.

The ventilation system in a mine is critical in dealing with a fire or gas inflow emergency. In underground mining, a fire or inflow of toxic gases can become a problem by quickly spreading deadly gases through the whole mine. Air flow speeds of up to 22 kph or 13 mph are not uncommon in Saskatchewan mines.

Anyone downstream of a fire could have very little time to react and secure safe refuge from the fire or smoke source. With the large size of some mines, it could still take a long time for products of combustion to flow throughout the ventilation circuit. For example, a gas might need from two to four hours to travel from the downcast shaft to the upcast shaft in a potash mine.

Mine fires produce gases and heat that the ventilation system transports through the mine. The gases may be poisonous or explosive, and the heat may cause ventilation disturbances with unstable airways or airflow reversals.

Ventilation changes in a mine fire situation should not be made until all people underground are accounted for, or the effects are known. Despite safety precautions taken to prevent mine fires, their possibility will always exist.

The greatest hazards of mine fires are the noxious gases produced by combustion. These noxious fumes are carried by the ventilation air currents throughout the mine. The ventilation paths, along which hazardous combustion gases are carried, must be known in order to combat this hazard and design safe escape routes and firefighting activities.

Prediction of the air flow distribution in a mine after a fire is as complicated as the fire itself. Thermodynamic forces can cause considerable alteration in a mine's ventilation system. The size of the ventilation disturbances depends on a variety of factors in the mine. Unexpected air flow reversals have caused mine disasters.

Fundamentals of air flow

Air flow is determined by temperature and pressure differences. Air flows from high pressure areas to low pressure areas and, in a mine, is caused by pressure differences between intake and exhaust openings.

Air flow follows a square-law relationship between volumes and pressures. In order to increase the volume of air flow two times, four times the pressure must be exerted.

Assessing air flow

Assessing the direction and volume of air is an important function of the Mine Rescue Team because knowing the velocity and the cross-sectional allows the quantity of air flow to be calculated.

Knowing the direction and velocity of air flow allows one to check whether the ventilation system is functioning as it should be, including:

- whether the fans are on
- the condition of the seals, line brattice, or ventilation tubing
- the condition or the position of doors and regulators
- the condition of the air lines or the position of the air line valves, and
- short circuits or recirculation of air currents

Three instruments commonly used to measure air movement are:

- velometer
- anemometer
- smoke tube

Velometers and anemometers are used to measure medium and high velocity air movement (above 600 feet per minute, or 2.5 metres per second).

Smoke tubes are more suitable for measuring very slow-moving air (below 600 feet per minute, or 2.5 metres per second) and determining the direction of the flow.

Since testing the mine atmosphere is time consuming, it is a good idea to involve as many members of the team as practical to perform this task.

Important: A record should be kept of all the tests, times and the locations where the tests were taken. All team members must be kept informed of the conditions of the atmosphere in which they are working.

Pressure losses

Resistance to air flow can be caused by rough ground, restricted openings, and travel over long distances.

Shock losses can also increase the resistance to air flow. Shock losses are caused by abrupt changes in the velocity of air movement. They are the result of changes in air direction or of airway area, obstructions, and regulators. Anything that causes turbulence can decrease air flow.

Splitting air currents

Air will tend to follow the path of least resistance.

Dividing the mine ventilation system into multiple splits provides separate ventilating districts in the mine which permits easier air control.

Natural splits are those where the airflow divides naturally. Each split handles a volume of air dependent on the pressure drop and resistance factor for that circuit.

Regulated splits are those where it is necessary to control the volumes in certain low-resistance splits to ensure adequate air to flow into the splits of higher resistance.

A regulator is an artificial resistance installed in a low-resistance split. Regulators may be small openings in stoppings controlled by slide doors or may be doors latched partly open.

Leakage losses

Air leaking from the fresh air side to the exhaust side is considered a leakage loss. Leakage losses in any mine ventilation system will be influenced by the number and condition of brattices, bulkheads, and controls along its length.

Leakage losses seriously reduce the efficiency of a mine ventilation system. A leakage path is simply a parallel return path to the fan. The amount of leakage is determined by the pressure difference between intake and return and the condition of stoppings, doors, air splits and brattice.

In potash mines, each brattice separating the supply side from the exhaust side will leak an amount determined by the quality of the installation. This may be a few cubic metres per second or more and this leakage can greatly affect ventilation control in both normal mining operations and in mine fire situations.

Important: All ventilation equipment must be maintained and kept in good order for an efficient ventilation system.

Auxiliary ventilation

The practice of redirecting the main ventilation system with smaller local fans is termed *auxiliary ventilation*. Auxiliary ventilation is needed because workplaces in mines are continually moving away from the main ventilation air stream.

All auxiliary ventilation may be grouped into three categories:

1. Supplying air to both development and production dead-end workplaces (quantity control)
2. Supplying uncontaminated air to workplaces with contaminated air (quality control), or
3. Supplying conditioned air to faces of workplaces in uncomfortably hot or cold environments (temperature-humidity control)

Ventilation of dead-end workplaces is the most frequent and important application of auxiliary ventilation. It is employed for both development and exploration in potash, coal and metal mining. Drifts, raises, shafts, and winzes require auxiliary ventilation in metal mines, as well as stopes with only one entrance. Rooms, as well as entries, in mines require auxiliary ventilation when they proceed beyond the last connecting cross-cut.

Situations requiring auxiliary ventilation for quality-control purposes may arise in uranium mines because they produce radon gas. Radon gas is maintained within allowable limits by a combination of extraction and dilution ventilation. In uranium mines, it is generally necessary to vent contaminated air directly to the surface. Air contaminated by radon gas cannot be allowed to flow from a contaminated workplace to an uncontaminated workplace.

Methods of auxiliary ventilation

Supplying air to dead-end workplaces is the common denominator in auxiliary ventilation systems. This is normally done by moving fresh air to a workplace using ducts. Where there are multiple openings into a workplace, fresh air can be directed to the working face through one opening and returned through an adjoining opening. Connecting cross-cuts allow the air to flow between openings.

A major inconvenience with any method of auxiliary ventilation during development is the necessity of frequent extension. The auxiliary air stream must be delivered as close as possible to the face so that it can sweep away the impurities generated there.

The two main methods of ventilating the faces of dead-end workplaces are:

- ➢ line-brattice with air entering on one side of the brattice and returning in the other side, and
- ➢ fan and ventilation pipe or tubing.

The first is used in potash mines, while the other is employed principally in hardrock mines.

Line-brattice

Putting up a plastic curtain lengthwise in an entry or a room effectively divides that opening in two. If the brattice is erected from the last cross-cut to within a few feet of the working face, ventilating air can be directed to the face along one side of the brattice and returned along the other side. A line-brattice is usually constructed of fire-resistant plastic hung from posts, cross-pieces, spads or hangers in the roof. Plastic sheeting, a nonporous material, is now being used in place of brattice cloth. In line-brattice operation, air velocity is lost because of leakage to or from the exhaust side. These leakages are a major concern.

As well as airflow limitations, line-brattices can also slow the passage of workers and machines through a work area. Even in a wide underground passage, the brattice is installed off centre to allow room for the passage of mobile equipment.

Fan and ventilation pipe

The use of fans attached to vent pipes or tubing is the most desirable method of auxiliary ventilation for dead-end workings.

Fan locations

Fans are used in mining for fresh air supply, removing exhaust air or both. Fan locations in a mine are generally determined by the style of mining. Large supply fans are usually on the surface while distribution fans are normally located throughout the major work areas. Smaller fans provide airflow in individual work areas.

Booster fans

Booster fans can be located in long airways to boost the airflow volume. Booster fans can be free standing and used to siphon or jet air along a travelway without using bulkheads. The high outlet velocity of the booster creates excess momentum and exerts a forward force on the normal airflow. In Saskatchewan, booster fans are mainly used in potash mines.

Fan types

Axial flow fans

- are generally high volume, low pressure fans
- can be either directly driven by the motor shaft, with the motor inside the tube body, or remotely driven through the use of belts with the motor outside the tube body
- are generally adjustable for volume by setting the pitch of the adjustable blades on the rotor and, in some cases, motor speed can be tailored to adjust volume and pressure

Centrifugal fans

- are generally high pressure, low volume fans
- consist of a multi-bladed, “squirrel cage” wheel in which the leading edge of the fan blades curve toward the direction of rotation
- have low space requirements, low tip speeds, and are relatively quiet

Fan installation

Proper field installation will improve a fan’s air delivery. If practical, set the discharge and rotation of the fan so that the discharge is in the direction desired. Fans should be located away from sidewalls for easy inspection and service. Eliminate elbows and other discharge obstructions, if at all possible. Ducts should be of sufficient diameter and leak free. A poor duct system can detract from the performance of any fan.

Vent tubing

Tubing of various sizes and materials is used extensively in some mines.

The advantage of tubing is the ability to direct airflows to specific or selected areas. A common application of tubing is to attach it directly to a fan’s discharge, and route the air to the desired location. Tubing made with fire resistant material will help reduce the risk of fire.

Barricades and seals

Barricades and seals are used as a means of directing or diverting airflow to a desired area at a mining face. In potash mines, brattice is commonly used as a means of separating fresh air from return air (back fill and muck stops are also used). In hardrock mines, posting and frame work is used to support brattice seals. Barricades and seals can also be made from wood, styrofoam or belting.

Brattice can be ordered in various dimensions. Attaching a brattice to the sides and back of a mine is done by using spads, air powered nailers, or powder-actuated tools.

Airflow calculations

At most mines, airflow is calculated in cubic feet per minute (cfm or ft^3/min; cubic metres per minute (m^3 /min); or cubic metres per second (m^3/sec).

To calculate airflow:

1. Measure the height and width of the drift
2. Multiply these two numbers to obtain the drift's area (A=h x w)
3. Measure the speed the air is moving and multiply it by the drift's area

The equation is: area x air speed = volume per unit time

As an example: A drift three metres high and 10 metres wide with an air speed of 20 m/min has an airflow of:

$(3 \text{ m} \times 10 \text{ m}) \times 20 \text{ m/min} = 600 \text{ m}^3\text{/min}$

Use of measuring instruments

Smoke tube kit

A smoke tube kit consists of a handheld rubber aspirator bulb, two rubber plugs, and smoke producing tubes.

To measure airflow over a certain distance (eg., 3 m):

1. Insert a smoke-producing tube into the exhaust fitting of the aspirator bulb.
2. Squeeze the plastic tube to break glass ampoules inside tube. When these ampoules are broken, two different chemicals in the tube form an aerosol smoke as air is passed through the tube.
3. Squeeze the aspirator bulb to emit smoke and observe the direction and time it takes the smoke to travel the predetermined distance.
4. When finished, remove the aspirator bulb and install rubber plugs on the ends of the tube.

Velocity (speed) of air = distance travelled/time.

Hence if it takes 20 seconds for the smoke to travel 3 m, we obtain:

Velocity = 3 m/20 sec = 0.15 m/sec or 9 m/min

Velometer/Anemometer

A velometer or anemometer measures the velocity of air. A velometer will be of the vane or thermal type. Various manufacturers have devices that operate on one of these basic principles.

Vane anemometers are relatively simple. The movement of air spins the fan blades. The rotational motion is calibrated to the air velocity, and associated electronics compute the air velocity. The volumetric rate may be computed when the cross-sectional area of the drift is known.

Thermal anemometers use either a heated thermocouple or a hot-wire and associated electronics to determine the velocity and volumetric rates. Most errors are made by operators not familiar with their operation or misinterpretation of volume rates.

Caution: Both types of instruments are relatively accurate. However, very low air velocities cannot be determined with any degree of confidence. Both types of anemometers are sensitive to rough treatment and are easily damaged.

Velocity and Volumetric Rates: If the volumetric flow rate is required, the cross-sectional area of the passageway must also be known. The cross-sectional area is multiplied by the velocity determined by the instrument. If the velocity is measured in feet/minute, the cross-sectional area is determined in square feet, and the volumetric flow rate is in cubic feet per minute (cfm). If the instrument reads velocity in metres per second, the cross-sectional area of the drift is calculated in square metres and multiplied by cubic metres/second (m^3/sec). The average velocity is determined by taking several readings across the drift.

An anemometer is used for measuring velocities from 40 to 610 metres per minute. The individual uses the anemometer to measure the airflow for at least one minute and up to two minutes. The average air speed during the measurement period would then be recorded.

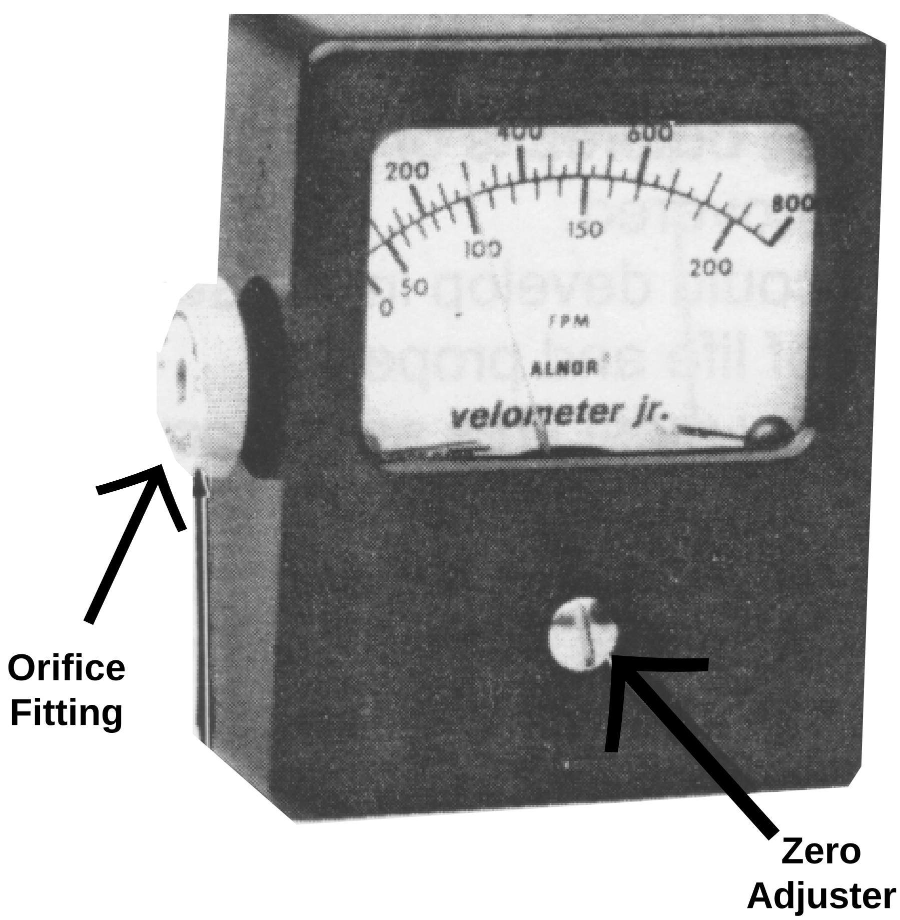


Figure 3-1: Velometer Jr

Chapter Four - Mine Fires

Mine fires

Occurrences

Mine fires are much more common than most people realize. Most fires in underground mines are small and quickly put out. Disasters caused by mine fires are less frequent. Any mine fire could, however, become a major disaster if not quickly brought under control.

Fire knowledge

Everyone who works underground in a mine should have a basic understanding of what fire is and how fires are best controlled. Knowledge of fire and the hazards of mine fires will encourage every underground worker to do his part to prevent fires. Workers must be trained to take the appropriate action if they discover a fire. The health and safety of workers cannot be left to chance.

Considerations upon locating fires

A worker discovering a fire must consider several possible actions very quickly. Any action taken, or not taken, will have a big effect on the fire and on the safety of everyone in the mine.

If you discover a fire in a mine, do you:

- Attempt to put it out? How do you attack the fire and long should you try?
- Sound an alarm? How?
- Attempt to get out of the mine? By what route?
- How do you notify workers in your area?
- Should you shut off burning electrical motors? How?
- Should you shut off fans? Close or open ventilation doors?

It is much better to make informed decisions on the basis of understanding the situation than to leave the well being of the workers and the mine to chance. Knowing what to do if a fire is discovered is important. Knowing how to prevent fires is even better.

Each mine must develop specific emergency procedures for its site. All employees must be well trained in those emergency procedures and understand how to apply them. The proper response to alarms should be practised at least once a year. All fire equipment must always be kept in proper working condition.

Summary of general underground emergency fire procedure

Whoever discovers a fire must take prompt action. The following is a generic emergency procedure for an underground mine fire.

> **Important:** Safety must be the top priority at all times.

1. If the fire is large and/or obviously cannot be quickly controlled:
    1. Sound the alarm by the established means.
    2. Warn the workers in your area.
    3. Begin evacuation.
2. If an incipient or small fire is found, then the following actions should be immediately taken to contain or extinguish it:
    - ➢ Use water and Class A extinguishers on Class A fires and the smothering approach for Class B and Class C fires (See Classes of fires P.73)
    - ➢ The current must always be turned off in an electrical fire.
    - ➢ Never attempt to put an electrical fire out with a stream of water.
    - ➢ Approach the fire from the upwind side and be very careful when using the smothering type of extinguisher in a confined space.
    - ➢ After a fire extinguisher is used, it must always be returned for recharging and its use reported.
3. If, after a few moments, definite progress is not made or it becomes clear the fire cannot be contained, follow #1.

> **Important:** Always remember that deadly gases are constantly being produced and workers must not be exposed to these gases or other hazards, such as explosions, weakening timber and deteriorating ground.

Every fire, no matter how small, must be reported at once as it may have released deadly gases into the mine air. Once put out, the fire area must be monitored until re-ignition is impossible.

What is fire?

Fire description

Fire or burning is a form of rapid oxidation of a substance that produces much heat and light energy. The release of heat energy in a fire may be so rapid as to cause an explosion (a violent expansion of the gases produced).

Oxidation is the chemical reaction combining oxygen with another element or compound. This reaction is almost invariably accompanied by a release of heat energy (exothermic reaction). The amount of heat energy released depends on the oxidizing (burning) compounds. Among the hottest heat energy releases are those occurring when oxygen combines with carbon, hydrogen, or a compound of both elements.

If the chemical combination of carbon and oxygen is complete, carbon dioxide, a colourless gas, is produced. If hydrogen and oxygen combine, water vapour or steam is produced. If the chemical combination includes both carbon and hydrogen and the reaction is complete, then carbon dioxide and water vapour are produced and the resulting smoke is white. If the combustion is incomplete, the products of combustion are carbon monoxide, carbon dioxide, water vapour, and particles of free carbon, and the resulting smoke is grey or black.

Sources of heat

Heat, as energy, is a measure of molecular motion in a material. Because molecules are constantly moving, all matter contains some heat regardless of how low the temperature. The speed of the molecules increases when any matter is heated. Anything that sets the molecules of a substance in motion is producing heat in that substance. There are five general sources of heat energy:

- chemical
- electrical
- mechanical
- solar, and
- nuclear

Chemical heat energy

Chemical heat energy is rapid oxidation or combustion. Substances capable of oxidizing rapidly are known as combustibles. The most common of these substances contain significant amounts of carbon and hydrogen.

Sufficient heat for combustion is normally achieved when combustible material absorbs heat from an adjacent substance acting as a source of ignition. Some combustibles are capable of self-generating temperatures which increase to a point where ignition can occur. This is known as spontaneous ignition. While most organic or carbon-based substances do oxidize and release heat, this process is usually slow enough to dissipate the heat before combustion takes place. Spontaneous ignition occurs when combustion heat is not sufficiently dissipated.

Electrical heat energy

Electrical energy can produce enough heat to start fires through arcing, dielectric heating, induction heating or through heat generated by resistance to the current flow. This last process may be intentional heating (e.g., filaments or heating elements) or accidental heating (e.g., electrical "shorts" or overloading).

Static electricity causes an arcing effect between a positively and a negatively charged body when frictional electricity becomes great enough so that a spark is discharged from body to body. This spark may not be hot enough or last long enough to ignite ordinary combustibles. However, it may ignite flammable liquid, vapour or gases.

Lightning has an action similar to that of static electricity. It occurs when one cloud arcs to the ground or to another cloud with an opposite charge. The magnitude of a lightning charge often generates sufficient heat to ignite combustible materials. The high amperage and high voltage potential, although of short duration, can do much structural damage even though fire may not occur.

Mechanical heat energy

One source of mechanical heat energy is friction or the resistance to motion of two bodies rubbing together. Another source is produced by the compression of gases. When a gas is compressed, its temperature increases. This can be demonstrated by pumping compressed air into a car tire or tube. As the pressure builds, the tube valve and pump fitting heat up. This can easily be felt by the hand.

In mines, a more common occurrence of mechanical heating can be found when the bearings seize or the brakes lock on a moving vehicle. Small fires from such sources are quite common.

Solar heat energy

The energy transmitted from the sun in the form of electromagnetic radiation is known as solar heat energy. Typically, solar energy is distributed fairly evenly over the face of the earth and, in itself, is not really capable of starting a fire. However, when solar energy is concentrated on a particular point, as through the use of a lens, it may ignite combustible materials.

Nuclear heat energy

The release of very large quantities of energy from the nucleus of an atom is known as nuclear heat energy. Nuclear heat energy can be released from the atom by two methods. Nuclear fission is the splitting of the nucleus of an atom. Nuclear fusion is the fusion of the nuclei of two atoms.

Heat transfer

A number of the laws of physics explain the transmission of heat. One, the Law of Heat Flow, says heat tends to flow from a hot substance to a cold substance. The colder of two bodies in contact will absorb heat until both objects are at the same temperature.

Heat can travel by one of three methods:

1. conduction
2. convection
3. radiation

The following sections describe how this transfer takes place.

Conduction: Heat may be conducted from one body to another by direct contact of the two bodies or through another heat-conducting medium. For example, one end of a metal rod will become heated when the other end is placed in a fire. The amount of heat that will be transferred and its rate of travel depend upon the conductivity of the material through which the heat is passing.

Not all materials have the same heat conductivity. Aluminum, copper and iron are good conductors, however, fibrous materials such as felt, cloth and paper are poor conductors. Liquids and gases are poor conductors of heat because of the movement of their molecules. Air is a relatively poor conductor.

Convection: Convection is the transfer of heat by the movement of air or liquid. For example, as air near a steam radiator becomes heated (by conduction), it expands, becomes lighter and moves upward. As the heated air moves upward (convection), cooler air takes its place at the lower levels.

Fire spread by convection moves mostly in an upward direction because heated air in an area will expand and rise. However, air currents can carry heat in any direction. Convection currents are usually the way heat is transferred from one area to another.

Although often mistakenly thought to be a separate form of heat transfer, direct flame contact is actually a form of convective heat transfer. When a substance is heated to the point where flammable vapours are given off, these vapours can be ignited, creating a flame.

Radiation: Heat energy can travel in waves or rays from one area to another as radiation. Like light, radiant heat travels in a straight line through air, glass, water and transparent plastics to heat combustible materials that are not in direct contact with the heat source. The quality and quantity of heat radiation depends on the temperature of the radiating body and the size of the radiating surface.

The ability to absorb radiated heat depends on the kind of surface the cooler, absorbing body has and the area of the hotter, radiating surface. If the receiving surface is black or dark coloured, it will absorb heat readily. If the surface is light in colour or shiny and polished, it will reflect much of the heat.

Radiated heat is one of the main ways fires spread. Immediate attention is required at points where radiated heat is severe. When fires produce flames of large size and volume, radiated heat can ignite nearby combustibles.

The use of water fog and wetting down can help block heat radiation from large fires. The fog reflects the heat rays and breaks up the straight line path of heat radiation.

The burning process

Elements of a fire

In reviewing the rapid oxidation process known as combustion, we note that three factors are necessary for a fire:

- a combustible material
- the presence of oxygen or an oxidizing agent, and
- enough heat to increase the temperature of the combustible material to its ignition temperature

Fire burns in two ways

- smoldering (surface), or
- flaming combustion

The smoldering (surface) mode of combustion is represented by the fire triangle (fuel, heat and oxygen). The flaming mode of combustion, such as the burning of logs in the fireplace, is represented by the fire tetrahedron (fuel, temperature, oxygen and the uninhibited chemical chain reaction).

The Fire Triangle

These three factors, fuel, oxygen, and heat, have been incorporated into the simple fire triangle model:

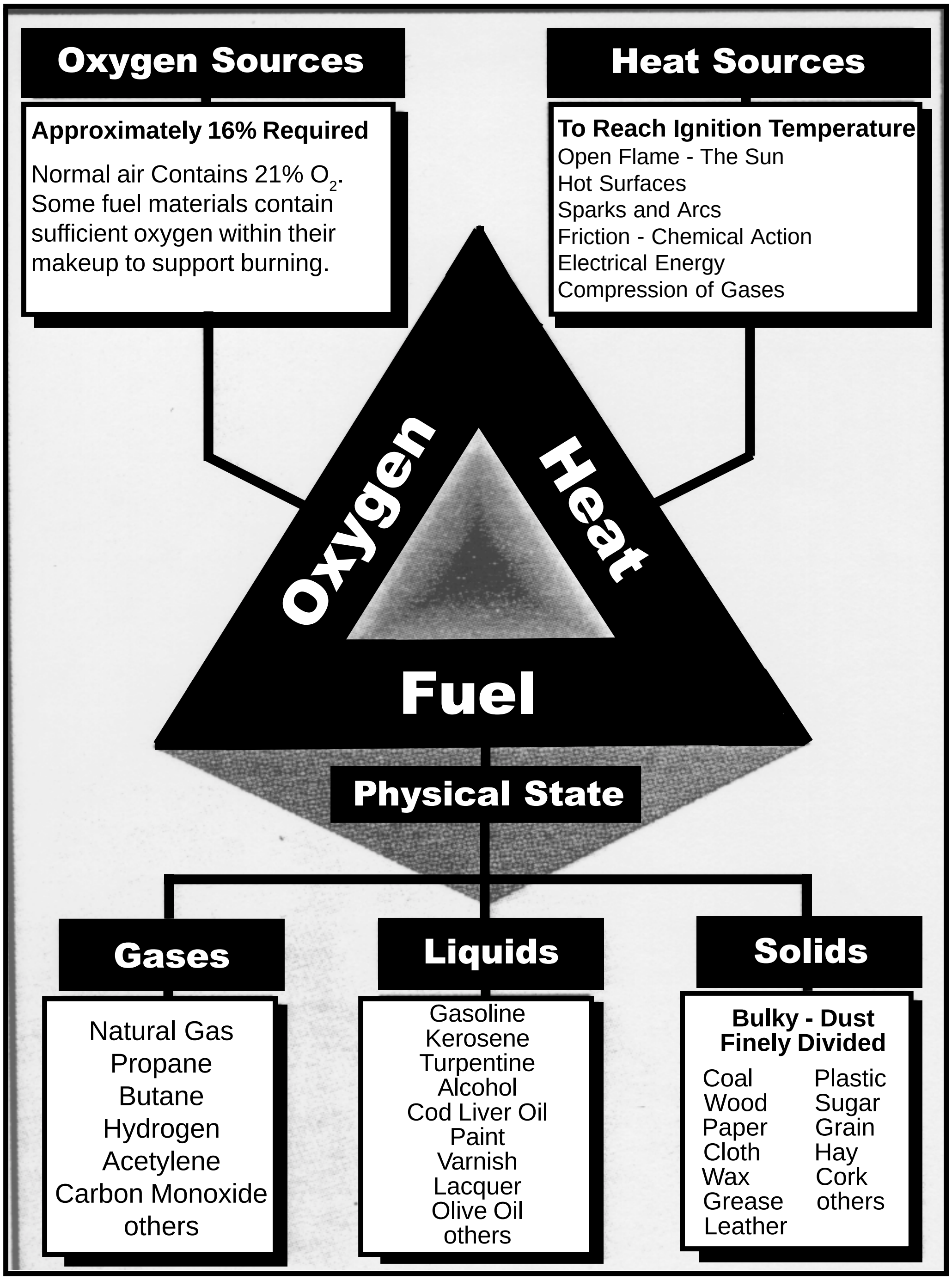


Figure 4-1: The fire triangle

The fire triangle is used to explain the components necessary for burning to occur.

Once combustion has begun, with ample fuel and oxygen, a fire can become self-supporting. As the fuel burns, it creates more heat. The increase in heat raises more fuel to its ignition temperature. As the need for more oxygen arises to support combustion, it is drawn into the fire zone. The oxygen, in turn, increases the heat and more fuel becomes involved. Combustion will continue as long as the factors from the three sides of the fire triangle are present.

While oxidation is speeding up to the combustion stage, another process is occurring that helps combustion. A chemical decomposition process occurs when a substance is exposed to heat. As chemical decomposition takes place, the substance emits vapours and gases that can form flammable mixtures with air at certain temperatures (pyrolysis).

This chain reaction and interaction continues until either all the fuel has been consumed, all the oxygen has been used up or the heat has been dissipated so that the temperature of the fuel drops below its ignition temperature. This, in essence, states the fundamental method of fire extinguishment – removal of one side of the triangle by:

Cooling: Cooling reduces the temperature of the fuel to below its ignition temperature.

One of the most common ways to put out fire is by cooling it with water. The process of extinguishing by cooling depends on cooling the fuel to a point where it does not produce sufficient vapour to burn. Solid and liquid fuels with high flash points can be extinguished by cooling. Low flash point liquids and flammable gases cannot be extinguished by cooling with water as vapour production cannot be reduced sufficiently. Lowering the temperature is dependent on the application of enough flow in proper form to establish a negative heat balance.

Smothering: Smothering is used to prevent oxygen from reaching the fire by:

- displacing the air with an inert gas
- sealing the fire off within an inert blanket of foam
- smothering the fire in some other way

Extinguishment by oxygen dilution means reducing the oxygen concentration in the fire area. This can be done by introducing an inert gas into the fire or separating the oxygen and the fuel. This method of extinguishment will not work on self-oxidizing materials or on certain metals that are oxidized by carbon dioxide or nitrogen (the two most common extinguishing agents).

Separation: In some cases, a fire is effectively extinguished by removing the fuel source. This may be accomplished by stopping the flow of liquid or gaseous fuel, or by removing solid fuel in the path of the fire. Another method of fuel removal is to allow the fire to burn until all fuel is consumed.

The fire tetrahedron

In addition to the fire triangle, the fire tetrahedron is a four-sided figure, similar to a pyramid, with the four sides representing fuel, heat, oxygen and uninhibited chemical chain reaction (Figure 4-2).

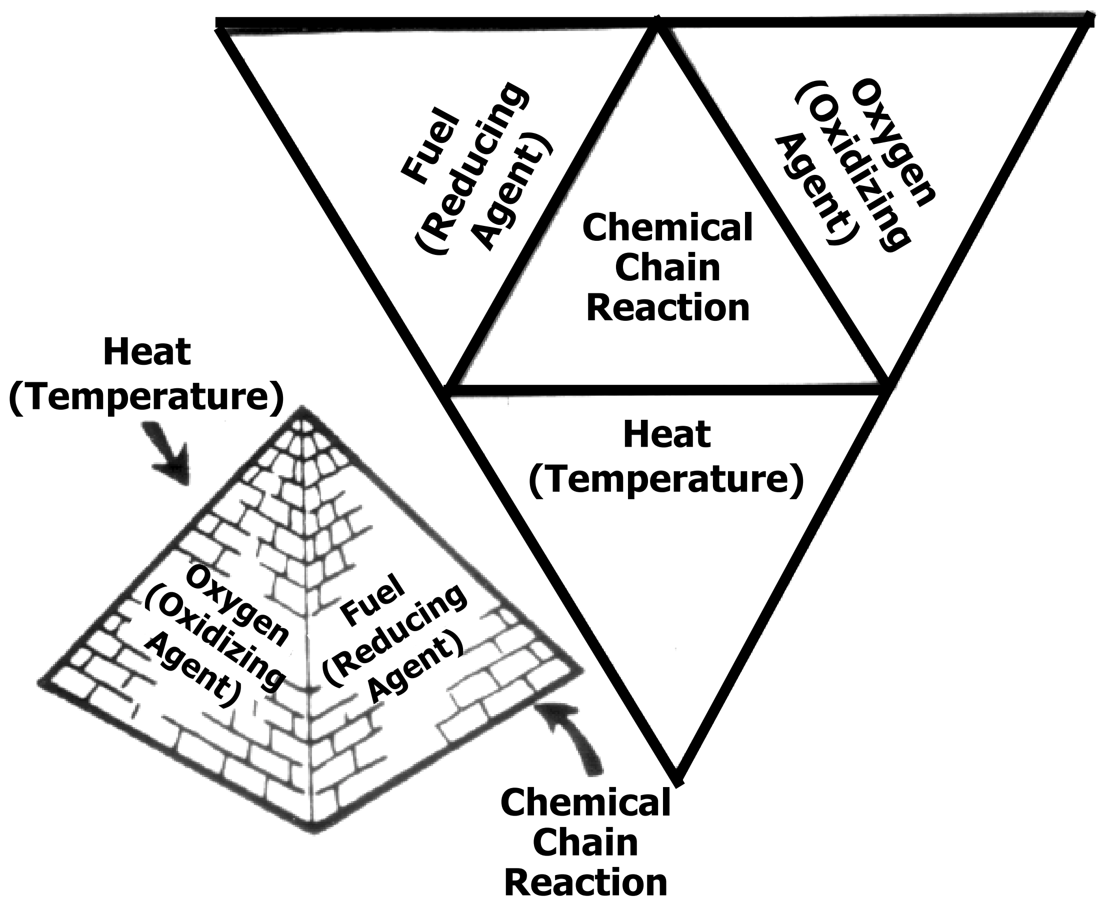


Figure 4-2: The fire tetrahedron

There are many by-products from fire. These can include carbon monoxide (CO), carbon dioxide (CO_2) and sulphur dioxide (SO_2). The flammable by-products can combine with oxygen and burn, thus feeding the chemical chain reaction of combustion and contributing to the chain that expands the fire. The vapours that are produced in a fire may also be combustible and contribute to the fire.

Hazards from burning materials

The health hazard from exposure to the thermal decomposition (burning) process depends on the particular material involved and the decomposition temperature. These materials could include such things as tires, conveyor belting, electrical equipment and cables, styrofoam, brattice. Gases and smoke produced in fires involving material can be acutely toxic or severely irritating to the respiratory tract. Decomposition products may include hydrogen cyanide, hydrogen chloride, aldehydes, nitrogen oxides, phosgene and heavy smoke (particulate). Refer to MSDSs to find information on hazards specific to a material.

About 10 percent of all fire deaths are unexplained by carbon monoxide poisoning or other clear causes. They include deaths with signs and symptoms of respiratory tract irritants. Such irritants prevent proper breathing (i.e. choking, suffocation) and impede escape, thus increasing exposure to asphyxiants such as carbon monoxide and hydrogen cyanide.

Other than for carbon monoxide, it is difficult to assess the acute health risk of exposure to fire decomposition products. There is not one degradation product that can be used as an index for the toxicity of the smoke. Smoke from fires involving plastic material should be considered more toxic than smoke produced by burning wood or fossil fuel.

Extinguishment by chemical flame inhibition

Some extinguishing agents, such as Halon and certain dry chemicals, interrupt the flame producing chemical reaction, resulting in rapid extinguishment. This method of extinguishment is effective only on gas and liquid fuels as they cannot burn in the smoldering mode of combustion. If extinguishment of smoldering materials is desired, cooling will also be necessary.

Principles of fire behaviour

Fuel may be found in any of the three states of matter:

- solid
- liquid
- gas

Only gases burn. Burning liquid or solid fuel requires its conversion to a gaseous state by heating. Fuel gases are evolved from:

- pyrolysis for solid fuels and gases, and
- vaporization for liquids

This is the same process as boiling water to evaporate it, and water in a container evaporating in sunlight. In both cases, heat causes the liquid to vapourize.

Generally, the vapourization process of liquid fuels requires less heat than does the pyrolysis for solid fuels. This limits the control and extinguishment of liquid fuel fires because their re-ignition is much more likely.

Gaseous fuels can be the most dangerous because they are already in the natural state required for ignition. No pyrolysis or vapourization is needed for combustion. Gaseous fuel fires are also the most difficult to contain.

Solid fuels: Solid fuels have a definite shape and size that significantly affects how efficiently they catch fire. Of primary consideration is the surface-to-mass ratio, that is, the ratio of the surface area of the fuel to the mass of the fuel. As this ratio increases, the fuel particles become smaller and more finely divided (i.e., sawdust as opposed to logs), and the ease of ignition increases tremendously. As the surface area increases, heat transfer and vapourization of the small particles is easier and the material heats more rapidly, thus speeding pyrolysis.

The physical position of a solid fuel is also of great concern to firefighting personnel. If the solid fuel is in a vertical position, fire will spread more rapidly than if the fuel is in a horizontal position. The speed of fire spread is due to increased heat transfer through convection as well as conduction and radiation.

Liquid fuels: Liquid fuels have physical properties that increase the hazard to personnel because they are harder to put out. A liquid, like a gas, assumes the shape of its container. When a spill occurs, the liquid will assume the shape of the ground (flat), flowing and accumulating in low areas.

The density of liquids in relation to water is known as specific gravity. Water is given a value of one. Liquids with a specific gravity less than one are lighter than water, while those with a specific gravity greater than one are more dense than water. If a liquid also has a specific gravity of one, it will mix evenly with water. It is interesting to note that most flammable liquids have a specific gravity of less than one. This means that if a firefighter is confronted with a flammable liquid fire and pours water on it improperly, the whole fire may just float away, igniting everything in its path.

The solubility of a liquid fuel in water is also an important factor. Alcohols and other polar solvents dissolve in water. If large volumes of water are used, alcohols and other polar solvents may be diluted to the point where they will not burn. As a rule, hydrocarbon liquids (nonpolar solvents) will not dissolve in water and will float on top of water. This is why water alone cannot wash oil off our hands; the oil does not dissolve in the water. In addition to the water, soap must be used to dissolve the oil.

Consideration must be given to which extinguishing agents are effective on hydrocarbons (insoluble) and which affect polar solvents (soluble). Today, multipurpose foams are available that will work on both types of liquid fuels.

The volatility, or ease with which a liquid gives off vapour, affects fire control. All liquids give off vapours to some degree in the form of simple evaporation. Liquids that give off large quantities of flammable or combustible vapours are dangerous because they may be easily ignited.

Gases

Vapour density is the density of gas or vapour in relation to air. Vapour density is of concern with volatile liquids and gaseous fuels. Gases tend to assume the shape of their container, but have no specific volume. If a vapour is less dense than air (air has a vapour density of one), it will rise and tend to dissipate. If a gas or vapour is more dense than air, it will tend to hug the ground and travel, as directed, by terrain and wind.

It is important for all firefighters to know that every hydrocarbon except the lightest one, methane, has a vapour density greater than one and will sink and hug the ground, flowing into low lying areas. Hydrocarbons are very dangerous for that reason. Common gases such as ethane, propane and butane are examples of hydrocarbons that are heavier than air.

Fuel-to-air mixture

Once a fuel has been converted to a gaseous state, it must mix with an oxidizer to burn, usually oxygen. The mixture of the fuel vapour and the oxidizer must be within the flammable limits for the fuel. That is, there must be enough, but not too much, fuel vapour for the amount of oxidizer. If there is too much fuel vapour, the mixture is too rich to burn. If there is not enough, it is too lean to burn.

The flammable limits of how rich or lean a fuel vapour mixture can be and still burn are recorded in handbooks and are usually reported for temperatures of 21^{o}C (70^{o}F). These are referred to as the lower explosive limit (LEL) and the upper explosive limit (UEL). These limits change slightly with temperature.

Oxygen

Oxygen is in the air and will support combustion of any fuel. The air we breathe contains approximately 21 percent oxygen (20.94 percent). When oxygen content is reduced to 16.25 percent or lower, flames are extinguished.

Some fuels (eg., celluloid, explosives), contain sufficient oxygen in their makeup to support combustion themselves.

Pure oxygen is an intense supporter of combustion.

> **Important:** Oils or greases sometimes burst into flames or explode in the presence of compressed oxygen.

Smoke and gases

Smoke consists of gases and finely divided solids. It may be combustible and even explosive under some conditions (e.g., a sudden inrush of air from opening of a door). During a fire, smoke and gases rise, therefore air is more breathable closer to the floor.

Of the various gases associated with fire, you will probably be most concerned with carbon monoxide (CO), a product of incomplete combustion. Common usage of polyvinyl chloride (PVC), polyurethanes and plastics mean precautions may have to be taken for phosgene and hydrogen cyanide gas as well.

Suitable breathing equipment must be worn when it becomes necessary to enter heavy concentrations of poisonous or objectionable gases. The mine rescue person will constantly assess conditions based on chemical and physical facts. Such basic knowledge is very important in fighting mine fires.

Causes of fires

Most fires occurring underground are caused by the following:

- electricity
- human intervention
- manmade (deliberate or accidental)
- friction

Electricity

Some mine fires are caused by the use or misuse of electricity on battery locomotives, power cables, trolley wires, motors, electric heaters and even light bulbs. Worn insulation on live wires is a common source of fires in mobile equipment. Overloaded electrical circuits can cause electrical cables to overheat.

Circuit breakers or fuses provide protection against overloaded electrical circuits, but if someone tampers with fuses or circuit breakers, then this protection is lost and overheating can take place. Electrical circuit protection devices are fire prevention devices and tampering with one can cause electrical cables or motors to burst into flames.

Other common causes of mine fires are the overfusing and shorting out of deteriorating wiring on vehicle control panels and faulty battery cables.

Manmade (deliberate or accidental)

Welding and burning, and smoking and blasting operations, are among the many causes of fires. Strict control and patrol procedures must be observed whenever welding is done in any place where the welder may bring the three sides of the fire triangle together.

A worker in a lunch room may throw a hot match or cigarette into the garbage can. A welder cutting steel in a shaft or a raise can provide a source of heat (hot metal or slag) that causes a fuel to ignite. Active burning can be delayed for long periods of time by a slow smouldering or oxidation of wood started by the hot slag.

An active fire can break out many hours after the hot work is finished.

Accidental leakage of petroleum products on hot machinery is another common cause of fires. For example, the leakage of hydraulic fluids and diesel fuel onto hot engine exhaust manifolds causes a number of underground fires every year.

Spontaneous combustion

Spontaneous combustion occurs when ventilation is not sufficient to carry away the heat of oxidation. Slow oxidation of a pile of oily rags, old timber, etc. can generate enough heat to cause burning to start without any outside source of heat because the material is highly combustible. As oxidation starts, heat is produced which causes the oxidation to speed up which, in turn, creates more heat. This chain reaction eventually causes the material being oxidized to burst into flame.

Friction

Friction causes overheating of brake bands or clutches on slushers, transmission gear boxes and v-belt drives. Two of the most common friction-caused fires are the result of forgetting to release vehicle parking brakes and clutch slippage. Conveyor belts slipping, overheated bearings or rubbing against flammable items have also caused fires.

Classes of fires

Class A

Class A fires involve ordinary combustible materials, such as wood, cloth, paper, rubber and many plastics. They require the cooling effects of water or water solutions, or the coating effects of certain dry chemicals that slow down fire.

Class B

Class B fires occur in the vapour-air mixture over the surface of flammable liquids such as greases, gasoline and lubricating oils. A smothering or combustion-inhibiting effect is necessary to extinguish Class B fires. A dry chemical, foam, vapourizing liquids, carbon dioxide and water fog can all be used as extinguishing agents, depending on the fire.

Class C

Class C fires involve live electrical equipment where safety to the operator of the extinguisher requires the use of electrically nonconductive extinguishing agents. Dry chemical and carbon dioxide are suitable. Because foam, water and water-type extinguishing agents conduct electricity, their use can kill or injure the person operating the extinguisher, and severely damage electrical equipment.

(Note: When electric power is disconnected, Class A or B extinguishers may be used.)

Class D

Class D fires involve certain combustible metals (such as magnesium, titanium, zirconium, sodium and potassium) and require a heat-absorbing extinguishing medium (dry powder) that will not react with the burning metals. Specialized techniques, extinguishing agents and extinguishing equipment have been developed to control and put out this type of fire. Normal extinguishers should not be used on metal fires because they may contain substances that will react chemically with the burning metal, and make the situation even worse.

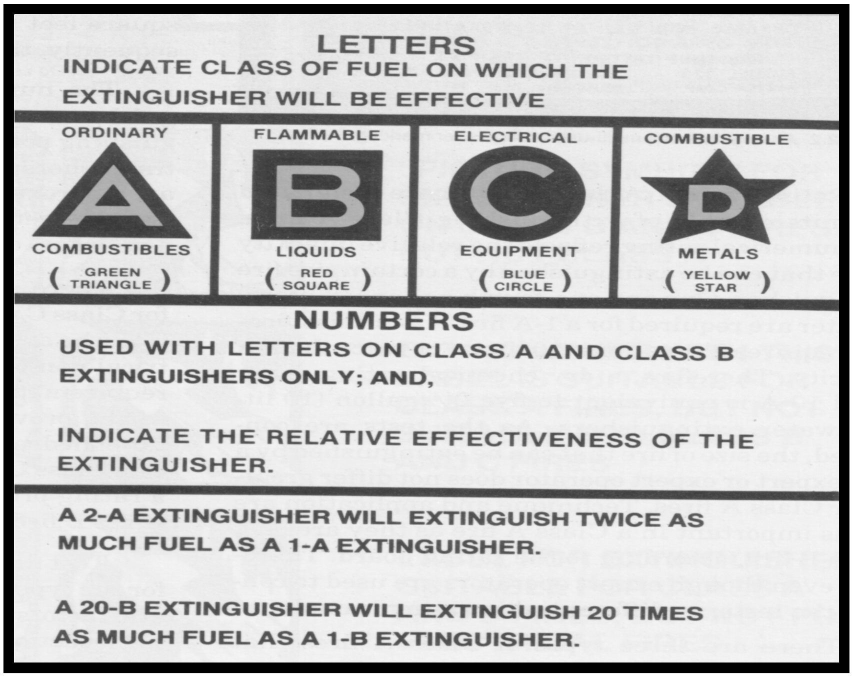


Figure 4-3: Extinguishers

Stages of mine fires and control

Fires may start at any time. Fires are more quickly discovered and suppressed when they occur in an occupied area. If a fire breaks out in an enclosed space or empty building, it may go undetected until it causes major damage. When a fire starts in a building, situations develop that require carefully thought out and executed solutions, like changing ventilation procedures, if danger is to be reduced and further damage is to be prevented.

This type of fire can best be understood by examining its three progressive phases. A firefighter may be confronted by one or all of the following phases of fire at any time. Knowledge of these phases is important for understanding ventilation and firefighting principles.

Stage 1: Incipient phase

In this first phase, the oxygen in the air has not been reduced significantly. The fire is producing water vapour, carbon dioxide, sulphur dioxide, carbon monoxide and other gases. Heat is being generated and the amount will increase as the fire progresses. Although the temperature in the area may be only slightly increased, the fire may be producing a flame temperature in excess of 537^{o}C (1000^{o}F). Incipient fires generate heat, smoke and flame damage.

Control: In this stage, the fire is just getting started and can generally be extinguished on the spot with water or suitable extinguishers by the workers who discover it.

Stage 2: Free-burning phase (steady state burning phase)

During the second phase of burning, oxygen-rich air (+16.25% oxygen) is drawn into the flame as convection carries the heat to the top of the enclosed area. From the top downward, the heated gases expand laterally, forcing the cooler air to lower levels and eventually igniting the combustible material in the upper levels of the area. The first indication of a fire may be the discovery of smoke in air currents at some distance away or even on surface.

Control: This is the time when breathing apparatus must be worn by persons trying to locate and put out a fire. One breath of this superheated air can sear the lungs.

It may be possible to get within sight of such a fire from the fresh air side while staying in fresh air. This is often the case, and should always be carefully considered. Workers should never attempt to get to a fire against the smoke if it is possible to get to it in fresh, clean air. A fresh air route has two advantages: time and safety.

A fire may grow quickly and will often create its own convection currents that are strong enough to overcome strong drafts and back up smoke. Every attempt should be made to fight an underground fire by direct action, even if it will take many days.

Fire temperatures can exceed 700^{o}C (1300^{o}F). As the fire progresses through the latter stages of this phase, it continues to consume any free oxygen until there is not enough oxygen to react with the fuel. The fire is then reduced to the smouldering phase.

Stage 3: Too hot to proceed phase

In the third phase, there may be no detectable flame if the area is sufficiently airtight. Burning is reduced to glowing embers. The area becomes completely filled with dense smoke and gas. Smoke and gas may be forced by pressure through any openings and cracks. The fire will continue to smolder at a temperature well over 537^{o}C (1000^{o}F).

Such conditions could make it impossible to get directly at a fire in a stope, underground hoist room, chute, manway, sublevel, mining room, etc.

Control: If direct methods fail, the next step is to erect fire seals in a reasonably safe and comfortable location to seal off the area involved on both the level above and below, or even on the same drift as the fire.

Once sealed, the mine rescue team must follow proper procedures before opening seals, and they must be aware of the potential for back draft.

Stage 4: Out of control phase

It is not always possible to control a mine fire by conventional methods. This condition is called the fourth stage. A fire in this stage can only be controlled by sealing it off on the surface.

Control: This is a long drawn-out process, as every surface opening may have to be sealed, plugged or covered with solid bulkheads, concrete or tonnes of fill.

Carbon monoxide may build to explosive proportions when combined with mine gases and cause severe damage to the bulkhead seals. Large quantities of dry ice could be dumped down the openings, or the fire area flooded with inert gases, such as carbon dioxide and nitrogen.

Flooding of a mine with water is the very last resort. It is used only when every other method has failed. Although Saskatchewan has no underground coal mines, there are coal mines in Canada and North America that have been sealed after stage four fires.

Fire extinguishing and control methods

Fire regulations

Safety regulations require that fire extinguishers be kept at places where known fire hazards exist, such as:

- ➢ mobile equipment
- ➢ electrical switchgear and transformer stations
- ➢ fuel storage stations
- ➢ shaft stations, and
- ➢ shops, warehouses, or where cutting and welding takes place

During a fire emergency, valuable seconds can be lost locating extinguishers, reading directions or trying to figure out how they work. Regular refresher training and putting fire extinguishers in appropriate locations are important. Learning how to operate the types of fire extinguishers at a mine should be part of the survival and orientation given to new employees before they start work.

Extinguishing agents

Fire extinguishers provide excellent protection against a minor fire becoming a raging inferno when suitably applied to the hazards for which they are intended.

The four basic classes of fires require slightly different extinguishing methods for safe and effective control.

Water-type extinguisher: These are a Class A type fire extinguisher. The method of fire control is by cooling the fire with a quenching agent (e.g., water). The water is applied to the fire with:

- hand operated pump tank
- pressurized tank with a release valve mechanism
- tank pressurized with a high pressure cartridge
- water lines
- mobile water trucks, tanks, etc.

Water type extinguishers are effective and safe on Class A fires only. They must not be used on Class C and D fires.

Carbon dioxide extinguisher: These are safe to use for Class A, B, and C fires, but only recommended for Class B and C fires because they are only moderately effective on Class A fires. The extinguishing agent is liquid carbon dioxide while in the extinguisher, but is discharged as a snow that vapourizes quickly to carbon dioxide gas and extinguishes fires mainly by excluding or diluting oxygen.

> **Important:** Caution must be exercised in using this smothering type of fire extinguisher in an enclosed area. It is designed to prevent oxygen from reaching the fire and it can, of course, prevent oxygen from reaching the firefighter as well. Often, a “frost” residue will form on the nozzle horn. Contact with the skin could result in frost bite.

Dry-chemical extinguisher: Dry chemical extinguishers are among the most common portable fire extinguishers used today. There are two basic types of dry chemical extinguishers:

- ordinary dry-chemical extinguishers rated for Class B and Class C fires
- multipurpose dry-chemical extinguishers rated for Class A, B and C fires

The following dry chemicals are commonly used in ordinary base and multipurpose agent fire extinguishers:

<u>Ordinary Base:</u>

- sodium bicarbonate
- potassium bicarbonate
- potassium chloride

<u>Multipurpose Agent:</u>

- monoammonium phosphate
- barium sulfate
- ammonium phosphate

These chemicals are mixed with small amounts of additives to prevent the agent from caking and to allow it to be discharged easily. Care should be taken to avoid mixing or contaminating ordinary agents with multipurpose agents and vice versa.

Like the carbon dioxide extinguisher, dry chemical extinguishers are safe on Class A, B, and C fires and are highly recommended for Class B and C fires. The extinguishing agent is usually sodium bicarbonate or potassium bicarbonate in dry powder form that has an added component to repel moisture and maintain free-flow. The powder is expelled under pressure produced by puncturing a small carbon dioxide cartridge attached to, or confined within, the extinguisher or just by pressurizing with injected nitrogen.

As the ejected powder granules are warmed by the heat of the fire, each granule produces carbon dioxide gas, which excludes or reduces oxygen in or near the fire or by chemical flame inhibition.

High-expansion foam: This foam is created by spraying a mixture of concentrated detergent and water through a knitted nylon netting, causing bubbles to form. Enough bubbles are generated to form a “foam plug”. The velocity of air forces a steady stream of foam (i.e. the plug) with a continuous volume against the fire. Once the foam reaches the fire, it continues to displace fresh air and hold the steam and oxygen deficient atmosphere around the fire. The resulting steam-air mixture has an oxygen content that does not support combustion, so cooling and extinguishing occurs. Foam wets all objects that it contacts, thus making it useful only in fighting Class A and B fires.

Water fog: This is a modern firefighting device, useful and safe for Class A and B fires on the surface and underground. A water fog is made up of millions of fine particles of water sprayed through a special high-pressure nozzle. As the super-fine spray hits the fire, the heat is reduced from as much as 982^{o}C to 93^{o}C and the water is turned into steam. This cuts off the oxygen and extinguishes the fire. A water fog produced by a proper “impinging type” nozzle is very useful as a heat barrier for rescue teams advancing towards a Class A fire.

Halon (1301 and 1211): Halon is an electrically nonconductive gas. It is an effective medium for putting out a fire. Halon extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. The extinguishing effect due to cooling, or dilution of oxygen or fuel vapours, is minor. Fire extinguishing systems, either total flooding systems or local applicators, are useful in extinguishing fires where an electrically nonconductive medium is essential or where clean up of other types of extinguishing media presents a problem. Halon has not been found effective on combustible metal (Class D) fires.

Potash or rock dust: Fine potash, limestone or shale dust can be used successfully in fighting fires in the early stages and for larger fires under some conditions. It excludes oxygen from the heated area and may also reduce the heat of the burning material. Small fires may be controlled by potash dust applied by hand shovels. Fine sand and backfill can also be used in making a direct attack. Sand, however, is heavier than potash dust and, therefore, more difficult to handle. Covering burning material with rock dust does not produce fumes as chemicals do, nor does it produce steam and hydrogen like water. Potash or rock dust can be used on all classes of fires.

Dry powder for class D fires: The agent used in most dry powder extinguishers is sodium chloride. Flow enhancers and a thermoplastic material are added to the sodium chloride to enhance crusting after the material is discharged onto the metal fire. Refer to the manufacturer's recommendations for use and special techniques for extinguishing fires in various combustible metals.

Sealing of a mine fire

The purpose of sealing in a mine fire is to cut off the oxygen supply and help keep contamination from smoke and gases entering other areas of the mine. A mine fire might also be sealed because:

- the fire cannot be fought by direct means of extinguishment, or
- the location of the fire is in a stope, chute, manway, mining room, etc.

Important: Seals built on the intake and exhaust sides simultaneously are best. If this is not possible, the seal on the fresh air side should be put up first.

When it is determined necessary to seal the exhaust side first, the rescue team will be in danger from the extremely toxic and hot atmosphere. The team will also face the danger of an explosion caused by explosive gases backing up over the seat of the fire.

A short pipe or tubing built into the stoppings can be used for a vent and for inserting probes to check the gases and temperature in the fire area.

After sealing is complete, all non-mine rescue personnel must immediately leave the fire area until it is safe to return. If workers have been trapped in the mine, mine rescue teams must concentrate on rescuing them as soon as it is safe to do so.

Temporary stoppings or seals

Temporary stoppings or seals can be built very quickly in an emergency. They can be constructed with brattice that is fastened to walls, backs, floors or wooden frames. Non-sparking tools should always be used in an explosive atmosphere.

Stoppings should be set at an adequate distance in the opening and as close to the fire as safety permits. Allow enough room for a secondary seal. All ground in the vicinity of the stopping must be well checked and scaled down.

> **Important:** Special attention must be given to backs (roof) because experience has shown that heat will deteriorate backs in some types of ground. Temporary stoppings should be of sufficient strength to provide a tight seal.

Unsealing

No attempts should be made to unseal a mine fire until the:

- oxygen content of the sealed atmosphere is low enough to eliminate the possibility of explosions
- carbon monoxide (indicator of combustion) has been reduced to a safe level, and
- the temperature has cooled down well below the point of ignition

Gas tests of the atmosphere behind the stoppings should be taken at reasonable intervals as determined by the Director of Rescue Operations. Gas tests should be taken through the seal with as little disturbance as possible to the seal. Mine rescue teams testing gas levels must wear self-contained breathing apparatuses.

Method of unsealing

Once the conditions listed above are met, the rescue team, wearing self-contained breathing apparatuses and carrying extinguishers, may proceed to the sealed fire and:

1. Erect an air-lock on the fresh air side of the seal.
2. Carefully open the temporary fire seal.
3. Check the fire area thoroughly for bad backs and sidewalls (expect poor roof conditions).
4. Note the temperature in the sealed area.

5. Reseal fire if conditions indicate the fire is not out.
6. Repeat the above steps at reasonable intervals.
7. If temperature, oxygen and carbon monoxide levels are within safe limits, open barricades or stoppings and restore ventilation.
8. Maintain constant patrols until conditions return to normal (any increase in carbon monoxide is cause for alarm).
9. Once ventilation is restored and the air is within the regulated limits, open or barefaced miners can begin recovery and preparation of mining operations.

Permanent stoppings

These are done by erecting permanent barricades or stoppings. These must be constructed in accordance with any mine regulations and require the permission of the Chief Mines Inspector, OH&S Division, Saskatchewan Labour.

They can be built of timber, concrete, cinder blocks, bricks, back fill or other suitable material.

Summary

In summary, if any fire is found in a mine, prompt action must be taken. Safety always comes first.

If an incipient or small fire is found, action must be taken immediately to contain or put it out. Use water and Class A extinguishers on Class A fires. Use a smothering approach for Class B and C fires. Use only “dry powder” extinguishers for Class D fires. Electricity must always be turned off in electrical fires. No attempt should ever be made to extinguish electrical fires with water.

Approach a fire from the upwind side, and be careful in enclosed areas when using smothering type fire extinguishers.

If, after a few moments, definite progress is not made or it becomes apparent the fire cannot be contained: Sound the alarm! Warn workers! Initiate evacuation!

Remember that fires constantly produce deadly gases. Workers must not be exposed to these gases or other hazards associated with fires, such as explosions, weakening timber or deteriorating ground.

Every fire, regardless of how small, must be reported at once because it may have released deadly gases into the mine’s air. Once put out, the fire area must be watched until re-ignition is impossible.

After a fire extinguisher is used, it must always be returned for recharging and its use recorded.

Any unusual occurrences in the mine should be noted and reported at once. An unusual occurrence could be:

- the odours of smoke or other contaminants
- clouds of dust
- blasts of air, caused by a fall of ground or inrush of water
- sudden changes in ventilation
- interruption of normal services such as power failures
- unusual noises or explosions

Chapter Five - Mine Rescue Operations

Mine rescue team objective

Most people associate “mine rescue” with “ saving lives.” Although saving lives is the most important part of mine rescue work, there is more work involved. A more complete definition of mine rescue is:

> “the practiced response to a mine emergency situation that endangers life, property, and the continued operation of the mine.”

Mine rescue principles

Mine rescue and recovery work involves a wide variety of tasks. Four fundamental principles exist for an effective mine rescue operation. These principles, in order of importance, are:

1. Ensure the safety of the mine rescue team.
2. Make every effort to rescue or secure the safety of trapped workers.
3. Protect mine property from further damage caused by fire, cave-in, etc.
4. Return the mine to a safe condition so operations can resume.

Competent persons appointed

Each mine must appoint a certified person who is responsible for maintaining the rescue equipment, training mine rescue personnel and acting as a Coordinator or briefing officer.

The employer must have all breathing, resuscitating, testing apparatus, and mine refuge stations examined on a monthly basis and properly maintained. The record of this examination must be reported in writing to the employer who will have it countersigned. All rescue equipment must be maintained in a state of readiness for an emergency. Any supply shortages must be replaced.

Inspectors from Saskatchewan Labour, OH&S Division, Mine Safety Unit may inspect the breathing apparatus and any other mine rescue equipment to make sure that the mine is properly equipped. As well, the inspectors may examine mine rescue training records to ensure personnel have the training to carry out a mine rescue and recovery operation.

Mine rescue duties

Operating on the basis of the four fundamental principles, some of the duties a team may have during an actual emergency are:

- exploring the affected area of the mine
- searching for and rescuing survivors
- performing first aid
- resuscitating victims
- administering oxygen
- determining the extent of the damage
- determining gas conditions and ventilation flows
- mapping the team's findings
- locating and fighting fires
- building temporary and/or permanent stoppings
- erecting seals in a fire area
- clearing debris, pumping water and installing temporary roof supports
- moving equipment
- extricating casualties
- restoring ventilation by restoring power and moving fans, etc.

Careful consideration must be given to:

- the method and the extent of work a team is expected to perform
- how the team wearing breathing apparatuses can best be utilized
- weighing the benefits of the operation against the hazards the team will encounter
- the best way to perform the work safely
- what offers the best chance of saving trapped workers

The Chief Mine Inspector, through the Provincial Mine Rescue Coordinator, has control over the quantity and nature of equipment and the quality of training. The Mine Safety Unit will only provide a coordinating and consulting service during an actual disaster. Complete authority for responding to the emergency is in the hands of the general manager of the mine.

Senior management

Senior management is responsible for:

- having the required number of mine rescue team members trained and available
- providing the required equipment
- having an emergency plan

Director of Rescue Operations

A mine’s Director of Rescue Operations has a very important function, must be a senior company official, and must also know mine emergency and emergency response procedures. He must also be thoroughly familiar with, or have the appropriate resources available for:

- mine and mining methods being used in that mine
- equipment used in normal day-to-day operations and its location
- supply of power the equipment uses
- ventilation system;
    - amount and direction of airflow
    - location and capacity of fans
    - location of electrical power lines and switches for the fans, and
    - location of ventilation doors and brattice stoppings
- location of telephones and other communication equipment
- location and availability of firefighting equipment, storage depots for brattice, and other material and equipment required to build fire seals, control fires, and change or restore ventilation
- location of facilities such as refuge stations, vehicles, and any other emergency equipment that may be used in recovery operations
- location of possible hazardous areas such as fuel and oil storage areas, timber, bad ground conditions, water problems, and gaseous situations
- functions and limitations of the breathing apparatus used by the team
- capabilities of the team, and the atmospheric testing equipment used by them
- emergency first aid equipment, material, and its location, and
- latest large scale mine plan and all pertinent information that is relevant to the problem areas

All important information, messages, and directions should be logged.

Since the Mine Rescue Team, the Coordinator, the Director of Rescue Operations and his assistants are required to work cooperatively, careful consideration and planning are essential.

When making decisions and plans, the Director of Rescue Operations should consider:

- the details and facts provided by persons involved in the incident
- probable conditions in the part of the mine to be explored as known from information already received
- the route of travel, visibility, and familiarity with the location
- the number of competent rescuers available, and the limitations of both them and their equipment
- the vehicles available to speed up the operations, and the possible hazards that may result from their use
- the distances to be traveled and the limitations of the apparatus in the event of vehicle failure on the journey in or out of an emergency area
- communications between the rescue team and the coordinating centre
- the availability of emergency equipment and material stored underground that could be used by the rescue team
- the potential hazards the team may encounter such as cave-ins, water, gases, etc.
- anything to make sure no work done will endanger the team and trapped workers; and
- the assistance and material that could be made available from neighbouring mines and suppliers

All important information, messages and directions should be logged.

Mine Rescue Coordinator duties

The Mine Rescue Coordinator, otherwise known as the Briefing Officer or Fresh Air Base Coordinator, must have mine rescue experience and will be stationed at the fresh air base. The Coordinator must have direct communication with the team in the mine as well as with the Director of Rescue Operations in the control centre.

The Coodinator reports directly to the Director of Rescue Operations and acts on his orders or advice. He should also be in a position to inform the Team Captain of all relevant data and give instructions on the work to be done. The progress and actions of the team should be accurately marked on the mine plan and all relevant details logged.

Because the Coordinator's job is so important, it is essential that everyone at the fresh air base respect the Coordinator's authority and do whatever they can to help. In order to make the job easier, only those people necessary for the operation should be allowed at the fresh air base.

The main responsibilities of the Coordinator are:

- ➢ maintaining communications with the rescue team and the control centre
- ➢ following the team's progress on the mine plan and recording the findings as the team reports
- ➢ coordinating and overseeing the activities of all personnel who are at the fresh air base; and
- ➢ ensuring that the team is properly checked out, equipped and well briefed before leaving the base

Team Captain

One member of the mine rescue team is designated the Team Captain. The Team Captain leads the way when a team is advancing on foot. The most important quality of a mine rescue Team Captain is leadership.

The Team Captain leads and directs the team members and is responsible for discipline, general safety and the work they perform. The Team Captain must not take part in any work other than that directly involving the safety of the team. He must have their respect and confidence at all times.

The Team Captain reports to the Mine Rescue Coordinator and is under his direction. However, when the team is on a mission, the Captain is its chief decision maker. It is vital for the Captain to be knowledgeable in all facets of mine rescue theory and procedures so that he can make correct and timely decisions as circumstances dictate.

The Team Captain will probably have some team members with more detailed knowledge of certain subjects, but it is up to the Captain to utilize to their best advantage, the team's skills and resources on the rescue operation.

Vice-Captain

The Vice-Captain on a rescue team follows at the rear of the team when it is advancing on foot. In the event the Captain is unable to continue, the Vice-Captain takes control of the team. The Vice-Captain must, therefore, have similar qualifications to that of the Captain.

One of the Vice-Captain's main duties while travelling is to keep watch on all members of the team and to warn the Captain should any team member show signs of distress. The Vice-Captain acts as a second pair of eyes for the Captain and, in addition to observing the team members, keeps a sharp lookout for any condition missed by the Captain.

The actual distribution of jobs among team members may vary from team to team. However, it is common practice to have the Vice-Captain assist the Captain in updating the mine plan and taking gas and ventilation tests. He also makes close checks of team members during rest breaks and assists the Captain with routine duties. The Vice-Captain must be kept informed of the Captain's findings, the work done and the work still to do.

Rescue Team Member

Various other duties, such as first aid and firefighting, are distributed among the other team members. When vehicles are used, a driver will be designated. Generally, it is desirable to have all team members well trained in the common types of work that teams do, such as first aid, firefighting, air sampling, and installing seals.

As mine rescue teams are assembled, consideration must be given to the special skills that may be required. Team members should be chosen with these factors in mind. Emergencies in mines require the special skills of mine rescue workers.

Training

Only through regular practice will individuals learn to work effectively on a team and develop confidence in their mine rescue skills.

In mine rescue work, the life of every team member depends on the actions of the other team members. If members of a mine rescue team do not work effectively as a team, then their lives are in danger. The importance of cooperation cannot be overemphasized.

The first consideration of any mine rescue operation is the safety of the individual team members. Without the team, there will be no rescue and no recovery.

Control or command centre

A rescue headquarters should be established to direct the rescue and recovery operation. This headquarters is called the Control or Command Centre and houses the Director of Rescue Operations and his advisors.

A good communications system is essential for the effective operation of the Command Centre. This centre should be linked with the fresh air base at all times and must have access to a switchboard so that staff can talk with various personnel at the mine site and points outside. The Control Centre must have:

- an up-to-date copy of the contingency plans for the mine
- updated mine and ventilation plans
- the names and phone numbers of personnel that may be involved in a rescue and recovery operation
- any other information that may be of assistance in planning and carrying out the rescue operation; and
- a directory of resources

Mine rescue stations

At each mine, a qualified, certified person shall be appointed to supervise rescue teams in all rescue work and operations at the mine.

Each underground mine is required to install, equip, operate and maintain a mine rescue station (*The Saskatchewan Mines Regulations*). The station should be equipped with the following items:

- an room adequate for proper storage and maintenance of the equipment
- adequate supplies of primary four-hour self-contained breathing apparatus and testing equipment
- enough oxygen and carbon dioxide absorbent to allow at least five trips into the mine by the teams
- adequate supplies of secondary self-contained breathing apparatus for rescue
- gas detecting instruments and their accessories
- stretchers
- first aid equipment

- equipment for testing breathing apparatus
- spare replacement parts, and
- emergency tools and materials to be used in mine rescue work

Firefighting equipment must also be immediately available.

The fresh air base

The fresh air base is the base of operations from which the rescue team advances into unbreathable atmospheres.

It functions as a base of communication for the rescue operation, linking the team, the control centre and support personnel. The Fresh Air Base Coordinator and assistants are stationed at the fresh air base. Rescue crews begin their operations from the base.

The base may be on surface or underground, as conditions require, but should be as near the emergency scene as possible.

The essentials of a fresh air base should include the following:

- an assured supply of fresh air
- an assured travelway in fresh air for workers and material travelling to the surface
- communications with the control centre and with the Captain of the team on the mission
- the best illumination possible
- sufficient room to permit work without confusion
- first aid supplies
- necessary tools and equipment
- oxygen (O) and carbon dioxide (CO_2) absorbent

Basic tools/equipment/personnel

Team members should be equipped with:

- fire retardant and highly reflective clothing
- approved industrial protective headwear with a retention system, and
- CSA approved steel toed, steel shanked, oil, acid, and water resistant work boots

Communication between the fresh air base and the team

It is important that the mine rescue team stay in close contact with the fresh air base to report the team's progress and to receive further instructions. It is also essential that communication be established between teams working ahead of the fresh air base and the base itself.

When wearing breathing apparatus, communication may be carried on by telephone, two-way radio or other suitable means. A microphone on the facepiece can help boost the sound to provide effective communication over the phone.

A wired telephone system is another method of communicating with the fresh air base. One team member wears the equipment and is responsible for staying in contact with the base while another is in charge of winding and unwinding the telephone line. This method is suitable only when the exploration involves short distances.

There is less anxiety and a more efficient overall rescue operation if the Captain reports to the fresh air base at every convenient opportunity. This also enables the Director of Operations to follow the progress of the team and plot it on the mine plan.

A speaker phone works well at the fresh air base because it permits all concerned personnel at the base to listen in on the two-way conversation. Two-way radios can be used if the proper aerial system is in place underground.

Standard code of signals (horn, whistle, or similar)

The standard code of signals for mine rescue teams adopted in Saskatchewan, other provinces and the United States is:

One:	Stop
Two:	Advance (move toward the Captain)
Three:	Retreat (move toward the last person in order of travel)
Four:	Distress or Emergency

Both the Team Captain and the Vice-Captain do the signaling. It is standard practice for each to return or acknowledge the other's signal before anyone on the team moves.

These basic signals are normally used in conjunction with various hand or sounding stick signals given by the Captain. Hand signals are not standardized. Each team uses what works best for them. No matter what method of signaling a team chooses, it will not be suitable for all occasions. For example, a signal by sight will not be visible in smoke, nor will a horn be audible in noisy areas.

Team rest periods may be signaled by hand, sounding stick motions or verbally. Since all modern facepieces are equipped with speaking diaphragms, voice communication is becoming more common in mine rescue work than was the case when mouth pieces were more prevalent.

Team members must know the Captain's signals so that instructions can be followed without hesitation. Strict discipline must always be maintained and all team members must obey, without question, all directions and signals given by the Captain.

Progress reporting and mapping (record keeping)

Information the rescue team relays to the fresh air base is known as the "progress report." Progress reports keep the fresh air base and control centre up-to-date on what the team is doing, where it is and what it has found. This information is used as a basis for making further rescue and recovery plans.

These reports not only inform the fresh air base and control centre on the whereabouts and conditions of the team, but also provide information on the conditions found in the mine. These reports, as they are phoned up from the mine, confirm or disprove the suspected problems and conditions. Whenever the Captain reports anything, it is important to log the location and time that the information was obtained.

As the team advances through the mine, all events and conditions encountered are marked on the Captain's mine plan. When the Captain makes his progress report to the fresh air base, this information is recorded on the mine plan on the surface. This mapping provides the fresh air base and command centre with a visual record of what is happening underground.

Team preparation before going underground

Briefing the team - directives

Team members must be fully briefed on mine conditions and the work expected of them before the team leaves the fresh air base.

The team briefing should only take place after all decisions about the operation have been made. This prevents argument about the proper steps to be taken once the briefing has begun. If possible, the briefing should take place in a quiet room where questions may be answered and the work expected of the team thoroughly explained without confusion.

The Captain only takes orders from the Coordinator. All pertinent instructions should be issued in writing.

During the briefing, the team must be given all relevant information available. The team should answer the following questions before beginning exploration:

- Is the evacuation complete?
- Are any workers missing? Where is their likely location?
- Has the down board been checked and secured?
- What is known about the cause of the disaster?
- Is this team the first team in the mine? Are other teams in the mine?
- Are guards stationed at all mine entrances?
- What is the team's mode of travel?
- What is the extent of the exploration and work performed by previous teams?
- Is the ventilation system operating?
- Will the team's travel be in the intake or exhaust? What are the gas concentrations and the amount of airflow?
- What is the team's objective?
- What is the team's time limit for the operation?
- What conditions are known to exist underground?
- Is the mine communication system operating?
- Is the power to the affected area on or off?
- What is the condition of the air and water lines?
- Are there diesel or battery-powered equipment or charging stations in the affected area?
- What equipment is needed or available? Where is it located?
- What type of fire fighting equipment is in the mine? Where is it located?
- What tools, rescue equipment, and supplies are available underground? What is their location?
- Are there storage areas of oil, fuel, oxygen, acetylene or explosives in the areas to be explored?
- Are there any other conditions or equipment that the team should be made aware of?

All important information should be marked on an updated mine plan and given to the Captain. The communication points or telephones that the Captain will use to make his reports to the fresh air base should also be agreed upon and marked on the mine plan.

Familiarization with mine workings

Rescue Team Guides: In a major fire, it may be necessary to bring in rescue teams who are not familiar with the mine workings. Each team must include more than one member familiar with the mine to guide the team.

Check and guard mine openings

The mine's exhaust air should be checked for gases. The shafts should be guarded so no unauthorized persons enter the area. Care must be taken that no one is exposed to toxic gases that may be discharging from the shafts.

Before going underground

Before going underground, the Coordinator must be certain the Team Captain has:

- ➢ confirmed all members of the team have been deemed fit by a physician to undertake the job
- ➢ field tested all primary, secondary and back-up breathing apparatus to ensure air tightness and proper functioning of the working parts
- ➢ had each team member complete the bench or field tests on the apparatus and any self-rescuers he may need to wear
- ➢ checked (or had team members check) the gas detectors, signal whistles, communication devices, link lines, cap lamps and any other equipment or tools that the team will take
- ➢ discussed the instructions with the team to make sure each member understands them and what he is expected to do
- ➢ noted the time the team has been given for the trip and synchronized watches with the Coordinator; the time limit of the trip must be understood by all
- ➢ checked that the required tools and materials are on hand
- ➢ made sure a mine map, notebook, pencil, chalk and paint are available to take underground, and
- ➢ the team put on the apparatus and "get under oxygen" when ready to proceed

The Captain inspects team members' equipment:

- ➢ headstraps and buckles
- ➢ facepiece (straight, no kinks in tubes, tight seal)
- ➢ gauge reading (record pressures), and
- ➢ overall condition of team member and apparatus (by sign or verbally)

The Vice-Captain makes a similar check of the Captain’s apparatus and ensures the Captain has all his equipment. The Vice-Captain:

- checks signal horns and communicating equipment
- carries apparatus tools
- reports to official in charge, and
- notes time of departure

> **Important:** Before re-entering, the Mine Rescue Team members must be examined by a physician, or in the absence of a physician, the most competent medical person available.

Number of persons required for mine rescue and recovery work

Oxygen breathing apparatus should be used only when there are enough trained people available to form a five-person team to carry out the operation. Teams of fewer than five members are only allowed with an exemption from *the Saskatchewan Mines Regulations*.

The deployment of the first team is dictated by the urgency of the situation during the early stages of an emergency. However, a second team must be preparing for back-up before the first team can proceed.

Generally, teams at the fresh air base should be organized in the following manner:

1. First team: on a mission in the mine.
2. Second team: at the fresh air base in a state of readiness as a “back-up” team.
3. Third team: on standby in support of the first and second teams until they are needed as a back-up team.

Fifteen trained people are needed to begin the team organization at the Mine Rescue Station. They are organized as follows:

- Five people constitute a standard mine rescue team for work in unbreathable atmospheres.
- Five people in apparatus, but not under oxygen, remain at the fresh air base as a “back-up” team.
- Five people acting as a standby or reserve team; they may work as assistants at the fresh air base until activated as the “back-up” team.

Important: The Mine Rescue Coordinator is not considered a mine rescue team member.

Note: If space permits and there is enough testing equipment, the "back-up" team should field test their breathing apparatus and equipment at the same time as the first team so they are ready for immediate "back-up" if needed.

The safety of the team always remains the main priority.

Suggested legend for mine plan

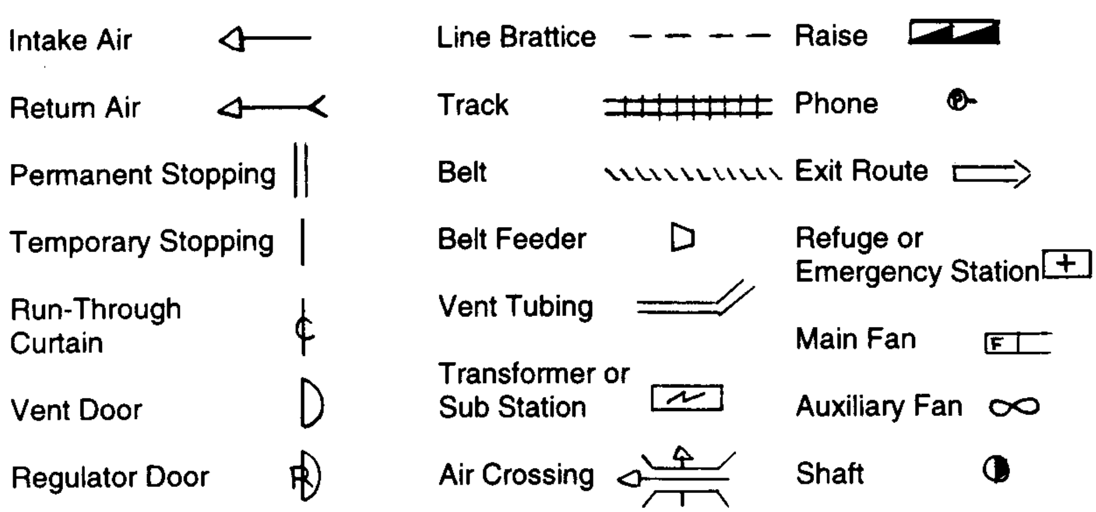


Figure 5-1: Suggested legend for mine plan

Time limits for rescue trips

A team should ordinarily allow twice the amount of time for the return trip it plans to use on the in-going trip. Only one-third of the oxygen in the apparatus cylinder worn by any member of the team should be used on the in-going trip. Two-thirds must be left for the return trip to the fresh air base. An exception to this procedure may be made where exploration or gas testing has been done on the way to the objective. The time or oxygen spent on these side trips need not be duplicated in estimating the amount required for the return trip.

The Captain should record the time of departure before the team leaves the fresh air base. It should be made clear that, if the team fails to return to the fresh air base, or fails to make contact as scheduled, the back-up team will be sent to search for them. All instructions about time limits must be obeyed.

Duration of rescue operations in high temperatures

Experience shows that mine rescue teams have less endurance in hot and humid conditions. A four-hour team rotation in high heat and humidity may be impossible. In that case, additional teams will be required to make up for the shorter work period.

After being exposed to extreme temperatures and humidity for even a very short time, the team should rest for at least four hours.

In temperatures of approximately 45°C (110°F) dry bulb reading and 38°C (100°F) wet bulb reading, the amount of time team members spend under oxygen may have to be reduced to 20 minutes or less because of heat exhaustion.

Procedures while underground

Every task or exploration is different. Each one involves unknown factors and presents its own problems. It is difficult to predict precisely what a team may be required to do.

Some accepted procedures developed over the years have become standard practice for teams during exploration. They are used as “guidelines” rather than “rules” because no procedure fits every situation.

Team/equipment checks

Team checks should be done as soon as practicable after the team leaves the fresh air base, when it enters into a bad atmosphere and at regular intervals of 15 to 20 minutes. These checks help make sure:

- each team member is fit and ready to continue
- each team member’s apparatus is functioning properly
- each team has enough rest

Usually the Captain or Vice-Captain checks the team by halting the team briefly and asking each team member how they feel. The Captain or Vice-Captain also records the time of the check and the cylinder pressures.

Discipline

Excessive talking should be discouraged. All team members must concentrate on the job at hand.

Team safety

The safety of the team is of utmost importance. It is the first principle of mine rescue. The Captain's top priority is always team safety.

Teams entering a mine in an emergency are taking a calculated risk. Captains must give each situation careful thought before proceeding. Team safety comes first! The Captain should lead his team through the mine cautiously. He should pay very close attention to the roof and sides and to the condition of the mine atmosphere.

The team must be rested regularly and members constantly checked for signs of distress. All work must be assigned as evenly as possible so that no team member becomes too tired. Excessive rushing or running, tires the team unnecessarily and, in some circumstances, may endanger lives.

Route of travel

The rescue team should explore a mine via the fresh air route whenever possible. There are two good reasons for this practice:

1. The danger to the exploring team is less, and
2. The fresh air base can be located closer to the emergency.

Circumstances may make it impossible to travel by a fresh air route. The Team Captain must always be sure the team has a safe route of retreat. If travelling underground via the exhaust shaft, ensure the hoistman is equipped with, and trained in the use of, breathing apparatus where necessary.

A rescue team should always properly mark the route it uses going in so that:

➢ the team can retrace its travel route without getting lost on the way out of the mine if working in poor visibility or in complicated mine workings, and

➢ if the team gets into trouble and cannot get out of the mine, the back-up team coming to its rescue can find it by following the marked route

The route should be clearly marked by whatever method the rescue operation chooses. Methods include:

➢ fencing off the untraveled (or side) entries with physical barriers

➢ drawing an arrow with a chalk or spray paint in the entry the team has taken from the intersection pointing towards the fresh air base. The arrow should be about 12" in length and drawn on the right wall about eye level in height

➢ trailing communication lines or life lines, or

➢ opening the rail switch points in the direction of travel

Short stub intersections need not be marked with route markers if the face of the stub has been explored, dated and initialed by the Captain. All places of the team's retreat should also be marked, dated and initialed. This could be the end of the entry, cave, seal, door, or just the team's turn around in a long entry.

If the team retraces its steps, route markers should be canceled. The details and method of route markings must be understood by all back-up teams.

All team members must remain in visual contact with one another at all times. If this is not possible due to poor visibility, the members must keep in physical contact by using life lines, holding hands, carrying a stretcher, etc.

This sometimes is not possible in smaller northern mines because cages are not big enough for a whole team.

Extreme caution must be used when travelling under conditions of poor visibility.

When any work is being done by the team (e.g., building stoppings, timbering, scaling, etc.), the Captain or Vice-Captain must always be on guard against hazards or risks to the team's health and safety.

Order of travel

The Captain always takes the lead as the team advances. It is standard practice for the Captain to enter unexplored areas first to check ground conditions, mine atmosphere and temperature.

The Captain first inspects the area that the team will be entering to make sure it is safe. After the inspection, the Captain allows the team to enter the area and directs their work in it.

The Vice-Captain will always be at the back end of the stretcher or last in line. In this position, the Vice-Captain can easily keep an eye on other team members to make sure they are proceeding without difficulty and can quickly halt the team if anyone appears to be in distress.

It is recommended that the team use the least obstructed travelway and stay in the intake air, wherever possible, as it advances. In multilevel mines, the team explores level by level, usually doing the drifts first and then the sublevels and stopes.

In single-level room and pillar mining, it is standard procedure to systematically explore all crosscuts and adjacent entries as they are encountered. That way, a team is never ahead of an unexplored area where a fire or toxic gases and smoke could close in behind them and cut off their retreat to safety.

Rate of travel

The speed that a team travels underground depends on many factors, including:

- visibility (smoke)
- climbing up and down raises or ramps
- obstructions in the travelways such as
  - parked machinery
  - cave-ins
  - water, and
  - slippery footing, etc.
- whether or not vehicles are available for use
- the amount of work to do (gas testing), and
- the load that the team is carrying (equipment, material, casualties, etc.)

The Captain should pace the team according to the conditions found. He should keep in mind that, if the team members have been doing strenuous work, they will be more tired and will require more rest periods on the way back to the fresh air base.

Travelling in smoke

Travelling in smoke is always difficult. Smoke will not only limit the team's rate of travel, but will also conceal hazards. Smoke can be so dense that the team will not be able to see loose backs and walls, parked equipment, or drop-offs.

For these reasons, it is recommended that team members use a link line at all times. The Captain should use a sounding stick to feel his way along and look for obstructions and hazards. If the team is exploring a wide entry and not carrying a stretcher, or when searching for injured persons, it is recommended that the other team members also use sounding sticks.

Teams working in dense smoke will sometimes encounter a phenomenon called "spatial disorientation". Dense smoke will conceal the backs, sides, or other reference points normally relied upon for guidance, causing workers to experience disorientation and lose all sense of direction and balance. Disoriented team members will then be more likely to be injured by bumping or running into things.

Visibility can be improved by removing the lamp from the cap and shining it close to the ground. High intensity lights carried by the team or suspended on vehicles can be helpful in some instances. The disadvantage of wearing a light on the hat is that the light reflecting back off the smoke close to the face tends to blind the wearer.

Travelling through water

When a team encounters water, the decision about how to deal with the problem is usually made at the control centre.

If the water is not too deep and the team can get through it without danger, then it will probably just proceed through it. On the other hand, if it is possible to avoid the water by using an alternate route, it may be best to do so.

Careful consideration must be given to problems that flooding may cause, including:

- What effect will water have on electrical equipment?
- Is the water carrying flammable or toxic gases, such as hydrogen sulfide?
- Will the water flow increase?
- Should it be pumped out immediately?
- Is the water deep enough to submerge any breathing apparatus?

Electrical safety

Only qualified electrical workers may construct, install, alter, repair or maintain electrical equipment.

To turn the power on or off:

1. Do not stand directly in front of the switchbox.
2. When pulling the switch, avert your eyes to avoid being exposed to any potential flash.

The whole team should stand back while the switch is being thrown. Be sure that you know what the results will be before throwing the switch and that the Coordinator knows your intentions.

Do not throw a switch in an explosive atmosphere. Have the power shut off from a remote location.

Blasting

Mine rescue workers should have a basic understanding of blasting, including blasting agents and detonators used at the mine. Rescue teams members should have a general knowledge of *the Saskatchewan Mines Regulations* about explosives in a mine. The rescue team should be familiar with safety requirements for the explosives magazine.

Ground control

Proper roof and rib control measures can greatly reduce the dangers mine rescue teams face.

Inspection and testing

Roof support devices include timbers, posts, roof bolts, bolts, rebar, etc. Whether supported by auxiliary devices or not, the rescue team should visually inspect the area before entering a workplace.

Inspect the roof and ribs for:

- stress cracks in roof, floor and rib
- any abnormal rock formation
- a formerly dry place that is now wet
- small chips or bark around timbers, and
- moisture or cracks that may appear in the roof long after the area has been supported

Scaling-checking backs and sides

Team members should make constant visual inspections of the back and sides for ground deterioration. Along with the visual checks, it is recommended that backs be sounded when:

- poor visibility does not permit proper visual checks
- fallen slabs of loose roofs or backs are found on the floor
- the backs have been subjected to extreme heat
- the team intends to erect a seal, line-brattice, or post
- travelling on or working any known bad ground area

If a team encounters bad ground, it may have to scale, timber, or go around the area. It is standard practice to warn others by either marking or fencing off the hazardous area. The hazardous area should also be marked on the Captain’s mine plan.

Inspect supports for:

- crossbars, timbers and posts that are bent or under heavy pressure
- roof bolts that show signs of stress
- cap pieces squeezed down and over posts, and
- timbers decayed through time

Roof support devices

Roof support devices can be either temporary or permanent. Temporary supports may be timbers with cap blocks, screw type jacks, or hydraulic jacks. Temporary supports are used to support the roof:

- before and during installation of permanent support at the face
- during advance mining
- when cleaning up after a roof fall
- when replacing, adding, or removing permanent supports, and
- to ensure safety during pillar removal

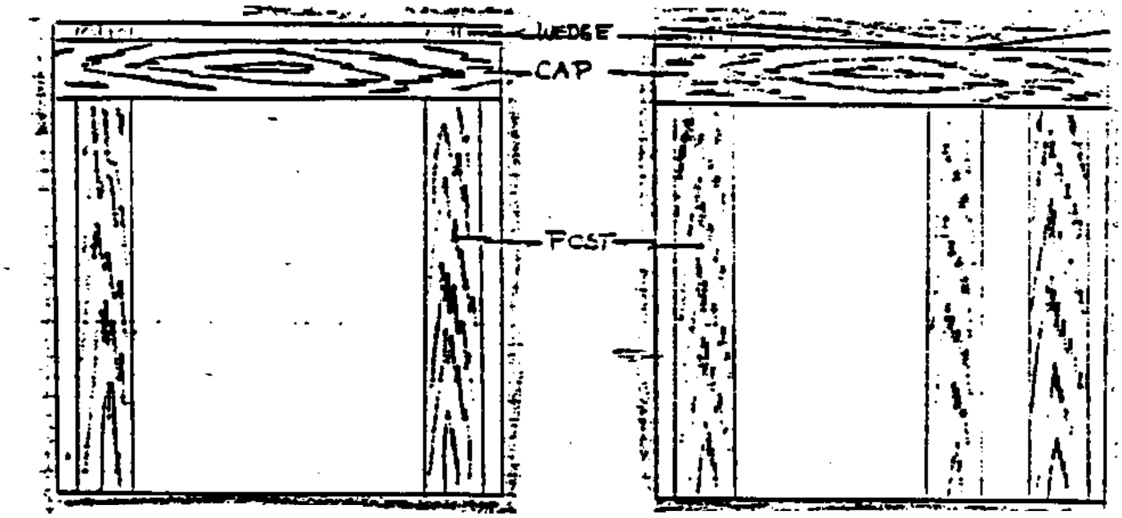
Temporary supports should be no more than five feet apart. The roof should be tested and loose material taken down with a scaling bar before temporary supports are installed.

The most common type of permanent roof support is the roof bolt. The conventional roof bolt is installed using a drill on a roof bolting machine. Another type of roof bolt is the rebar or resin (glue) bolt. To install a resin bolt, a hole is drilled as for conventional roof bolts. Then, long tubes of resin are inserted and the bolt is forced into the hole, breaking the tube. The bolt is held in place until the resin hardens.

In addition to roof bolts, various types of timber supports are used. Timber supports are called “conventional roof supports.”

Timbering

The following is one method of installing a timber set.



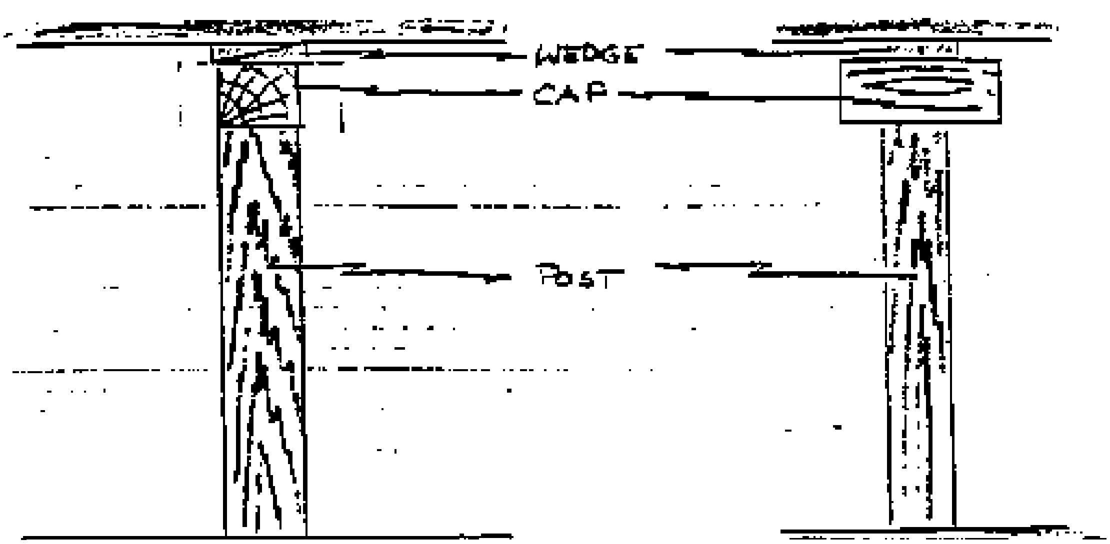
Timber Set

Modified Timber Set

Figure 5-2: Timbering

Installing a post

The following is one method of installing a post.



Side View of Timber Set

Single Post Prop

Figure 5-3: Installing a post

Testing the mine atmosphere

One of the most important considerations in mine rescue and recovery work is the condition of the mine's atmosphere. To determine the condition, you must monitor the atmosphere and find out if there are any harmful gases and what the volume and direction of the airflow is.

Mine rescue teams should never alter ventilation systems without direct orders from the control centre, unless the effects are known and all the people in the area are accounted for.

Unauthorized or unplanned changes in ventilation could:

- force deadly gases or smoke into areas where survivors are located
- force explosive gases over fire areas or hot spots
- cause an explosion
- redirect oxygen laden air into a fire, or
- change the ventilation status of the fresh air base

Gas detection

A team will make frequent tests for gases as it advances beyond the fresh air base. It will be necessary to determine what harmful gases are present, how much oxygen is in the atmosphere and whether or not gas levels are within the explosive range.

Testing is done with portable gas detectors, such as a:

- multi-gas detector in conjunction with the appropriate tubes
- direct readout detector
- methane monitor, or
- flame safety lamp

These tests should be made at each intersection and at the furthest point of travel into each entry.

It may also be necessary to conduct gas tests when the team travels through a door or bulkhead beyond which conditions are not known.

Sampling is done more often when potentially dangerous gas conditions are found.

Passing through ventilation doors and stoppings

A Team Captain should never alter any doors and ventilation stoppings unless he receives definite instructions to do so from the Coordinator.

When passing through ventilation doors and stoppings, follow these procedures:

1. On coming to the closed door, the Captain should halt the team and find out if anyone is behind the door by knocking on it.

2. Before the door is opened, careful consideration must be given to the possible consequences of opening it. Will opening the door:

    - alter the direction and volume of airflow enough to force toxic gases into an area with trapped workers
    - provide fresh air to incipient fires
    - destroy a needed air lock, and
    - if there are double doors, can the condition of the other door be determined

3. The Captain should carefully try to determine the conditions behind the closed door by first feeling it for heat, or by looking through any regulators, man-doors, or windows.

4. If there are no double doors to provide an air lock, it may be necessary to erect a back seal or safety seal to create one.

5. The Captain or the Vice-Captain will open the door. The Vice-Captain will hold or secure the door while the Captain carefully leads the team through. The Captain will then halt the team, the door will be closed and the Vice-Captain will resume his position with the team.

Similar precautions are taken when a team passes through a ventilation stopping. Again, a safety seal will have to be erected to prevent an inadvertent change in the airflow or contamination of the unexplored area.

Once a team has passed through a door or a ventilation stopping, the door or stopping must be restored to its original position. These precautions should be observed whether a team travels with a vehicle or on foot.

Opening seals, barricades or doors

Opening a miner's seal

Two methods can be used to rescue personnel taking refuge behind a seal, barricade, or door. One way is to have personnel wear respiratory protective devices and the other is by ventilating the contaminated area and bringing the workers out bare-faced.

It is always desirable to first ventilate the area, but this may take some time.

Using respiratory protective devices is much faster, but two precautions must be taken:

1. The trapped workers must be familiar with the respiratory protective devices.
2. An air lock must be built to ensure workers are not exposed to a burst of contaminated air when the door or seal is opened.

If workers are unfamiliar with the protective devices, or when such devices are unavailable, or cannot be worn due to injuries, it will be necessary to ventilate the contaminated area and bring the trapped personnel out bare-faced.

Bare-face exits require clearing the contamination by ventilation or erecting a line-brattice.

If a seal has not already been installed, a secondary or double seal should be erected against the miner's seal to make it air tight. This prevents the possibility of forcing contaminated air through the original miner's seal with the line-brattice.

Before an attempt is made to rescue the workers from behind the seal, the entry should be checked for toxic gases with a gas detector. Testing helps make sure that the workers can be brought out in safety. (See also "Rescuing survivors found behind a seal").

The procedure for opening a barricade or seal that has been erected to control a mine fire is entirely different than the procedure for opening a miner's seal. Opening a barricade or seal built to control a mine fire must only be done with the explicit orders and instructions of the Director of Rescue Operations. These procedures are explained in Chapter 4, "Dealing with Mine Fires".

Stretcher procedures

When exploring a mine on foot, supplies used by the team are usually carried on a basket type stretcher. The stretcher is also available for transporting injured workers found in the mine or an injured team member.

The work expected of the team and the situation in the mine determines the supplies and equipment that the team takes with it.

Unnecessary equipment on the stretcher only tires the bearers. Equipment that a team might take along includes:

- gas detectors
- air sampling instruments
- communication equipment
- long-link line or rope
- scaling bar
- first aid supplies
- fire extinguisher
- blankets
- sufficient quantity of brattice
- tools: axe, hammer, nails, spad gun and spads, shovels, etc.
- breathing protection for missing workers
- two self-rescuers for the mine rescue team, and
- spare oxygen bottles for breathing apparatus

Four team members should share the load of the stretcher whenever the width and condition of the roadway permits. Frequent rests should be taken and team members allowed to change hands on the stretcher.

At times, narrow roads and pathways may mean only two team members are able to carry the stretcher. Under such circumstances, more frequent rests and rotation of stretcher carriers will be required.

A stretcher limits the material and equipment a team can take on a mission. Carts or vehicles should be used when possible.

Link lines and safety lanyards

The link line, which could be a rope or lanyard, is a device used to keep team members from becoming separated.

The members of the rescue team should be fastened together by means of an approved link line or safety lanyard when travelling in atmospheres where visibility is limited or may become so.

In some emergency situations, the link line may become a hazard. For example, when carrying a stretcher in cramped entries or giving first aid to a victim, it is permissible to disconnect the link line if team members keep in touch by some other means. Team members can maintain physical contact with each other by holding hands, or by hanging on to a life line or stretcher at all times.

Important: Team members must never become separated when visibility is poor!

Changing oxygen cylinders

If the air in a team member's oxygen cylinder runs out, the cylinder must be replaced. The steps in changing an oxygen cylinder are:

1. Remove the back cover; then use the bypass to fill the breathing bag or chamber.
2. Turn off the cylinder and use the bypass to bleed the line.
3. Once the line is bled, remove the cylinder and replace with a full one from the stretcher.
4. The new cylinder will pre-flush the system when opened.
5. Securely tighten the cylinder and then turn it on.
6. Replace cover.

Important: if the spare cylinder has to be used, there is a problem with the equipment and the team must immediately return to the fresh air base.

Diesel vehicles in mine rescue

During a mine disaster, time is of the essence. Often a mine rescue team can be better used if it travels over long distances using two diesel-powered vehicles. This requires some deviation from the procedures normally followed by a team.

Some allowance for procedural changes has to be made, but these changes must not be so critical as to endanger a team. Normally, the condition a team finds in the mine will dictate the procedures to be used. All procedures should be based on common sense and sound mine rescue principles so that the safety of the team and any workers in the mine is not endangered.

The advantages of using diesel vehicles during a fire are:

- speed; teams can accomplish more work in less time
- more equipment for fire fighting and first aid can be carried
- less tiring for team members as they do not have to carry a stretcher, tools and material
- heavier, more sophisticated, modern gas monitoring devices can be carried
- it is easier to transport casualties
- vehicles can be equipped with long-duration respiratory protective equipment for evacuating trapped and injured workers, and
- vehicles can be equipped with high intensity lighting and heat sensing devices making it easier to locate workers or fires

The disadvantages of diesel vehicles are:

- danger of travelling too great a distance from fresh air base; should the vehicle fail, the team might have to return on foot thereby overstaying time limits
- going too fast may result in overlooking ventilation checks at an intersection where smoke could cut off retreat
- possibility of vehicle failure
- teams may split up when using two or more vehicles
- seats on regular vehicles not suitable for personnel in apparatus
- specialized vehicles and equipment are usually not available in an emergency, and
- not suitable in atmospheres containing heavy smoke or explosive gases

Several types of diesel-powered vehicles are used for mine rescue work in Saskatchewan. Ordinary personnel carriers with seating modifications are used primarily for transportation. Others are sophisticated, custom built units used for firefighting and rescue.

Personnel carriers

Ordinary long-wheel base personnel carriers have been used satisfactorily in emergency situations. The only modification required is an alteration to the back of the driver's seat to allow comfortable operation while wearing an apparatus. The rest of the team members normally ride in the back of the vehicle with the stretcher.

Custom built vehicles

Several custom built vehicles are in use. These are not standard designs, but are built and equipped in accordance with the respective mine's specifications. These units may include a variation of the following:

- seating capacity for at least five members of a mine rescue team wearing SCBAs
- sufficient room for a stretcher and one or two casualties
- fire fighting equipment (portable dry chemical, extinguishers, large dry chemical tanks, AFFF solution, etc.)
- first aid boxes, splints and resuscitators
- high intensity lighting and spot lights
- equipment and material for erecting stoppings
- auxiliary breathing protection (self-rescuers, facepieces and large air or oxygen cylinders)
- scaling bars, axes, etc., and
- jacks

Guidelines for using vehicles

Several procedures for using diesel vehicles in mine rescue work have been developed because every mine has its own, unique features.

The following procedures should be thought of as "guidelines" rather than "rules":

- The team should use two vehicles in case one breaks down.
- Members should be split-up with at least two persons on each vehicle.
- The distance between the vehicles should be as short as possible so that they can constantly communicate.
- Contact can be maintained by two-way radio, hand held horns, vehicle horns, lights and hand signals.
- The Captain should be on the lead vehicle and the Vice-Captain on the trailing vehicle.
- The Captain and Vice-Captain should not be driving the vehicles.

Vehicles should not be used in heavy smoke. Teams should park the vehicles in good air and continue on foot where practicable.

Travel should be done in fresh air wherever possible. It is possible to travel in light smoke, but caution must be observed.

All contact points with the fresh air base must be prearranged. The Captain should make progress reports at these points and at regular intervals.

The distance traveled and the time required to walk this distance should be marked on the Captain's and Fresh Air Base Coordinator's plans. This gives the team an idea of how long they will have to travel on foot to get to the fresh air base if the vehicles break down or are abandoned for any reason (e.g., smoke, breakdown).

If the location of the fire and the contaminated areas are unknown, the approach must include the systematic exploration of all cross-cuts and adjacent entries. That way, as the team advances, it is never ahead of an unexplored, dangerous area. One vehicle is stationed at the main entry while the other inspects the cross-cuts. Both units must constantly be in contact with each other.

If the problem area is known and there is no danger of being "cut-off" by smoke, the team can proceed directly to it.

Routes should be marked in the same manner as when travelling on foot. If the team is travelling in good air on the main route, it may not be necessary to fence off or mark every intersection, providing the Captain travels directly to the prearranged contact points and reports.

Continuous gas monitoring using direct read out gas analyzers can be carried on while the team advances. Tests can be made without getting off the vehicles, thereby saving time.

Vehicles should not be used in atmospheres containing highly explosive gases.

Tests have been made to determine the least amount of oxygen that diesel vehicles need to operate. In one test, the engine was still running in 13 percent oxygen, but the engine heat was almost unbearable for the operator.

Experience shows that diesel engines can be successfully used in mine rescue work, but they have to be used with discretion and careful planning by those in charge of the mine rescue operation.

Care of survivors and recovery

While rescuing survivors may be the most rewarding job a rescue team does, no one enjoys recovering bodies. There is very little one can do to prepare for the associated emotional trauma.

Searching for survivors

Several questions should be asked before a rescue team enters a mine:

1. How many workers are missing?
2. What areas were they supposed to be working in?
3. Where are their escape routes?
4. Where are the workers likely to take shelter?
5. Where are the refuge stations? What supplies do they contain?
6. Are there any areas where the workers might go to obtain fresh air?
7. What is the company's evacuation procedure?
8. How much mine rescue and first aid training do the workers have?
9. What rescue supplies are available or stored in the mine? Where?

Survivors may be found in open entries, escape routes, shops, or refuge stations. They may be injured and unconscious, or apparently healthy and walking around. They may be trapped behind or underneath a piece of equipment, rock falls, debris, or other obstructions. They may have sealed themselves off behind seals or barricades. In hard rock mines, workers have often been found on the ramp.

It is important to both LOOK and LISTEN for clues when the team is searching for survivors. Survivors will often try to leave indications of where they are seeking shelter. These clues could be in the form of notes placed on equipment. There might be chalk or paint marks on the walls or doors. They may leave clues like covers from self-rescuers lying in the travelways.

The rescue team should listen for noises, such as voices, or pounding on equipment, pipes, rails, walls, or cave-ins. When survivors are located, their location, identities and conditions should be reported immediately to the control centre and recorded on the mine plan.

Extrication equipment: A hazards analysis should be done at every mine to determine the probability of accidents where extrication equipment may be required by mine rescue teams. Where such equipment may be required, it must be made available to rescue teams. Members of the team must also be trained in the use of such equipment.

Technical rope rescue: A safety hazard analysis should be conducted at each mine for potential rope rescue requirements. If technical rope rescue is needed for mine rescue and recovery operations, established procedures must be followed such as those set out in the CMC Technical Rope Rescue training manual. The training must be given by an instructor qualified in Technical Rope Rescue.

Rescuing survivors found behind a seal

Survivors that have taken shelter behind a seal or in a refuge chamber should not be taken from this shelter until the route to the fresh air base is safe. An exception would be made if the survivors need immediate medical attention or their shelter is in danger. In such cases, the Captain determines the severity of the situation, sets priorities and issues instructions accordingly. For example, the Captain might deem that giving emergency first aid to stop severe bleeding or supplying survivors with respiratory protection is the immediate priority of his team. Normally, the seal or the refuge station door is not opened unless absolutely necessary.

When a rescue team comes across a miner's seal in a contaminated entry behind which survivors have taken refuge, the Captain will knock on it to determine the number of survivors and their condition. The seal should then be examined for air leaks to ensure that gases do not enter the refuge. There are three courses of action that the Captain must consider:

1. Leave the survivors behind the seal. When the survivors are safe and the route to fresh air is contaminated, it may be best to leave them where they are until the air is cleared. A secondary or double seal should be erected and the survivors reassured before the team leaves them. Double sealing would also protect the miner's seal from changes in ventilation pressure during the ventilating process.

2. Remove the survivors immediately. When survivors are in immediate danger or require emergency first aid and respiratory protection, the team may have to go through the seal without erecting an air lock. This decision would be made 'on-the-spot' by the Captain. Survivors would be warned to move away from the seal, if possible. The seal should then be opened just enough to admit a couple of the team members and then quickly resealed to prevent contamination of the refuge area. The survivors are then treated, supplied with respiratory protection and removed if necessary.

3. Remove the survivors at the team's convenience. When the team evacuates the survivors, two methods can be used. If the air in front of the seal is tested and found to be free of contaminants, the team will simply take down the seal and evacuate the survivors. If the atmosphere in the vicinity is contaminated, an air lock will have to be erected. The air lock should be placed as close as possible to the miner's seal. Again, an opening just large enough to permit entry should be made and quickly closed after the team passes through. The survivors can now be fitted with respiratory protection and taken to the fresh air base.

Survivors must be physically able to wear such breathing apparatus properly. Care should be taken to ensure that there are no facial injuries or vomiting. In such situations, it is best to leave the survivors in a refuge station or behind the seal until the mine is ventilated.

The mine rescue team must be certain that the survivors are trained and know how to use the breathing apparatus that they are expected to wear. Survivors may panic and attempt to remove their breathing apparatus while travelling in a toxic atmosphere.

Caring for survivors

When survivors are found, it is important for the team Captain to determine their physical condition and the condition of the atmosphere around them.

The Captain must determine exactly what the team has to do to protect the injured and what treatment to give.

If the atmosphere is questionable or dangerous to life, immediate respiratory protection must be provided. If possible, survivors should be moved to a location with a good air supply for treatment. Whenever safe passage to the fresh air base is not possible, the survivors should be taken to good air (e.g., in a refuge station, shop, dead end entry, etc.) and isolated until the entries are ventilated. Seals may have to be erected for this purpose. If safe passage to the fresh air base is available, the survivors should be immediately taken there.

The rescue of survivors depends on prevailing conditions. Care must be taken not to expose survivors to further harm. Survivors must be reassured that they will be properly looked after. First aid must be properly and promptly administered to all of the injured.

When survivors are found, their behavior may range from apprehension to hysteria. The best way to relieve psychological stress in survivors is to talk with them as soon as possible. It is most important that the talking and reassuring be continued. Survivors who lose contact with a rescue team may feel abandoned and try to escape to fresh air, even though it is unsafe.

It may be necessary to physically restrain irrational survivors to prevent them from injuring themselves or others. Above all, survivors should not be left alone.

Similarly, survivors should never be allowed to walk out on their own even if they appear to be in good shape. They need the support and assistance of team members when leaving the mine. Team members may even need to restrain an individual to prevent him from “bolting” for fresh air as it is neared.

If a survivor is able to walk, he should be positioned between two rescue team members and guided out. If the person is unconscious or unable to walk, use the stretcher.

First aid tasks

The mechanics and function of breathing: Many gases found in a mine during normal times are toxic even if inhaled for a short period of time in concentrations above the recognized safe limit.

At the time of a fire in an underground mine, great quantities of deadly gases can be quickly released. The biggest problem confronting the miner during a fire is protection from toxic gases.

Even during normal operations, circumstances can cause gases to build up that make the air harmful to breathe.

Most dangerous gases have a harmful effect when being inhaled. Understanding what happens when we breathe helps us understand what must be done and why, to protect ourselves from dangerous gases.

<u>The mechanics of breathing:</u> When we inhale, the diaphragm and chest muscles pull away from the lungs. This has the same effect as the bellows on an accordion when they are pulled open. A vacuum is created in the lungs by this chest expansion and the outside air rushes in to fill the vacuum.

The air enters the body by way of the nose and throat (pharynx), passes through the voice box (larynx) and travels down the wind pipe (trachea) and bronchial tubes to the lungs.

When we exhale, the muscles of the chest and the diaphragm push in against the lungs. Again, this has the same effect as when we push in on an accordion bellows. The air is forced out of the lungs, taking the same path to the outside as it took on entry.

Obviously, air can only get to the lungs if the passage ways are clear of obstructions and the muscular action needed for expansion and contraction of the chest cavity takes place.

Some gases, when inhaled, can cause air passages to swell and become obstructed. These gases can also interfere with the muscular action that moves the chest and diaphragm.

The muscular action that causes us to breathe is controlled by a portion of the brain at the base of the skull. This portion of the brain is stimulated and controlled by the amount of carbon dioxide gas in the blood.

In summary, the mechanics of breathing are like a bellows. When the bellows contract, air is forced out. When the bellows expand, air is sucked in by the difference in air pressure. The bellows of our lungs are expanded and contracted by our chest muscles and diaphragm. Before air can enter the lungs, these muscles must be free to work and the passage ways clear of obstruction.

<u>The function of breathing:</u> Normal air contains a certain amount of oxygen and oxygen is required for life. Breathing secures the oxygen that our bodies require. Lungs make the oxygen available for use by the body.

Just as a fire cannot burn without oxygen, the energy-producing combustion and bodybuilding processes cannot occur without oxygen. Without oxygen, our bodies die.

When oxygen enters the lungs, it is distributed to the millions of tiny air sacs that make up the lungs. These tiny air sacs, or compartments, have walls so thin that the oxygen can pass into the blood itself.

Blood is composed of red and white cells carried in an almost colorless liquid called plasma. A part of the red cell called hemoglobin (pronounced heem-o-glow-bin) attracts oxygen.

As blood circulation brings the red cells into contact with the air sacs of the lungs, the oxygen is attracted to the hemoglobin. The hemoglobin then carries the oxygen throughout the body, where it is used in the energy-producing combustion of the digested food stuffs.

On the blood's return trip to the lungs, it carries the carbon dioxide which is a waste product of the combustion of food. As the blood passes the air sacs in the lungs, it picks up more oxygen and the carbon dioxide is forced out of the blood into the air sacs. The carbon dioxide is then breathed out when we exhale.

Simply put, as we breathe, fresh oxygen is added to our blood and carbon dioxide filtered from it, through the air sacs in the lungs.

Anything that interferes with the steady flow of oxygen to the tissues of the body will slow down or damage the body's function.

Oxygen therapy: Oxygen therapy is the administration of 100 percent oxygen (by inhalation) to victims of asphyxia from gases, smoke fumes, drowning, collapse, suspended respiration from electric shock, oxygen deficiency and other causes. Oxygen given to a casualty is considered to be a drug and the rescuer must be trained and certified to administer it.

Oxygen therapy units are classed under two headings:

1. Those which act as inhalators only; and
2. Resuscitators that provide artificial respiration by mechanical control of the oxygen bottle pressure. These may also be used as an inhalator if resuscitation is not required.

<u>Oxygen inhalation equipment:</u> The inhalator consists of a 300 litre capacity "D" oxygen cylinder capable of delivering at least 10 litres of oxygen per minute. It is normally equipped with a yoke, pressure gauge, flow meter, delivery tube and a semi-open, valveless, disposable mask.

<u>Resuscitators (oxygen-powered mechanical breathing devices):</u> These are oxygen-powered devices that apply artificial respiration automatically and meet CSA standards. The older style resuscitators (with the manual push button) should not be used for resuscitation.

In recent medical evaluation the following advantages of oxygen-powered devices were cited:

- simplicity
- delivery of 100 percent oxygen
- two hands can be used to maintain a mask fit
- high flow rates permitting adequate ventilation in spite of the mask leaks
- eliminates personal contact with the victim
- in an emergency, the IDLH masks can be used for hazardous atmospheres during mine rescue and recovery operations (See the section on rescue of workers who have taken refuge), and
- the casualty can be transported in a basket stretcher while being resuscitated

The disadvantages include:

- the lack of ready availability of the units, and
- their dependence on compressed oxygen as source

Fatalities

When the team encounters a body, its location is reported to the control centre, mapped and marked on the mine plan. Regulatory agencies must be notified.

Every effort should be made not to disturb the body or any possible evidence in the area. If it is absolutely necessary to move a body, it should be outlined with chalk on the floor, or the floor marked to show where the head and feet were. If there is more than one body, an identifying number is usually given to each.

Unfortunately, there is little that prepares a rescue team for what they will encounter while recovering a body. Team members should expect to see some very unpleasant sights. In some cases, bodies will have no obvious injuries, while others may be badly burned, or disfigured, or even dismembered. In addition, after death, the body goes through various changes and stages of decay.

Debriefing

When the team returns to the fresh air base, the team Captain talks with the Fresh Air Base Coordinator and the Captain of the incoming team. This consultation is done to exchange information about what the team, saw, found and the work it did. Maps are also compared to ensure that the markings correspond.

Debriefing is a very important part of a rescue team's work. Often, significant details that appeared to be unimportant while the team was underground, or were simply overlooked in the report to the fresh air base, come out during the debriefing.

After debriefing, the Captain of the team should discuss the next tasks to be undertaken with the Coordinator and the incoming Captain. He should point out any problems and warn of hazards still in the mine. Finally, before discharging the team, the team members should be briefed on how to deal with media representatives. No statements about an emergency should be made to the media by team members until a full investigation has been carried out.

Defusing and critical incident stress debriefing (CISD): Following the completion of a mine rescue emergency response, a critical incident stress debriefing should be conducted with all personnel directly involved in the response. This CISD should be held within six hours of the end of the emergency response and be facilitated by a qualified professional.

Chapter Six - Survival Program

Recognizing emergencies

Mine workers must always be on the alert for unusual occurrences or emergencies. Early identification of a problem and the response to it, can mean the difference between life and death for everyone in the area.

It is extremely important that every worker be able to recognize the early signs of an imminent emergency, such as a fire, inrush of water, severe fall of ground, or an unusual gaseous condition.

The following are some of the signs or indications of possible emergencies:

- sudden changes in ventilation
- blasts of air, caused by a fall of ground or inrush of water
- the odours of smoke or other contaminants
- unusual noises or explosions
- interruption of normal services such as power failures
- fire alarm/emergency warning system such as stench gas
- visual or audio warning, and
- unusual hurrying of workers

> **Important:** Any of these signs could mean that something irregular or dangerous has happened and that quick action may be necessary to prevent loss of life.

Upon discovering a problem a worker should:

- Investigate the problem or report to the supervisor who should take control.
- If the supervisor is unavailable and an alarm has still not been activated, an effort should be made to phone the hoistman, dispatch centre, or mine officials.

If the situation is such that the worker believes that evacuation is warranted, or anytime the fire alarm warning system is activated, all work should cease. Workers should, without delay, implement the emergency procedures that are outlined in the company's emergency procedures manual.

Important: Normally, workers should not attempt to make their way to safety through smoky and heavily contaminated areas while wearing only the filter-type self-rescuers. Filter-type self-rescuers will only provide respiratory protection against low concentrations of carbon monoxide. They do not provide protection against various other gases or an oxygen deficient atmosphere. A worker is usually far better off taking refuge behind a barricade in a safe and uncontaminated entry.

During a mine emergency, workers with basic knowledge and proper emergency training, who act in a calm, rational manner, have an excellent chance of surviving.

Self-rescuers (filter-type)

General

"Self-Rescuers" are onetime use devices used for escape purposes only. The types commonly used are the:

- MSA W-65, and
- Dräger FSR-810.

Rugged construction allows both to be carried by workers or mounted on mobile equipment ready for instant use. As part of underground orientation for workers, the mine employer must familiarize each worker with the emergency procedures and the rescue equipment available. This includes self-rescuers available in the mine.

Follow the manufacturer's instructions for use of self-rescuers.

Filter-type self-rescrurers

This type of rescuer consists of a small canister with a mouthpiece directly attached to it. The wearer breathes through the mouth, while the nose is closed by a clip. Filter-type carbon monoxide self-rescuers do not protect against noxious gases or a deficiency of oxygen.

The presence of carbon monoxide in the air is indicated by heat generated in the self-rescuer when it is being worn. Both types of respirator will provide adequate protection for 60 minutes in air with a one percent concentration of carbon monoxide.

At one percent or higher carbon monoxide concentrations, heat generated by the chemical reaction with the hopcalite in the self-rescuer will make breathing practically unbearable. All units have a built-in heat exchanger to help reduce the temperature of the air reaching the wearer's mouth.

Figure 7-1: Wearing the MSA W-65 Self-Rescuer

Self-Contained Self-Rescuers (SCSR)

A self-rescuer has or is able to generate its own supply of oxygen. Types commonly used are the MSA Auer SSR30/100 and the Ocenco M-20. These are generally good for 20 minutes to one hour of use, depending on the type and how hard the wearer is working.

Rugged construction allows SCSRs to be carried by personnel while at work or be mounted on mobile equipment ready for instant use. These units are compact and isolate the user's lungs from the surrounding atmosphere. They use compressed or chemically produced oxygen to provide respiratory protection. These are easy to activate and don.

> **Important:** The self-rescuer must be kept on and used, regardless of the heat generated, until the wearer reaches safety.

Taking shelter behind seals

When workers have been trapped by fire in a mine, they must not rush about aimlessly. All workers in an emergency must take immediate action to protect themselves.

When the way of escape is cut off, but the local atmosphere is still uncontaminated, consideration should be given to building a temporary refuge. The refuge will isolate the workers from the air in the rest of the mine and provide a safe location where they can wait for the rescue teams to arrive.

If the worker is in a dead-end entry, it may be possible to get temporary protection by short circuiting the airflow to the face by:

- shutting off the local auxiliary fans that supply air to the face
- breaking the ventilation ducting
- breaking the line-brattice
- tearing down the brattice stoppings at intersections, cross-cuts, or breakthroughs and redirecting the airflow, or
- opening the compressed air line (many lives have been saved this way in hard rock mines)

For maximum safety, seals or barricades are required. They should be erected without delay as dangerous gases often travel quickly. The time required to build an efficient seal depends on conditions in which it is being built.

Anything that might be useful for erecting the seal, or needed while in isolation, should be collected, including items such as:

- tools
- timber
- canvas
- ventilation tubing
- brattice material
- water
- lunch kits, and
- lights, etc.

The area chosen for refuge should meet the following requirements:

- If compressed air is not available, the area should enclose the maximum practicable volume. Each person uses approximately one cubic metre of air per hour (Figure 7-2). The sealed area should include as much territory as possible, including long entries and cross-cuts.

- Before constructing seals, make sure there are no other openings or connections to other workings that gases can enter through. It may be necessary to construct seals at more than one end of the entry.
- If possible, the sealed area should include a telephone and compressed air line and valve. The telephone allows trapped workers to talk with the mine officials on surface. The air line supplies compressed air to the refuge area.

Seals can be constructed of any material that is available, such as:

- brattice seals
- cut up ventilation tubing
- canvas
- cloth, or
- timber

In potash mines, most work areas should be stocked with an ample supply of brattice, spad guns and spads for such emergencies.

After the seal has been built, the workers should keep as still as possible. People use several times more oxygen when exerting themselves as they do when at rest. However, one person should walk around occasionally to mix the air. Workers should not gather in one place. Electric batteries, water and food should be conserved.

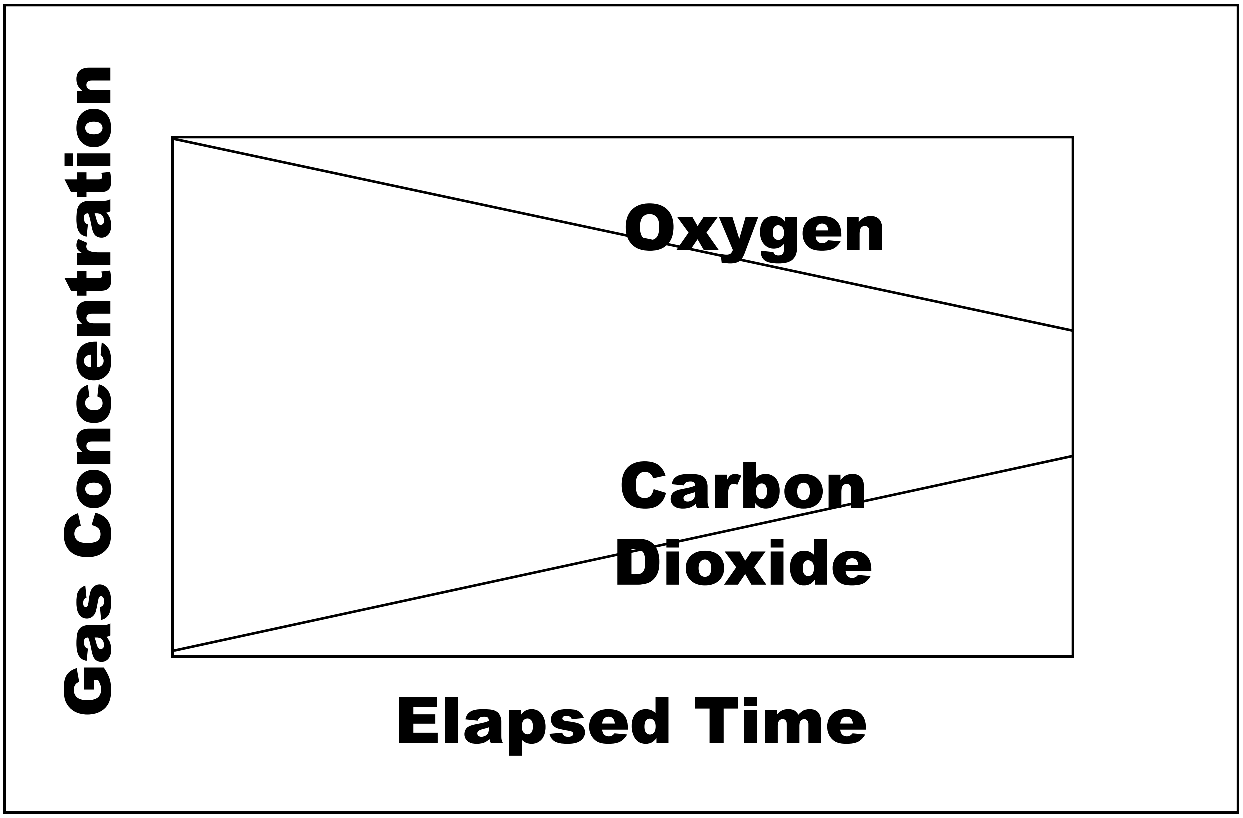
Smoking must be prohibited!

Before going into isolation behind the seal, workers should try to get a message to the surface. Such a message would report:

- where the workers are trapped
- the names and numbers of trapped workers, and
- their condition

A sign should be also placed outside the stopping giving the names and tag numbers of the workers inside. If circumstances permit and materials are readily available, a second seal should be erected inside the first to provide an air lock.

Under no circumstances should workers attempt to leave their place of refuge! They must stay in the refuge until the rescue team or supervisor comes for them.



The oxygen concentration decreases and the carbon dioxide concentration increases in a sealed inhabited area

Figure 7-2: The effects of oxygen and carbon dioxide in an enclosed area

Refuge stations

Every underground mine in Saskatchewan must install, equip, operate and maintain such refuge stations as are necessary to protect the workers.

Permanent refuge stations must be provided with food, water, air, first aid supplies and telephone communications to surface. Temporary refuge stations contain more limited supplies, but communication with the surface is also required.

Refuge stations vary in size and should have the volume to provide air for a large number of people without any additional supply of fresh air or oxygen. As a general rule, where there is no source of compressed air, a worker at rest will require 1 cubic metre of air per hour. In the hard rock mines, refuge stations are smaller than in the potash mines but they are supplied with compressed air lines from surface.

In all cases where workers are forced to seek refuge, proper procedures must be employed:

- Workers should carry their lunch and water, as well as available respirators, to the station.
- Communication should be established with the surface.
- The location of the refuge station and the number and names of the workers in it should be reported as soon as possible.
- All nonessential activity in the station must stop to conserve oxygen and reduce CO_2 production.

Once the station is sealed, workers in the station should not emerge until the atmosphere outside the station is checked by mine rescue teams or the “all clear” is given by the authorized authorities.

The types of refuge stations provided in Saskatchewan are as follows:

Permanent type: Usually a stub or drift is cut in the rock and closed at each end with permanent bulkheads and man doors. This type of refuge station is usually strategically located and is large enough to accommodate all the workers in the area.

Portable type: Portable or moveable steel or fiberglass enclosures are usually provided for remote areas in the mine and where travel to a central refuge station is uncertain or unsafe. These units are small enclosures designed for from six to ten workers. They are usually located very close to a work area. This type of refuge station is generally equipped with compressed air or oxygen and a CO_2 absorbent to compensate for the limited air content.

Appendix A
Conversion formulas

To convert	Into	Multiply by
atmospheres	ton/square inch	0.007348
atmospheres	feet of water	33.90
atmospheres	inch of mercury	29.92
atmospheres	pounds/square inch	14.70
atmospheres	tons/square feet	1.058
bars	atmospheres	0.9869
bars	pounds/square inch	14.50
Btu	kilogram-calories	0.2520
bushels	cubic metres	0.03637
centigrade	fahrenheit	$(c^0x9/5)+32$
centilitre	cubic inch	.6103
centimetres	inches	0.3937
centimetres of mercury	pounds/square inch	0.1934
centimetres/sec	feet/min	1.1969
centimetres/sec^2	feet/sec/sec	0.03281
cubic centimetres	cubic feet	3.531×10^{-5}
cubic centimetres	cubic inches	0.06102
cubic centimetres	cubic yards	1.308×10^{-6}
cubic feet	cubic centimetres	28,320.0
cubic feet	litres	28.32
cubic inches	cubic centimetres	16.387
cubic inches	litres	0.01639
cubic metres	cubic feet	35.31
cubic metres	cubic yards	1.308
cubic yards	cubic metres	0.7646
cubic yards	litres	764.6
fathom	metre	1.828804
feet	centimetres	30.48
feet	metres	0.3048
feet	millimetres	304.8
feet/minute	metres/minute	0.3048

To convert	Into	Multiply by
gallons	cubic centimetres	3.785.0
gallons	cubic metres	3.785×10^{-3}
gallons (imperial)	litres	4.5460
gallons (US)	litres	3.785
grams	ounces	0.03527
grams/litre	parts/million	1,000.0
horsepower(metric)	horsepower	0.9863
	(542.5 ft. lb/sec)	(550 feet lb/sec)
horsepower	horsepower (metric)	1.014
	(550 feet lb/sec)	(542.5 ft. lb/sec)
inches	centimetres	2.54
inches of mercury	atmospheres	0.03342
kilograms	pounds	2.2046
kilograms	ton (long)	9.842×10^{-4}
kilograms	ton (short)	1.102×10^{-3}
kilometres	feet	3280.84
kilometres	miles	0.6214
kilopascals	pounds-force per square foot	20.8854
litres	cubic feet	0.03531
litres	cubic inches	61.02
litres	gallons (imperial)	0.2201
metres	feet	3.2808
metres	inches	39.37
miles	kilometres	1.6093
miles/hour	centimetres per sec	44.70
ounces	grams	28.3495
ounces (fluid)	litres	0.02957
pounds	grams	453.5924
pounds	kilograms	0.4536
pounds-force per square foot	kilopascals	0.0479
quarts (liquid)	litres	0.9463

To convert	Into	Multiply by
square centimetres	square inches	0.1550
square feet	square metres	0.0929
square inches	square millimetres	645.16
square kilometres	acres	247.1
square kilometres	square miles	0.3861
square metres	square feet	10.7639
square metres	square inches	1,550.
square metres	square yards	1.196
square miles	square kilometres	2.590
square yards	square centimetres	8,361.
square yards	square metres	0.8361
temperature (F^o)	temperature (^oC)	($F°$-32) x 5/9
ton (long)	kilograms	1,016.
ton (long)	pounds	2,240.
tonne (metric)	kilograms	1,000.
tonne (metric)	pounds	2,205.
ton (short)	tonne (metric)	0.907
yards	centimetres	91.44
yards	metres	0.9144

Conversion of TLV's in ppm to mg/m^3:

Where 24.04 = molar volume of air in litres at Normal Temperature and Pressure (NTP) conditions (20^oC and 760 torr), giving a conversion equation of:

$$\text{TLV in mg/m}^3 = (\text{TLV in ppm})\ (\text{gram molecular weight of substance})/24.04$$

Conversely, the equation for converting TLV's in mg/m^3 to ppm is:

$$\text{TLV in ppm} = \frac{(\text{TLV in mg/m}^3)\ (24.04)}{\text{gram molecular weight of substance}}$$

Airflow Rate in Volume:

One m^3/sec equals 2,118.88 ft^3/min (cfm)

Appendix B
Abbreviations

ACGIH	American Conference of Government Industrial Hygienists
BH	Brake Horsepower
CANMET	Canada Centre for Mineral and Energy Technology
CFR	Code of Federal Regulations (USA)
CSA	Canadian Standards Association
IRS	Internal responsibility system
LTA	Lost-time accidents
MSHA	Mine Safety and Health Administration – a US government (Department of Labour) body that sees to the safety of mines and equipment used in mines
MASHA	Mines and Aggregates Safety and Health Association, Ontario, Canada

Appendix C
Units of measurement

bar	measure of pressure
bhp	brake horsepower
btu	British thermal unit – a measure of energy
cfm	cubic feet per minute (0.0283) – a measure of airflow
ha	hectare (2.47) acres
Hz	hertz (cycles per second) – a measure of electrical frequency
kg	kilogram (2.2 pounds)
km	kilometre (0.62 miles)
kpa	kilopascal – a measure of pressure
kW	kilowatt (1.34 horsepower) – a measure of power
lpm	litres per minute
m	metre (3.28 feet)
mcfs	thousand cubic feet per second (28.3m^3/s)
m/s	metres per second – a measure of velocity
m^3/s	cubic metres per second (35 cfm)
mm	millimetre
mpa	megapascal (145 psi)
Pa	pascal
ppm	parts per million – a measure of psi (pounds per square inch chemical
s	second
t	tonne

Appendix D
Glossary

8-hour average contamination limit	The time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.
15-minute average contamination limit	A 15-minute time-weighted average exposure which should not be exceeded at any time during a workday.

A

Abutment	The part of a mine that supports the strata above an opening in the mine. For example, (1) the weight of the rock above a narrow roadway is transferred to the solid ore/muck along the sides, which act as abutments of the arch of strata spanning the roadway; (2) the weight of the rock over a longwall face is transferred to the front abutment (the solid ore/muck ahead of the face) and the back abutment (the caved and settled material behind the face).
Active workings	All places in a mine that are ventilated and inspected regularly.
Airflow	The amount of air moving through a mine opening; usually measured in m^3/s (cubic metres per second) or cfm (cubic feet per minute).
Airlock	A pair of doors in an airway that permits the movement of equipment and personnel without affecting the ventilation airflow, since at least one door is kept closed at all times.
Air shaft	See ventilation shaft
Airway	Any passage in a mine along which an air current moves. Some passages are driven solely for air; others are all-purpose, to move air, personnel, materials and ore/muck.
Anemometer	An instrument for measuring air velocity.

Atmospheric monitoring system (AMS)	A system of sensors that continually samples the air at various locations underground and tests for such constituents as noxious gases, oxygen, methane, smoke, and dust. The results are transmitted electronically to a remote monitoring station and recorder, usually on the surface.
Auxiliary fan	A fan temporarily required for the effective ventilation of a working place in the mine.
Auxiliary ventilation	The process of bringing fresh air to individual working areas and exhausting contaminated air into the main return, usually accomplished by fans and ducting or by brattice.
Anxial-flow fan	A fan in which airflow is parallel to the shaft of the fan.

B

Back	The roof or upper part of any underground mining cavity.
Belt road	A roadway in which a conveyor is located.
Blind heading	The portion of a mine opening that only has a single entrance.
Boom	1. A horizontally set wooden support of the mine roof. 2. A device for lifting.
Boom truck	A flat-bed truck equipped with a hydraulic boom used for heavy lifting.
Booster fan	A fan in a mine operated in conjunction with the main fan to assist in the ventilation of the mine.
Borehole	A hole drilled in rock for any number of reasons, commonly loaded with either explosives to fragment the rock or instruments for investigation purposes.
Brake horsepower	A measure of the actual power output delivered by the crankshaft of an engine.
Brattice	A portion, often made from canvas or plastic, to direct airflow in the working areas of a mine. See also line brattice.
Bull hose	A large flexible hose that attaches pump to pipes.

C

Cable reel	A device on mobile electrical equipment that stores, winds and unwinds trailing cable as needed.
Cage	A mine elevator in which personnel and materials are transported in a shaft.
Cap lamp	The battery-operated source of light that each person working underground carries.
Carbon dioxide (CO_2)	A colourless, odourless, toxic gas formed by the incomplete combustion of carbon; the main constituent of afterdamp.
Cave	1. A deliberate collapse of the mine roof into mined-out areas; a common practice in longwall mining. 2. A partial or complete failure of mine workings. 3. A falling-in of the roof strata, sometimes extending to the surface and causing a depression there.
Chamber	The miners' working place; sometimes referred to as abreast (British) or room.
Chief mine inspector	In Saskatchewan, the person designated to fulfil certain functions under *The Saskatchewan Mines Regulations*.
Clearance	The distance from an object to the nearest point of roof, rib or floor.
Contamination limits (CLs)	*The Saskatchewan Occupational Health and Safety Regulations, 1996* limits for chemical or biological substances that an employer must take all reasonably practicable steps to ensure they are not exceeded in any area where a worker is usually present at a place of employment.
Continuous miner	A machine that cuts or rips ore directly from the face, without the use of explosives, and loads it onto conveyors or shuttle cars in a continuous operation.
Convergence	The squeezing inward of walls, floor and roof to decrease the size of a mine opening.
Conveyor belt	A moving belt that carries material, such as mined ore/muck, from one part of a mine to another.

Core	A cylindrical sample of rock obtained in diamond drilling.
Cribbing	A construction of timbers laid at right angles to each other, in log-cabin style; sometimes filled with earth or rock, as a roof support or as a support for machinery.
Cross-cut	A passage driven to connect an entry with a parallel entry or air course.
Crush	A settling of the strata overlying a portion of an excavated ore seam; generally accompanied by local falls of roof, in mine openings. See also gob.
Cut	1. To excavate ore/muck. 2. A groove excavated in the ore face preparatory to using an explosive. 3. The advance by a continuous miner into the face during one mining cycle.
Cutter roof	Longitudinal cracks in the roof of an entry caused by horizontal stresses.

D

Detonation	A violent and rapid explosion producing shock waves and very high pressure; usually associated with explosives.
Diamond drilling	Drilling boreholes with a rotating, hollow, diamond-studded bit that cuts a circular channel around a core, which can be retrieved to provide a columnar sample of the rock penetrated. The core is commonly used by geologists and engineers for prospecting and analysis.
Dip	1. The angle at which a bed, stratum or vein is inclined from the horizontal. 2. The direction of decline from the horizontal.
Downcast	A shaft or passage through which fresh air is drawn or forced into a mine or part of a mine.
Drift	An underground horizontal passage.

Drill canopy	An overhead canopy that protects a miner operating a roof bolter from material that may fall from the roof.
Drill platform	An elevated platform on which the driller stands during roof bolting operations.
Drive	1. To excavate an underground passage horizontally or at an angle. 2. An excavated passage. 3. Machinery used to power a conveyor belt.
Drum	A revolving cylinder on which the hoist rope is wound when hoisting a load up a shaft.
Dry-bulb temperature	The temperature of air as measured by a standard thermometer, without regard to atmospheric humidity.
Duct	A pipe or passage for ventilation in a mine.
Ducting	A section of an air duct; also referred to as vent tubing.
Ducting wire	Wire, in the form of a spiral, located inside, and providing support for, ventilation ducting.

E

Entry	An underground roadway or airway, usually providing access to working areas.
Environmental monitor	A device that monitors the atmosphere of the underground mine workings; it may detect methane and carbon monoxide and give an alarm if levels are too high. See also atmospheric monitoring system (AMS).
Exhaust fan	A fan that sucks used air from a mine or heading, thereby causing fresh air to enter by separate entries. An auxiliary exhaust fan uses ducting to ensure that used air is removed from the most advantageous point.
Extensometer	An instrument used to measure small deformations, deflections or displacements, such as downward movement in the mine roof.
Extraction	The mining and removing of ore/muck from a mine.

F

Face	1. Solid ore at the advancing end of a working place. 2. The place where a miner works to extract ore/muck and rock.
Fan	Any mechanical device used to circulate air through mine workings.
Fault	A break in a body of rock along which movement of the two sides relative to each other has occurred.
Feeder-breaker	A relatively mobile crusher into which ore/muck is dumped. The feeder-breaker then loads the muck onto a conveyor.
Finger pillar	A long, narrow pillar.
Flameproof	Enclosed and capable of withstanding, without damage, a methane-air explosion within the enclosure. This is to prevent ignition of the same methane-air mixture surrounding the equipment.
Flame safety lamp	In mine rescue, a lamp of an approved type which is relatively safe to use in atmospheres that may contain flammable gas.
Formation	In geology, any assemblage of rocks that have some character in common, such as origin, age or composition.
Fresh-air base	An underground station located in the intake airway, used by rescue teams during underground fires and rescue operations.
Friable	Easy to break, or crumbling naturally. Descriptive of certain rocks and minerals.

G

Grade	1. The angle of ascent or descent of a roadway. 2. The quality of the ore.
Ground cable bolt	A piece of wire cable used instead of a roof bolt to secure ground. Often used where long bolts would be impractical or in very narrow tunnels with limited clearance.

Ground control	Any effort made to stop or reduce unwanted movement of rock surrounding mine openings, including installation of steel arches, rock bolts, etc. Also referred to as strata control.
Ground pressure	The pressure to which a rock formation is subjected by the weight of the superimposed rock and other materials or by forces created by movements in the rocks forming the earth's crust. Such pressures may be great enough to cause rocks having a low compression strength to deform and be squeezed into and close a borehole or other underground opening not adequately strengthened by an artificial support, such as casing or timber. Also called rock pressure.
Grout	A cement mixture, sufficiently fluid, to be pumped into fissures, cracks or holes in rock, thereby increasing the strength of a foundation, ceiling or wall for an engineering structure, or for sailing against air movement.

H

Headframe	A wooden or metal frame erected over a shaft which bears the hoisting wheels (headsheaves) from which the conveyances are suspended.
Heading	Any road or passage driven in solid ore for the purpose of developing and working the mine.
Hoist	A powered drum that hauls or hoists a conveyance or cage by winding a rope onto or over the drum.

I

Igneous rock	Rock formed by solidification from a molten state.
Inbye (also "inby" or "in by")	A commonly used ore/muck mining term to denote locations or movement further into the mine (away from the mine entrance). Specific locations within the mine are often referred to as inbye or outbye a certain reference point.

Incline	A shaft that is not vertical and is often on the dip of a vein.
Inspector	In Saskatchewan, a person appointed to perform certain functions (occupational health officer) under *The Saskatchewan Mines Regulations* and under *The Occupational Health and Safety Act, 1993*. Includes chief mine inspector.
Intake airway	Any heading through which fresh airflows as part of the ventilation system.
Intrinsically safe	A term applied to equipment in which any spark or source of heat that may occur in normal use, or under any conditions of fault likely to occur in practice; is incapable of causing an ignition of a methane-air mixture.

L

Line-brattice	Brattice used to temporarily create both ventilation intake and exhaust paths within a single heading.
Log	A written and graphic description of the geological characteristics of a vertical column of rock. The information is obtained from drill core.

M

Magnetometer	An instrument that detects bodies of rocks that affect the earth's magnetic field; used mainly as an exploration tool.
Main haulage	That portion of the haulage system that moves the ore/muck from the secondary haulage system to the shaft or mine opening. The method employed is the same for either longwall or room-and-pillar mining.
Mains	The principal entry or set of entries driven through the ore/muck bed from which cross entries, room entries or rooms are turned.
Main ventilation	The process of bringing fresh air from the surface into the mine and exhausting contaminated air from the mine.
Manway	A passage in or into a mine used as a footpath only. (A vertical manway may be called a ladderway.)
Metamorphic rock	Rock that has undergone change in texture and mineralogy through heat and compression.

Methane (CH_4)	An odourless, tasteless, colourless and non-poisonous gas formed by the decomposition of organic matter. The most common gas found in ore/muck mines, it is also called firedamp and marsh gas. Methane is lighter than air and highly flammable.
Methanometer	A device used to measure the concentration of methane in the air.
Mine plan	A map showing features such as mine workings or geological structure on a horizontal plane.
Mine rescue team	A team consisting usually of five miners who are thoroughly trained in the use of mine rescue apparatus and techniques and are capable of entering a mine following an explosion or to combat fire.
Mine resistance	The resistance to airflow caused by the friction of air against mine surfaces and other obstructions in a mine.
Miner	A person employed underground in any ore/muck mine to cut, shear, break or loosen ore/muck from the solid, whether by hand or machinery.
Mining engineer	A person qualified by education, training and experience in mining engineering.
Mining geology	The study of geological structures and particularly the modes of formation and occurrence of mineral deposits and their discovery.
Muck	Rock or ore broken in the process of mining.

N

Natural ventilation	The ventilation produced by natural causes in a mine as a result of a difference in density of the air in the upcast and downcast shafts. Natural ventilation is feeble, seasonal and inconstant.

O

Opening	Any excavation in or into a mine.
Operator	1. The person, company or corporation working a mine. 2. The person at the controls of a machine.

Outbye (also "outaby" or "out by")	A commonly used ore/muck mining term that refers to locations or movements towards the mine entrance. Specific locations within the mine are often referred to as outbye or inbye a certain reference point. Outbye is also used to describe working locations in some cases.
Outcrop	The portion of a geological stratum that appears at the surface.
Output	A quantity of ore/muck produced from a mine.
Overburden	1. Loose material, such as soil, overlying the mineralized rock and varying in depth from place to place. 2. Material of any nature that overlies a deposit of useful materials, ores or ore/muck.
Overcast	An enclosed airway that permits one airflow to pass another with interruption or mixing of the two, usually with solid ground separating the two airways. Also referred to as air passage.

P

Panel	A large rectangular block or pillar of ore identified to be mined, usually separated from other panels by large pillars.
Panic bar or panic button	A bar or button that, when pushed, will immediately deactivate the equipment to which it is connected.
Permissible	Electrical or diesel equipment that is certified for use in an explosive atmosphere.
Pillar	An area of ore left to support the overlying strata in a mine.
Pillar-and-chamber	A pillar-method of mining used to extract a portion of thick deposits where the value of the mineral, such as salt or gypsum, is less than the cost of setting artificial supports.
Portal	The entrance to an underground mine.
Powder	A miner's term for any explosive used for blasting the ore/muck face to fragment ore/muck.
Prop	A wooden upright post used to support the roof, usually temporarily.

Pyrolysis — The formation of flammable mixtures with air at certain temperatures when a substance emits vapours and gases during chemical decomposition.

R

Rebar — Steel rods used to reinforce concrete; used with a resin for ground support.

Regulator — A ventilating device, usually an opening in a door or a wall and usually placed in the return of a split of air, to govern the amount of air flowing in that part of the mine.

Return airway — Any portion of a ventilating system through which used or contaminated airflows out to the surface atmosphere.

Rib — The side of a pillar or the wall of an entry.

Roadway — Any underground passage capable of accommodating wheeled or tracked equipment.

Rock burst — The sudden yielding of a volume of rock into a mine opening, sometimes with explosive violence.

Rock mechanics — A study of stress patterns in rock masses and the response of the rock to that stress.

Roof — The ceiling of any underground excavation. Also referred to as the back.

Rock bolt/roof bolt — A steel bolt or cable secured into place in the roof or rib of a mine opening for the purpose of pinning layers of rock together. Roof bolting is a common form of roof control. See also steel arches and steel sets.

Roof bolter —
1. A machine used to place roof bolts.
2. A person who places roof bolts.

S

Scoop — A large shovel attached to a tractor or a mining machine for lifting coarse material. Also a common name for a low-profile front-end loader used underground.

Scooptram	A load-haul-dump unit (front-end loader) with a large shovel used to move ore/muck, rock and materials in the mine. A Wagner tradename. Also commonly referred to by miners as a scoop.
Sedimentary rock	Rock, often in layers, formed by the accumulation of sediments in water or air and becomes compacted.
Seismic survey	An exploration technique that uses the reflections of small explosions or vibrations to delineate subsurface geological structures of possible economic importance, such as ore beds.
Shock losses	In ventilation, any loss in ventilating pressure caused by a change in direction of airflow or diversion of a passage through which the airflows. Shock losses commonly occur at obstructions in airways, splits, or junctions of two or more currents of air.
Shortwall	A method of mining, in which relatively small (compared to longwall) areas are mined using a combination of longwall and room-and-pillar equipment and methods.
Short-term exposure limit (STEL)	See 15-minute average contamination limit.
Shotcrete	A cement mixture sprayed onto the surfaces of mine openings with a pressure gun to provide ground support, prevent erosion by air and moisture, and provide a smooth surface for airflow.
Split	In ventilation, any division or branch of the ventilating current or the workings ventilated by that branch.
Steel arches	Steel arches are used with wooden planks for ground support when high-load carrying capacity elements are required.
Steel sets	A traditional passive support system used in main ramp entries of ore/muck mines for ground support, usually consisting of I-beams for caps and H-beams for posts or wall plates. The term “passive” derives from the fact that steel sets and arches do not interact with the rock the way that roof bolts do.
Stope	An excavation, usually in highly inclined or vertical veins, from which ore or ore/muck has been excavated in a series of steps. It is frequently used (incorrectly) as a synonym for room in room-and-pillar mining.

Stopping	A wall built across old headings, chutes, airways, etc., to confine the ventilating current to certain passages and isolate gas in old workings. Permanent stoppings are commonly made of masonry or concrete; temporary stoppings may be made of such materials as plywood, plastic sheeting and brattice cloth.
Straps	Steel bands secured by roof bolts and used extensively to hold slabby ground between bolts or to prevent slabs from loosening.
Stripping	1. Mining ore by first removing the covering overburden down to the ore bed. 2. Open workings, as in a quarry. 3. Sometimes used to describe a final mining operation such as robbing or drawing pillars.
Subsidence	Lowering of the strata, including the earth's surface, due to underground excavations.
Sump	An excavation made underground to collect water, which can be pumped to surface or used as needed.

T

Tailings	Waste rock material resulting from processing ores.
Tee-jointed duct	A ventilation duct that splits the airflow into two parts to enable ventilation of two headings with one fan.
Threshold limit value (TLV)	Airborne concentration of a substance that represents conditions under which it is believed that nearly all workers may be repeatedly exposed to it day after day without adverse health effects.
Threshold limit value - ceiling (TLV-C)	The concentration that should not be exceeded during any part of the working exposure.
Time-weighted average (TWA)	See 8-hour average contamination limit.

Trailing cable	A flexible, electric cable that connects portable equipment used near the face with a power source some distance from the face.
Tram	To move a self-propelled piece of equipment.
Transfer point	Point at which muck is transferred from one conveyor to the next.
Transformer	A device used in electrical systems to reduce or increase the voltage of an alternating current.
Tunnel	A horizontal connecting passage between two mines or systems of workings.

U

Upcast	The passages from and in a mine from which air leaves the mine.

V

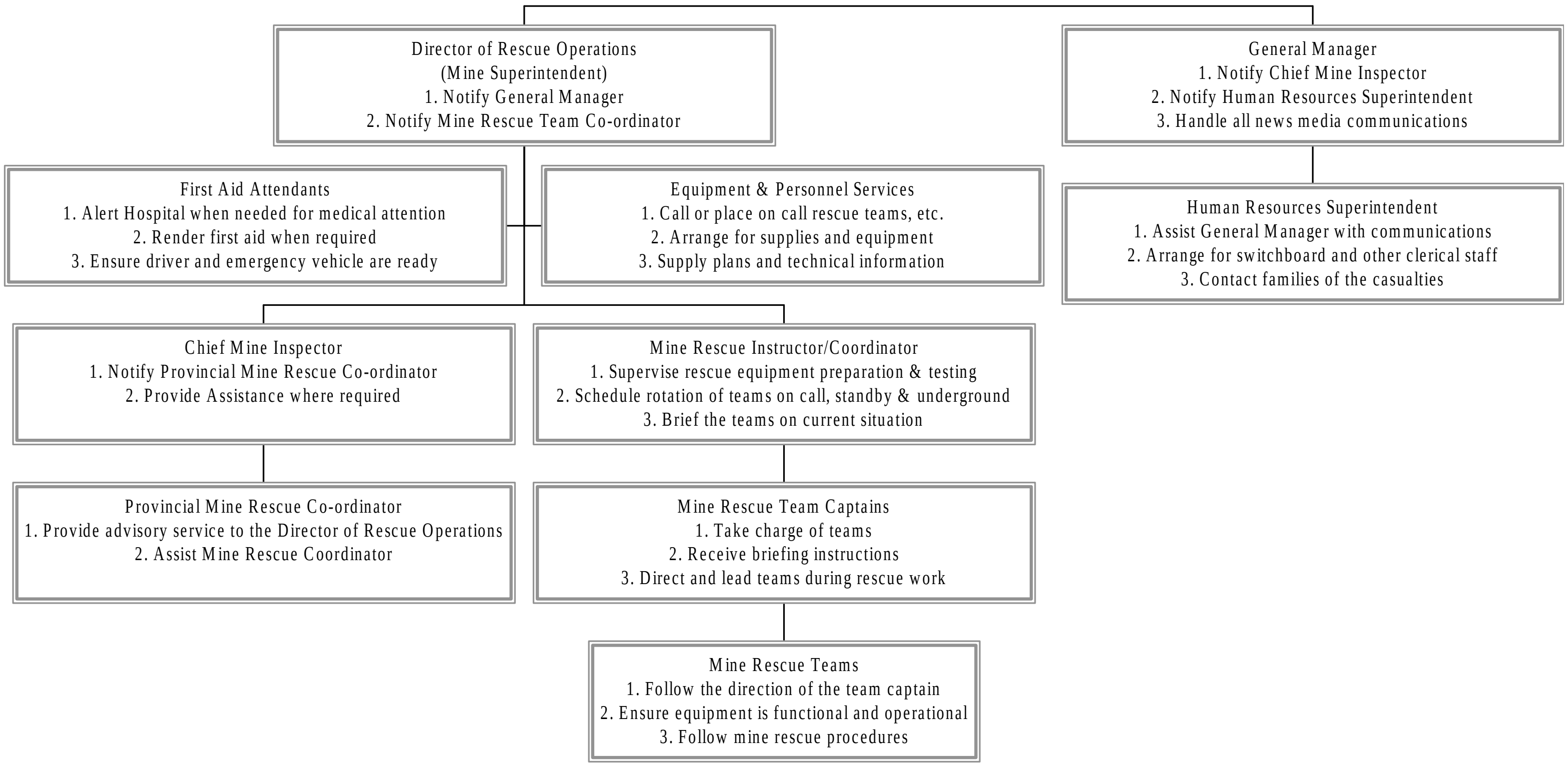
Ventilation	The provision of an adequate flow of fresh air along all roadways, workings, and service points underground. Ventilation is an essential factor in safety, health and working efficiency; it dilutes and removes noxious or flammable gases and helps abate such problems as dust and high temperatures.
Ventilation planning	The calculation and description of airflows, velocities and pressures, and the principal appliances, including fans, to control and distribute the air, either in a proposed new mine or a new area to be worked from an existing mine.
Ventilation shaft	A vertical opening into a mine for the passage of fresh air or the removal of dust and gases from the mine.
Ventilation survey	A quantitative survey to determine how much air is circulating through mine workings. Airflows are normally calculated from measurements of cross-sectional areas and air velocity using an anemometer or smoke tubes. The ventilation survey provides and updates the data required for ongoing ventilation planning.

W

Wet-bulb temperature	1. A measure of the combined effect of temperature and humidity. 2. The lowest temperature that can be produced in given air by the evaporation of moisture into that air.
Winch	A drum that can be rotated to exert a strong pull while winding in a line.
Working face	Any face in a mine from which ore is being mined, cut, sheared, broken or loosened.
Workings	A mine as a whole, or that part of a mine in which mining operations are going on.

Appendix E

Functional Mine Rescue Emergency Organization Chart



Appendix F
References

1. *The Saskatchewan Occupational Health and Safety Regulations, 1996*

2. *The Saskatchewan Mines Regulations, 1978*

3. Saskatchewan EHS: Emergency Treatment Protocols. Saskatchewan Health, Government of Saskatchewan

4. Handbook of Training in Mine Rescue and Recovery Operations, 1992. Ministry of Labour, Government of Ontario

5. British Columbia Mine Rescue Manual. Ministry of Employment and Investment, Energy and Minerals Division, Government of British Columbia.

6. TLV's and BEI's Handbook. American Congress of Governmental Industrial Hygienists (ACGIH)

7. NIOSH Pocket Guide to Chemical Hazards pocket handbook (June, 1997). US Department of Health and Human Services, National Institute for Occupational Safety and Health (NIOSH)

8. CSA Z94.4-93, Selection, Use, and Care of Respirators, Occupational Health and Safety. Canadian Standards Association (CSA).

9. First on the Scene, First Aid. St. John Ambulance

10. Patty's Industrial Hygiene & Toxicology, 3rd Edition

11. Essentials of Fire Fighting, IFSTA, International Fire Service Training Association, 3rd Edition