Handbook of Training in Mine Rescue and Recovery Operations
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Workplace Safety North (WSN)

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Written and issued by WSN for the use of persons training in mine rescue and recovery at the main mine rescue stations and substations established in the province.
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Assistance has been rendered by the manufacturers of breathing apparatus and other equipment used in mine rescue work.

Suggestions by a special fire committee set up by the mining industry of Ontario to investigate firefighting operations are gratefully acknowledged and deeply appreciated.
PREFACE

AUTHORIZATION

The responsibilities associated with mine rescue in Ontario are set out in Regulation 854 of the Occupational Health and Safety Act. The regulation sets out requirements for mine rescue stations, the financing of the mine rescue organization, the direction of the mine rescue organization, the qualification and training of mine rescue team members, the responsibilities of a mine owner in mine rescue, and the use of mine rescue services.
PURPOSE OF THE HANDBOOK

The purpose of the Handbook of Training in Mine Rescue and Recovery Operations is to provide a guide for the training of the members of mine rescue teams in the care and use of apparatus for protection in irrespirable atmospheres, in the detection of noxious gases, all specialized emergency response equipment, and in a general knowledge of accepted procedures for rescue and recovery operations during or after a mine emergency. It is meant to serve as a reference guide for the members of mine rescue teams and to assist mine operators during mine rescues or other emergencies.
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CHAPTER 1

ONTARIO MINE RESCUE

INTRODUCTION

Over eight decades, Ontario Mine Rescue has established an international reputation for high standards in mine emergency response, safe and effective mine rescue practices, and mine rescue training, and has served as a role model to mine rescue organizations across Canada and the world.

Thousands of volunteers have been trained and equipped to fight mine fires, rescue injured and endangered personnel, and respond professionally to a wide array of emergencies in the province’s mines.

Under the authority of the Occupational Health and Safety Act and headquartered in Sudbury, Ontario Mine Rescue staffs, equips and maintains a network of mine rescue stations across the province that ensure mines within specified geographic areas have adequate emergency response capability.

Its role includes delivering training to support personnel, providing advice on emergency preparedness, conducting periodic audits, ensuring WSN-owned equipment is maintained to the manufacturers’ recommended standards, equipping mine rescue substations where required, and providing advice during a mine emergency.
Ontario Mine Rescue believes that emergency preparedness and response is a part of achieving the mining industry’s Zero Harm vision, and remains committed to continual improvement, ensuring the industry’s needs are met.

Hollinger Gold Mines 1913 (Porcupine)

HISTORY

Hollinger Mine Fire, Feb.10, 1928

Ontario Mine Rescue was born out of the tragedy of the Hollinger Consolidated Gold Mine fire that claimed the lives of more than three dozen miners in Timmins in February 1928.

An estimated 900 carloads of flammable waste – paraffin wrapping paper, carbide, powder boxes, sawdust, fuse ends and
some detonators – was stuffed in Stope 55A, east of crosscut 12 on the 550 level. The area, 12 feet by 100 feet, was filled with refuse to a depth of approximately 45 feet.

Known to many, the waste was seemingly of concern to no one. No one seemed to think a damp, hard rock mine could experience a fire, so no precautions were taken – no alarm system, no fire doors, no evacuation plan, no emergency plan, nothing.

When fire did break out at approximately a quarter after nine the morning of Friday, Feb. 10, dense smoke and deadly carbon monoxide quickly moved through North America’s largest gold mine, endangering the lives of hundreds of miners and killing 39.

Neither the mine, nor the town, or even the province, had the expertise or the resources to respond to save miners’ lives or adequately fight the fire. The United States Bureau of Mines Mine was called in. Rescue teams left Pittsburgh about 9 a.m. Saturday and travelled for almost 22 hours, some 1,600 kilometres. They arrived about 6:20 a.m. Sunday by railway car equipped with special equipment and breathing apparatus to extinguish the fire.

These special rescue personnel and their equipment subdued the fire, restoring normal air currents, while local mine management directed recovery operations.

A Royal Commission by Justice T.E. Godson into the tragedy made 15 recommendations including equipping mines with a stench gas system to alert miners of emergencies; removing all flammable waste to the surface; limiting the amount of oil and
grease kept underground; placing fire doors at each station; the installation of fire protection measures; and posting emergency exit signs.

The most significant recommendation, however, was the creation of a provincial mine rescue service.

After the Hollinger Fire, Timmins was the first location for a Mine Rescue Station in 1929.

“I recommend that rescue stations be located at a place selected by the Chief Inspector of Mines in the Timmins, Kirkland Lake and Sudbury mining areas, and be in charge of one man, to be appointed by and under the control and direction of the Department of Mines. It should be the duty of such employee to take care of the apparatus, train men in
the mines in his area in rescue work and inspect and report upon the apparatus, if any, maintained at any such mine.”


Since then Ontario Mine Rescue has grown and developed into a world leader itself, as lessons learned from experience and mine rescue operations provided valuable insight.

**East Malartic Gold Mine Fire, April 24, 1947**

The first time teams from different districts worked together during a rescue operation was also the first and only time Ontario mine rescuers responded to an emergency outside of the province. The emergency not only provided Quebec with the impetus to establish its own mine rescue system, but resulted in Ontario setting province-wide mine rescue standards.

Teams from Kirkland Lake, Timmins and Sudbury districts rushed to the East Malartic Gold Mine, about 70 kilometres east of Rouyn-Noranda April 24, 1947, to help Quebec mine rescue teams battle a fire that claimed the lives of 12 miners.

At about 1:30 a.m., a graveyard crew of 16 men was mucking out a round at the bottom of No. 4 Shaft, when the shift leader noticed smoke coming down the shaft. He promptly went to 10 Level in a skip to investigate, leaving the crew working at the bottom of the shaft.
Chapter 1 – ONTARIO MINE RESCUE

Seeing the shaft and the level were full of smoke, he notified the hoistman at the hoist above 10 Level, the only other person underground, to warn the crew at the bottom of the shaft by bumping the skips up and down several times, while he hurried to No. 3 Shaft and surface to spread the alarm. Only the hoistman and two crew members survived.

When the shift leader reached surface, he rang the nine-bell alarm signal and went to get assistance. Several attempts were made to rescue the missing miners and fight the fire, but it wasn’t until 7 a.m. that mine rescue teams from Noranda and Val d’Or arrived.

Realizing the need for more trained men and equipment, officials called on Ontario Mine Rescue for help. The first Ontario rescuers, 22 men, left Kirkland Lake at 3 p.m., arriving at the mine to begin rescue operations at 7 p.m. A contingent of 11 mine rescuers from Timmins arrived later that night, and another 27 from Sudbury the next evening.

1922, George S. McCaa filed the patent and preliminary drawing for the McCaa Breathing Apparatus.
Despite the valiant efforts of all the teams, numerous blasts from exploding carbon monoxide and a continuous increase in CO concentrations forced rescuers to abandon efforts to control the fire from underground and it was decided to seal all surface openings and smother the fire.

The Kirkland Lake teams, the first to arrive, were after four days of hard work the last Ontario contingent to leave, while the Noranda teams remained for recovery work when the mine was opened.

Working together, it became evident each Ontario district had different training and maintenance standards. As a result, the position of Inspector of Mine Rescue was created to ensure province-wide standards in mine rescue training and equipment maintenance were established and maintained.

The McIntyre Gold Mine Fire, Feb. 8, 1965

The McIntyre Mine Fire, which involved 140 mine rescuers from Timmins, Kirkland Lake and Sudbury in a week of intensive firefighting, confirmed the wisdom of setting province-wide standards but also underlined the need to replace the McCaa, the primary breathing apparatus of Ontario Mine Rescue for more than 30 years.

At 1:56 a.m. on Feb. 8, 1965, a warning light indicated that an underground pump had failed to start and that somewhere in the mine water would soon be overflowing a sump. Upon investigation, smoke was found at the 4900 Level.

The Mine Fire Procedure was put into operation and the search for the fire began at 7:30 a.m. by crews wearing the two-hour McCaa breathing apparatus.
Investigation found that the fire, started by a collapsed timber ignited by a damaged electrical cable, was in almost the worst place possible, 6,500 feet below surface and 5,200 feet from the main shaft, more than three-and-a-half kilometres from fresh air.

So intense was the fire that carbon monoxide was present in the shaft house, requiring the seven-kilometre round trip to be made under oxygen in McCaa apparatus. In fact, a skip tender, working more than two kilometres from the fire, was overcome by carbon monoxide and lost his life.

Mine rescuers discovered that by the time they had arrived at the scene to fight the fire, they had little time to apply any effective control measures before the reduction in their oxygen supply forced them to return to the surface. Some teams did not even reach the fire.

Following extensive efforts, including the redirection of ventilation and the use of high-expansion foam generators, the fire was extinguished after a week of hard work. Recovery operations took several more weeks.

As a result of the fire, the Ontario Mining Association asked the Ontario Department
of Mines to investigate newer, longer-duration breathing apparatus since some mines had grown too large for apparatus of only two-hour duration. The short limitation not only restricted firefighting activity, but prolonged the emergency and increased the number of hazardous trips.

To provide a comfortable margin for travelling, and still allow sufficient time to produce effective results, several four-hour apparatuses were studied. The deciding factor was the weight difference. The Drager BG 174, approximately nine pounds lighter than the other models studied, was chosen.

Following further tests, the Ontario Mining Association requested the Ontario Department of Mines to proceed with the conversion from two-hour McCaa to the four-hour Drager BG 174 in all mine rescue training in the province.

**Falconbridge Mine Rockburst, June 20, 1984**

The series of tremors that shook the Falconbridge Mine, near Sudbury, in June 1984, did more than collapse backfill, killing four miners. It played a significant role in reshaping and expanding the role of Ontario Mine Rescue from fighting fires to a full mine emergency service.

The first tremor at 10:12 a.m. June 20, 1984, measuring 3.4 in Richter magnitude triggered the collapse of backfill in an undercut-and-fill stope about 4,200 feet underground, trapping four miners in the fill.

Several times mine rescue teams went underground to try to locate and make contact with the missing men, but had to retreat without success as the ground continued to move, causing rockbursts as high as 3.5 in magnitude.
By 4 p.m. seismic activity had subsided, contact had been made with a lone survivor, and six rescue teams, with emphasis on men with square set timber experience, had been selected for rotation under the extremely confining, and extremely hazardous conditions.

Almost 24 hours later, mine rescuers succeeded in extricating the miner, who despite high hopes he would survive the ordeal died just after being rescued.

Almost two years later a provincial inquiry into ground control and emergency preparedness at Ontario mines acknowledged and commended the skill and bravery of the rescue workers. The inquiry concluded that there was a need for more diversified training and equipment to reduce the length of time rescue workers are imperiled and to improve the chances of saving trapped men.

The commission believed that Ontario Mine Rescue was capable of dealing with non-fire emergencies and to achieve this, mine rescue should be expanded and improved.

The Stevenson Commission recommended that:
• The current mine rescue organization be expanded to handle all underground emergencies
• The necessary additional training in non-fire emergencies be developed by a tripartite committee of representatives of mine management, unions and government
• A tripartite committee also be established to advise on all aspects of mine rescue equipment and emergency warning systems
• Mine rescue personnel suffer no loss of income as a result
of injuries arising from mine rescue activities

- The Ministry of Labour mine rescue organization be responsible for identifying and introducing specialized equipment needed for use in non-fire emergencies, and for developing or finding sources for such equipment.

As a result, better training in rescue and recovery operations related to non-fire emergencies was instituted, and specialized lightweight, portable equipment for reaching and extricating workers was made available. In addition, improved first aid equipment and training was also implemented for mine rescue and underground workers.

**Transfer to MASHA and WSN**

Responsibility for Ontario Mine Rescue was transferred from the Ministry of Labour to the Mines and Aggregates Safety and Health Association (MASHA) in January 2001. Nine years later MASHA and Ontario Mine Rescue became a part of Workplace Safety North (WSN).

The mine rescue program was modernized with state-of-the-art equipment including the Drager BG4 self-contained breathing apparatus, the iTX Multi-gas Monitor, and the CAREvent DRA Automatic Rescue Ventilator. Standardized competency-based training programs were developed to ensure consistent delivery of information to mine rescue teams across the province.

These and other developments have made Ontario Mine Rescue and its mine rescue training and safety programs a role model to mine rescue organizations in other provinces and countries.
Chapter 1 – ONTARIO MINE RESCUE

ORGANIZATION

Structure

Ontario Mine Rescue is structured into an interlocking network of seven mine rescue districts, each under the direction of a Mine Rescue Officer/Consultant (MRO), responsible primarily for their own district, but also to support a neighbouring district experiencing a mine rescue emergency.

The Mine Rescue Officer/Consultants are accountable for the maintenance of the mine rescue equipment and the training of the teams in their district in accordance with standard practices and procedures outlined in the Ontario Handbook of Training in Mine Rescue and Recovery Operations.

The Ontario Mine Rescue Manager is responsible for the mine rescue program, and the Supervisor of Mine Rescue provides technical expertise to the Mine Rescue Officer/Consultants.

WSN maintains a Mine Rescue Technical Advisory Committee (TAC) that provides advice and guidance to Ontario Mine Rescue, and promotes continual improvement of emergency preparedness at Ontario mines. TAC members make recommendations regarding: content of mine rescue programs, mine rescue equipment requirements, identify research projects and changes to the mine rescue handbook.

During an ongoing operation it is vital that the services of a Mine Rescue Officer/Consultant or a relief person be made available at the shortest possible notice. The relief person will be replaced with a Mine Rescue Officer/Consultant as soon as possible thus ensure internal communications are maintained.
and optimum rescue services are provided.

With this in mind, a company requiring the use of mine rescue teams must immediately notify the MRO.

Funding for the mine rescue organization is borne by the Ontario mining industry and recovered by a special assessment levied by the Workplace Safety and Insurance Board against the mining companies. All training costs for the individual team members, such as salaries and mine rescue bonuses, are paid by the individual mining companies.

**Responsibilities**

The Mine Rescue Manager has direct responsibility for overseeing the mine rescue program.

The Supervisor of Mine Rescue is responsible for technical aspects of the program including providing ongoing advice and assistance to the Mine Rescue Officer/Consultants, as well as to co-ordinate the organization, and set standards for training and equipment.

The District Mine Rescue Officer/Consultant is responsible for maintaining WSN-owned mine rescue equipment and training the mine rescue teams in his/her district or a designated geographic area. The MRO responds to emergencies and provides advice during an emergency.

The Mine Manager is responsible for the cost of establishing, maintaining, and operating mine rescue substations.

The payment of the crews during training or rescue and recovery operations is the responsibility of the individual employer.
WSN’s Mine Rescue Program is responsible for the delivery of mine rescue training and the maintenance of mine rescue equipment owned by WSN. Workplace Safety North staff will co-operate fully in an emergency, giving all possible assistance in obtaining men and equipment from neighbouring districts, and in any other way possible.

The Ministry of Labour Area Management and Inspectors are responsible for ensuring compliance with the regulations.
CHAPTER 2

EMERGENCY PREPAREDNESS

To apply an effective response in an emergency situation there must always be a standard set of procedures and practices to ensure the proper and timely co-ordination of personnel and equipment.

MINE RESCUE POLICY

A five-member mine rescue team will be ready to go underground within 15 minutes of arriving at the mine. Each mine shall have equipment available, such as pressure-demand apparatus, self-rescuers, to equip personnel involved in the immediate evacuation (e.g. cagetenders and supervisors).

GUIDELINES DURING EMERGENCIES

Every mining company must be able to implement its emergency procedure, and organize and equip the mine rescue team for an underground emergency operation.
The following general guidelines have been established for the benefit of mines during an emergency:

• Each mine will have a complete list of all Mine Rescue Stations and Officer/Consultants/other pertinent staff, and their telephone numbers. If, during an emergency, the mine management is not able to locate the District Mine Rescue Officer/Consultant, they shall call another Mine Rescue Station.

• If, upon the first call for assistance, there is no answer at the Mine Rescue Station, or the answering service takes the message:
  – Mine security or another designated person must be dispatched with no further delay to the mine rescue station to obtain the mine rescue truck or the supplementary equipment;
  – Company vehicles may be used if desired for transporting the equipment.

• The Supervisor of Mine Rescue shall be notified of the emergency by a designated company representative and shall immediately ascertain that a Mine Rescue Officer/Consultant has been contacted and that correct services are being provided. If such is not the case then the Supervisor of Mine Rescue shall contact another Mine Rescue Officer/Consultant.

• If a substation at a neighbouring mine serves the mine, the emergency procedure will specify the mode of transportation and list the authorized persons who will obtain the substation equipment.
• The company emergency drill will include practice in obtaining the available mine rescue equipment from the nearest Mine Rescue Station or substation without any assistance from a Mine Rescue Officer/Consultant.

• Each Mine Rescue Officer/Consultant will list all emergency apparatus and equipment available in the district. This list will be updated annually.

PROCEDURE FOR AN UNDERGROUND EMERGENCY

All Ontario mines are to have a standardized emergency procedure and include the following:

1. Any person who detects smoke or discovers a fire that cannot be extinguished shall immediately notify his/her supervisor or a designated person on surface.

2. The designated person shall arrange to alert all personnel underground by means of the stench warning or other approved warning system.
3. Upon receiving the warning, all persons underground shall proceed to a predetermined place such as a refuge station, a shaft station or an emergency escapeway, as stated in the fire procedure.

4. When workers are required to go to a refuge station, they shall follow the procedure established for that refuge station.

5. When workers are required to go to an emergency escapeway to surface, they shall immediately proceed to surface and report, in accordance with the established fire procedure.

6. In an underground or tower-mounted hoist room where the normal air supply may become contaminated, a source of uncontaminated air shall be available to the hoistmen and cagetenders.

7. The person who activates the fire warning system shall notify mine management. Mine management shall follow the fire control procedure and advise persons on the notification chart that there is an underground emergency.

Mine management has the responsibility to:

• Establish an Emergency Control Group for the direction of mine rescue and recovery procedures
• Ensure personnel underground are located and brought to safety
• Ensure that fires are located and extinguished or isolated, or that non-fire emergencies are resolved
• Ensure that the mine atmosphere and workplaces are in a
safe condition before normal mining activity is allowed to resume

- Ensure notices are made to the District Mine Rescue Officer/Consultant as per the regulatory requirements

The Mine Rescue Officer/Consultant will:

- Ensure that mine rescue equipment is available for use
- Be available to give technical assistance
- Ensure that the appropriate WSN officials have been notified, namely:
  - WSN Management personnel
  - The Supervisor of Mine Rescue
  - The neighbouring Mine Rescue Officer/Consultant
- With his superiors, arrange for additional equipment or assistance as needed
- Maintain all Ontario Mine Rescue equipment during an emergency
Chapter 2 – EMERGENCY PREPAREDNESS

MINE RESCUE POLICY

FOR NUMBER OF MEN TRAINED

The following information sets out minimum equipment and trained personnel that is recommended on site at all underground mines at startup, during operation and decommissioning. It is recognized that small, new, or decommissioning operations may not be able to support a full mine rescue team, and, in these instances, the mine emergency plan should reflect this, and mutual assistance arrangements should be made with neighbouring properties.

Number of Trained Rescue Personnel Required

The suggested ratio of trained personnel should be one trained individual available for each five underground employees, until one five-member team is available. At this point, a full training program will begin. When two teams are available and regular mine rescue training commences, consideration will be given to establishing a substation.

a) **Up to 24 underground workers** – Two to four trained personnel available so they can act as guides. Besides being trained rescue personnel, they must be familiar with the mine.

b) **25 to 50 underground workers** – Requires a minimum of 10 trained personnel available to form two teams with reserve personnel being available from a nearby property.

c) **51 to 100 underground workers** – Requires a minimum of 15 trained personnel available to form three teams with reserve personnel being available from a nearby property.
d) **Over 100 underground workers** – Requires a minimum of 20 trained personnel available to form four teams. An additional five trained personnel is required for every 100 employees. The maximum established by Mine Management in consultation with the Mine Rescue Officer/Consultant. Reserve personnel may be available from a nearby property.

The numbers above are the minimum numbers and, when establishing the mine rescue roster, history has shown that at least 30 per cent of the trained personnel will not be available at any one time, so the additional numbers must be included.

Mines with operating areas with high temperatures, such that modified work schedules are required, should review their manpower needs. During a mine rescue operation, heat exposure limits and additional reserves may be necessary.

Mutual assistance could apply to establish a six-team rotation.

**Point-in-Time Evaluations**

Since the ratio does not guarantee sufficient mine rescuers on all shifts, mine operators should use point-in-time evaluations to assess their response capability and to accurately identify the number of trained mine rescue personnel required for a site.

To conduct a point-in-time evaluation:

* Select a point in time.
* All available mine rescue manpower estimates are referenced to this point.
* Assume there is an emergency situation requiring mine rescue response.
• If stench were injected at this point in time where does the emergency plan require underground workers to report to?

• Establish where all mine rescue men identified on the mine rescue roster are at this point in time. They may be underground (unavailable because they are in the refuge station due to the emergency), on surface, at home, etc.

• Are there men who are not available due to vacation, shift work, shift rotation, sickness or other reasons?

• Do you have a sufficient number of trained men available to respond to this situation?

• This procedure should be repeated on other shifts, varying days of the week and other points in time.

• Record the results in a permanent log book for future reference.

• Make adjustments to your emergency plan and ensure adequate number of trained mine rescue men are available.

It is recommended this assessment be conducted regularly until the mine operator is satisfied that the results offer adequate emergency response capability.

It is the responsibility of each owner to assess the emergency response capability so that sufficient mine rescue personnel can be made available on site.

• Initial response – one team and backup team on surface

• A third team must be available on site before the second or backup team can go underground.

• Within six hours additional teams must be on site.
For extended operations, and/or for mines with areas of high operating temperatures, a six- to nine-team rotation will be required.

WSN has prepared Emergency Simulation Guideline for Underground Mines to assist mine operators in conducting effective point-in-time evaluations and emergency simulations.

**Arrangements for Mutual Assistance**

Mine operators are responsible to ensure arrangements are made with other nearby established mining operations for mine rescue assistance. If neighbouring mine rescue teams are required, the property requesting assistance should ensure personnel are available to receive the arriving teams and to act as their on-site guide. The arrangements will be incorporated into the District/Area Emergency Organization Plans. These are distributed annually to all mines by the mine rescue organization.

**Equipment and Assistance for Small Operations or Operations in Transition**

Some mines may not have an on-site mine rescue team, because of startup, decommissioning, or size of workforce.

Such mines must prepare a detailed emergency plan that will provide for the prolonged refuge of, or self-evacuation of, employees underground while awaiting the arrival of off-site mine rescue assistance.

This assistance must be prearranged by the operator with neighbouring mines.
Factors influencing the degree and type of protection include:

- Distance of travel, both to site and underground
- Number of people underground
- Location and concentration of employees underground
- Response time for mine rescue assistance
- Underground ventilation system
- Length of time the present transition period will continue (until sufficient manpower for own teams)
- Equipment available at the site
- Whether the emergency plan calls for refuge or evacuation

Options that may be included in the emergency plan include:

- Minimum rescue equipment, apparatus and standard equipment available on site
- Temporary or portable refuge stations
- Demand apparatus and jumbo cylinders for hoistman and cagetender as specified in mining regulation Section 38
- Self-contained breathing apparatus for protection and or self-evacuation of underground employees – i.e. oxygen supplied self-rescuers
- Or, any combinations of the above option and/or others.

Mine Rescue Officer/Consultants will provide necessary training in the use of breathing apparatus and emergency equipment for mine rescue personnel to ensure the operator can supply an adequate number of guides to responding mine rescue teams.
Seeking Assistance

The Workplace Safety and Insurance Board (WSIB) defines a Mutual Aid Agreement as “a formal agreement between two mining employers under which one employer provides a mine rescue team to the other employer in an emergency.”

The participating mine employers must sign the Mutual Aid Agreement, and a copy of the agreement must be submitted to the Director, Mining Sector (WSIB), for approval and coverage.

Should assistance be required from another mine, in the form of mine rescue teams or equipment from a substation, the mine seeking assistance must notify the Mine Rescue Officer/Consultant.

It is the Mine Rescue Officer/Consultant’s responsibility to inform the Supervisor of Mine Rescue of the situation. The Supervisor of Mine Rescue will then inform WSN management.

The two mines will co-operate in making the necessary arrangements regarding training, transportation, finances, insurance, etc.

WSN has prepared a Health and Safety Report on Mutual Aid Agreements to assist mine operators in creating responsive and effective agreements.

COMPETENCY OF ON-SITE OFFICIAL IN CHARGE

A mine rescue operation at a mine will be under the direction of the supervisor in charge of the mine, and he or she designated as the on-site official in charge. To ensure the
competency of this person, it is strongly recommended that he/she take the management course in mine rescue offered by Ontario Mine Rescue. Refresher training should be taken every three to five years.

**STANDARD MINE RESCUE OFFICER/CONSULTANT PRACTICES**

All Mine Rescue Officer/Consultants will:

- Make keys to the Mine Rescue Station available to mine management
- Provide the Supervisor of Mine Rescue and the mine with a schedule of training and monthly itinerary, showing their whereabouts in case of an emergency
- Keep 12 BG4s in the Mine Rescue truck, if possible
- Circulate a written emergency procedure describing the practices in the district to all district mines and all other Mine Rescue Stations
- Be familiar with neighbouring districts and standardize procedures as much as possible for all districts
- Notify the Supervisor of Mine Rescue, local mines, and the neighbouring Mine Rescue Officer/Consultant, whenever they leave their district

Unless special authorization is obtained from the Supervisor of Mine Rescue, no two adjacent districts will be without the services of at least one Mine Rescue Officer/Consultant.
STANDARD MINE RESCUE SUBSTATION

A substation will be established on a mine site when:

• The size of the operation justifies it
• Sufficient trained rescue personnel are available, and
• The operation cannot be effectively serviced from a mine rescue station or other substation

Substations will be equipped as follows. If the time for assistance exceeds:

• 30 minutes – six apparatus
• One hour – 11 apparatus
• Two hours – 16 apparatus

Acceptable mine rescue facilities must be available before a substation is established. Temporary storage facilities should not be accepted.

The space must be at least 18 feet by 24 feet. The substation should, if at all possible, be on the ground floor with outside access where the Mine Rescue vehicle can be driven to the door. The temperature must be moderate, in all seasons, and the space must be lockable and secure.

There must be secure storage space for oxygen cascade systems and spare cylinders.

Signs should be provided for both systems, and pressure indicating devices should be mounted above each cylinder in use. ‘No Smoking’ signs must be posted near the stored oxygen.

Storage must be provided for the protection of the six to 16 Drager BG4 apparatus and other equipment.
Proper washing and disinfecting facilities must be available. Sinks must be made of polypropylene, fibreglass or stainless steel as these materials do not damage breathing apparatus. Cement laundry tubs are not acceptable.

The sinks must not be used for any other purpose, such as washing floors. They must only be used to disinfect breathing apparatus. A drying rack or air drying system should be provided.

Strong durable tables are needed that can accommodate six men field-testing breathing apparatus. These tables should be large enough to hold 12 sets of apparatus for service. Stacking chairs are needed for classroom work.

A blackboard or a whiteboard and a cork or bulletin board are needed for class work and for team briefings.

There must be convenient and easily accessible storage space for standard and auxiliary equipment and briefing maps. A tall metal cabinet with adjustable shelves works well for this purpose.

In the event that the equipment stored must be moved to the site of an emergency, a large box or other suitable means must be provided to transport both standard and auxiliary equipment safely and efficiently. An inventory must be kept to ensure no equipment is forgotten.

**Minimum Equipment Required at Substations**

The purpose of a substation is to enable the mining company to cope with a minor incident. The amount of equipment kept at the substation is determined by the distance from a Mine Rescue Station to that substation.
The following equipment is supplied and maintained by WSN:

- BG4 breathing apparatus (stored with 200 bar/3,000 psi cylinders)
- Spare 200 bar/3,000 psi cylinders for each BG4
- 500 lb. soda lime
- Three anti-fog dispensers
- Spare masks for BG4s
- Spare gaskets, O-rings and seals for BG4s
- Disinfectant and sterilizing equipment
- Tools for servicing all equipment
- Freezer and ice molds
- Standard Equipment
  - One iBrid MX6 for each team set of BG4s
  - Four SSR 90 M rescue units
  - Captain’s clipboard, chalk, probe stick, first aid kit, and whistles

The mining company may choose to store its emergency equipment, such as stretcher, jacks, lifting bags, cutting saws, firefighting equipment and other breathing apparatus in the substation.

**REFUGE STATION**

Refuge stations are common in Ontario mines, and in many cases they are used both as lunchrooms and as refuge stations. This keeps the workers familiar with their location.
Under Sect. 26, Regulation 854 of the Occupational Health and Safety Act, where the procedure in case of a fire in an underground mine provides for the use of a refuge station for workers, the refuge station shall:

1. Be constructed with materials having at least a one-hour fire-resistance rating
2. Be of sufficient size to accommodate the workers to be assembled therein
3. Be capable of being sealed to prevent the entry of gases
4. Have a means of voice communication with surface
5. Be equipped with a means for the supply of:
   (a) compressed air, and
   (b) potable water

WSN has prepared Guidelines for Mine Rescue Refuge Stations to assist mine operators in establishing safe, effective refuge stations. In the guidelines, refuge stations should:

- Contain enough benches to comfortably seat the workers who will use it
- Contain a basket stretcher, blankets and a first aid kit; all of which are regularly inspected and maintained
- Have a supply of emergency tools such as axes, saws, ropes, shovels, jackets, etc., and 10 lb. dry chemical fire extinguisher
- Contain a copy of the fire procedure and the procedure to be followed in the refuge station during an emergency
- Be routinely inspected and properly maintained for its intended use
Refuge stations should have a door that opens outward, and be capable of being sealed with clay or plastic material. Some means must be provided in the door to allow the escape of air pressure in the event the compressed air inside the sealed area must be opened. A means of sealing this opening must be provided on the inside of the door.

Refuge stations are advisable in the vicinity of winze collars, where they may be readily converted to advanced fresh air bases if there is a fire in a location served by the winze.

The number of people that can occupy a refuge station and the length of time they can safely remain are determined by the volume of air in the station without an additional supply of fresh air from compressed air lines.

In breathing, humans consume \(O_2\) from the air and exhale an almost equal amount of \(CO_2\). When the proportion of \(CO_2\) in the air of the enclosed space reaches eight per cent, people breathe heavily and are at the point of complete exhaustion.

However, people have lived for considerable periods in an atmosphere in which a carbide light would not burn, e.g., in air containing less than 12.5 per cent \(O_2\).
A person at rest requires less O₂ and exhales less CO₂ than when working. In a confined space, however, the air will eventually become unfit to sustain life.

Experiments have shown that a man in a confined space requires approximately one cubic yard of air (0.76 m³) per hour. At the end of an hour this cubic yard of air will contain about 14 per cent O₂ and five per cent CO₂.

On the basis of one cubic yard of air per hour, an enclosed space 10 feet x 10 feet x 10 feet (1,000 cu. ft. or 28 m³) will support one human for approximately 30 hours before he begins to suffer from a lack of breathing air. This minimum allowance of one cubic yard per hour per person, however, does not provide for loss of O₂ through absorption by the ore or timber in the enclosed space or for the contamination of the air by noxious gases.

In one metal mine the air in a barricaded drift 250 feet long, six feet wide and six feet high (9,000 cu. ft. or 255 m³) kept 29 men alive for 36 hours.

In the same mine another drift 130 feet long, seven feet high and seven feet wide (6,500 cu. ft. or 184 m³) contained sufficient air to support six out of eight men for 50 hours. The other two men were found dead. The six who were alive were all unconscious but were revived.

The value of refuge stations cannot be overemphasized. They have been the means of saving hundreds of lives in coal and metal mines. Many additional lives may be saved if miners are properly instructed in their use.
CHAPTER 3
SELECTION AND TRAINING

SELECTION

The successful selection of suitable personnel for work in mine rescue and recovery depends on the judgment of mine management, the examining physician, and the Mine Rescue Officer/Consultant, based on four criteria:

1. Common Core Underground
2. Medical requirements
3. Physical requirements
4. Assurance of qualifications

Common Core Underground

While mine rescuers need not be experienced underground miners, it is important that they have a clear understanding of the underground environment and operations. Applicants must have successfully completed the minimum Common Core Underground modules required to go underground.

Medical Requirements

In order to identify medical conditions that could put rescuers at risk during a mine rescue operation, applicants must be examined by a physician and certified fit or unfit for mine rescue training. If accepted, they must be examined and certified fit annually thereafter to remain in active training.
Chapter 3 – SELECTION AND TRAINING

Mine rescue personnel and other persons assigned to wear SCBA shall have a preplacement (baseline) medical examination. Special attention should be paid to:

- History of, or presence of, disease of the respiratory system
- History of, or presence of, disease of the cardiovascular system
- Presence of perforated eardrum
- Visual acuity, and
- X-ray, as prescribed by a physician.

The following special tests should be included in the preplacement examination where possible to establish a baseline norm:

1. Electrocardiography
2. Pulmonary-function tests
3. Complete blood count
4. Biochemical profile of blood

Some or all of the examination should be repeated at annual intervals to confirm the ability of the person to safely use SCBA, and to identify deviations from previous norms.

It is the responsibility of the physician to determine whether the candidate is fit or unfit for mine rescue work.

A copy of a physical demands analysis for mine rescue work is available on request for physicians.

Immunizations against Hepatitis A and B, and tetanus is recommended for successful candidates.
(To be completed and retained by Physician)

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(Revised Feb. 11, 2011)

Physical Examination
The annual medical report form, as established by a Ministry of Labour physician, for an applicant for training in mine rescue and recovery consists of two sections – the original of the physical exam is kept by the physician, a section signed by the physician indicating the candidate is fit/unfit for mine rescue is kept by the employer, and a copy of that section is submitted to the Mine Rescue Officer/Consultant.

**Physical Requirements**

No specific height, weight, or strength standards exist for mine rescue, but the physical demands may be extreme for extended periods, so average or better-than-average strength and endurance are required by all applicants.

It is the responsibility of the examining physician to be aware of the physical and emotional demands put on workers during a mine rescue and recovery operation.

Persons over 60 should not engage in rescue and recovery work that involves wearing oxygen breathing apparatus.

**Assurance of Qualifications**

The Mine Rescue Officer/Consultant must be assured that a candidate has good potential for developing into a qualified member of a mine rescue team, and that a current member has the ability to remain as a qualified team member.

To qualify as an active mine rescue team member, a person must have successfully completed the introductory and refresher mine rescue training as required, and demonstrated the necessary physical and mental abilities to do mine rescue work.
A member of a rescue team should be:
1. In good health and physically fit
2. Clean-shaven, with no facial hair to interfere with the facemask seal
3. Calm and self-controlled in emergency and danger
4. Known to be of good judgment and initiative
5. Capable of performing long and arduous physical labour
6. Familiar with underground mining conditions and practice
7. A holder of a St. John’s Ambulance Standard Certificate (Mine Rescue) or equivalent
8. Able to communicate in the working language

**TRAINING**

The primary focus of mine rescue training is on mine rescue team members, who require an on-going training regime to maintain and improve their skills and knowledge of mine rescue techniques and procedures. Training for support roles as well as post-secondary students in mining programs, however, is also an important component of mine rescue.

**Introductory Mine Rescue Training**

To qualify as an active mine rescue team member, a candidate must successfully complete the competency-based five-day, 40-hour introductory training course. Topics include legislated requirements governing mine rescue, mine gases, and basic mine rescue equipment, operations and procedures.
Successful candidates are qualified to use and service the BG4 breathing apparatus. Whenever possible, some practical training is done in smoky and irrespirable atmospheres.

Candidates must pass a practical exam, and a written exam with a mark of at least 70 per cent. Successful candidates receive an Ontario Mine Rescue Certificate with a seal. Students who obtain their training while at a post-secondary institution receive a Mining Student Training Certificate.

**Refresher Mine Rescue Training**

To remain active, members must receive at least six eight-hour training sessions annually to cover basic and advanced training topics in the curriculum. The sessions, normally scheduled on a bi-monthly basis, consist of customized, on-site training delivered by Mine Rescue Officer/Consultants.

Practical sessions resemble as closely as possible actual emergency situations with the Mine Rescue Officer/Consultant acting as the briefing officer/on-site official in charge, and are conducted in an underground environment and apply standard competency-based mine rescue practices and procedures.

Refresher training is necessary to maintain the competency of mine rescue team members. Mine rescue personnel may be deemed inactive at the discretion of the Mine Rescue Officer/Consultant should the required six days not be fully attended or the volunteer not demonstrate competency in the use of critical mine rescue equipment, such as breathing apparatus.
Certification of Introductory Mine Rescue Training

This acknowledges that

______________________________

of __________________________

has been trained in the use of Mine Rescue Apparatus,

at __________________________

The trainee demonstrated ability to fit test primary breathing apparatus during underground training and was able to perform arduous work under limited visibility conditions.

To retain certification, the trainee must demonstrate competency during regular mine rescue training.

Trained under the direction of

______________________________

Approved by: ______________________

Mine Rescue Officer

Workplace Safety North™
A Health & Safety Ontario Partner

Certificate Number
Advanced Mine Rescue Training

Any individual active in Ontario Mine Rescue for two years or more may attain Advanced Certification through a one-day course. It involves competency evaluation in the use of special rescue and extrication equipment, techniques, and procedures, as well as more detailed coverage of breathing apparatus and standard equipment.

Participants are required to successfully complete a written test on Ontario Mine Rescue functions and procedures, and demonstrate the use of primary and secondary breathing apparatuses, standard equipment and randomly selected special equipment.

Upon successful completion, participants are provided with a gold seal to attach to their Ontario Mine Rescue Certificate.
Mine Rescue Technician Training

The technician program is a comprehensive introductory three-day, 24-hour course that trains individuals in procedures for maintaining and repairing key equipment used by Ontario Mine Rescue. Topics include Drager BG4 apparatus troubleshooting and repair, Panorama Nova facemask rebuild, oxygen booster pump operation and SSR 90 M servicing.

Upon successful completion of this course, participants will receive a Basic Technician Certificate. To remain competent, technicians, if active mine rescuers, must successfully complete a one-day technician refresher session delivered by the Mine Rescue Officer/Consultant annually. If not active mine rescuers, technicians must attend at least two regular mine rescue refresher training sessions, as well as successfully complete a one-day technician refresher session annually.

Supervisory Mine Rescue Training

Supervisory mine rescue training, or Day 1 of the Supervisory/Management course, is designed for underground supervisors who have no previous training in mine rescue. Training covers the history of mine rescue, mine gases, breathing apparatus, and underground emergencies. A written examination with a passing mark of at least 70 per cent is required. Successful candidates will receive a Supervisory Mine Rescue Certificate.

Management Mine Rescue Training

Management mine rescue training is a two-day, 16-hour course designed to give management a thorough knowledge
Certificate of Supervisory Mine Rescue Training

This is to certify that

John Martin of company

has been trained in the knowledge of

Mine Rescue Apparatus, and Emergency Supervisory Procedurees

required during mine rescue operations.

Consultant / Trainer

[Signature]

date
Date

Cert #
Certificate Number

Supervisory Certificate
of Ontario’s mine rescue program and management’s responsibilities during an emergency.

Participants with mine rescue experience need not attend Day 1, the supervisory mine rescue training portion, of the course. The second day consists of numerous case studies that require extensive problem-solving and decision-making skills that control group members will exercise during a real-life emergency.

Refresher training should be taken every three to five years depending on frequency of incident response involvement. Successful candidates will receive a Management Mine Rescue Certificate.

A mine rescue operation at a mine will be under the direction of the supervisor in charge of the mine. To ensure the competency of this person, it is strongly recommended that he/she take the management course in mine rescue training.
Certificate of Management Mine Rescue Training

This is to certify that

John Martin of company

has been trained in the knowledge of

Mine Rescue Apparatus,
and Emergency Supervisory Procedures
required during mine rescue operations.

Consultant / Trainer

Date

Certificate Number

Management Certificate
CHAPTER 4
MINE GASES

AIR

Air is the transparent medium surrounding the earth in which plants, animals and human beings live and breathe. It is a mixture of several gases, which, though ordinarily invisible, can be weighed, compressed to a liquid, frozen to a solid, and have their own specific gravity or weight. Air has a specific gravity or weight of 1.0.

Pure, dry air at sea level contains, by volume:

- Nitrogen ($N_2$) – 78.09 per cent
- Oxygen ($O_2$) – 20.94 per cent
- Argon (Ar) – 0.94 per cent
- Carbon dioxide ($CO_2$) – 0.03 per cent

Traces of gases such as hydrogen, helium, etc., are also present.

Mine air may be contaminated by other gases such as:

- Carbon monoxide (CO)
- Sulphur dioxide ($SO_2$)
- Hydrogen sulphide ($H_2S$)
- Methane ($CH_4$)
- Oxides of nitrogen ($NO_x$)
The presence of these gases may be due to:

1. Blasting or other explosions
2. Mine fires
3. Naturally occurring gas emissions
4. Absorption of $O_2$ by water, timber or ore
5. The use of diesel engines underground

Except in the case of fire, any dangerous accumulation of these gases, or a depletion of $O_2$ content can be prevented by proper air ventilation.

Gases may be considered harmful if they are:

- Combustible or explosive
- Poisonous
- Capable of displacing $O_2$

The effects may depend on atmospheric conditions, such as altitude, temperature, and humidity.

**EXPOSURE LIMITS**

Legislation and guidelines, such as the Occupational Health and Safety Act and the American Conference of Industrial Hygienists (ACGIH) Threshold Limit Values, set maximum limits, based on time and/or concentration, on an individual’s exposure to different hazardous gases.

In Ontario, OHSA Reg. 833 defines the time-weighted average limit (TWA) as the average of the airborne concentrations of a biological or chemical agent determined from air samples of the airborne concentrations to which a worker may be exposed in a work day or a work week.
The short term exposure limit (STEL) is the maximum airborne concentration of a biological or chemical agent to which a worker may be exposed in any 15-minute period determined from a single sample or a time-weighted average of sequential samples taken during such period.

An individual exposed to hazardous gases beyond the TWA or the STEL will experience an adverse reaction.

Immediately Dangerous to Life or Health (IDLH) refers to an atmosphere in any worksite, space, or area where the concentration of O₂ or flammable or toxic air contaminants

<table>
<thead>
<tr>
<th>Gas</th>
<th>Exposure Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>40,000 ppm</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>1,200 ppm</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>20 ppm</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Ammonia</td>
<td>300 ppm</td>
</tr>
</tbody>
</table>
would fatally injure a person without respiratory protection, or would have irreversible incapacitating effects on that person’s health.

An IDLH situation, requiring the use of breathing apparatus, must be assumed in the presence of any of the following:

1. A known contaminant in an IDLH concentration
2. A known contaminant, but at an unknown concentration
3. An unknown contaminant
4. An $O_2$ deficiency
5. A confined space
6. Contaminants at or above lower explosive limit
7. Firefighting

**NITROGEN ($N_2$)**

Nitrogen is inert, colourless, odourless, and tasteless, and the most abundant gas in the atmosphere. It will not burn or explode, nor will it support combustion. It has no physiological effect on humans and is only dangerous if it has displaced the $O_2$ below a safe limit. Nitrogen has a specific gravity of 0.97, slightly lighter than air.

Higher than normal concentrations of $N_2$ may be caused by the oxidation of various substances, the burning of an active fire or the consumption of $O_2$ by water in confined spaces.

In the mining industry $N_2$ is used to purge storage tanks and electrical installations and to operate pneumatic hand tools. It may be found stored in large (2,200 psi/152 bar) bottles on surface.
OXYGEN ($O_2$)

Oxygen is a colourless, odourless and tasteless gas and is the most important constituent of air. It is necessary to sustain life and though on its own it will not burn or explode, $O_2$ is needed for combustion to occur. Oxygen has a specific gravity of 1.11.

People breathe most easily and work best when the air contains approximately 21 per cent $O_2$. When the $O_2$ content is about 17 per cent, people at work will breathe a little faster and more deeply. The effect is about the same as when going from sea level to an altitude of 1,700 metres.

A person breathing air containing as little as 15 per cent $O_2$ usually becomes dizzy, notices a buzzing in the ears, has a rapid heartbeat and may have a headache. Very few people are free from these symptoms when the $O_2$ level falls to 10 per cent.

The effects of $O_2$ deficiency near or below sea level are the same as those of a reduction in $O_2$ at high altitudes. At approximately seven per cent $O_2$ the face becomes leaden in colour, the mind becomes confused, and the senses dulled.

When there is no $O_2$ in the atmosphere, loss of consciousness is quicker than in drowning. Not only is the supply of $O_2$ cut off, but the $O_2$ in the lungs is rapidly depleted. Loss of consciousness is followed by convulsions, then cessation of respiration.

Oxygen deficiency is one of the greatest gas hazards in underground mining. The effects of extreme $O_2$ deficiency are so rapid that a person’s life is in peril before he realizes the danger.
### Causes of Oxygen Deficiency

- Absorption by water or certain types of rock or fill
- Breathing by people in confined spaces
- Displacement by CH\(_4\), CO or other gases
- Combustion or heating situations

Sect. 253, Regulation 854 of the OHSA requires underground mines to have a partial pressure of oxygen of more than 18 kpa. Breathing O\(_2\) in concentrations higher than the normal 20 to 21 per cent apparently has no injurious effect. The inhalation of 100 per cent O\(_2\), as used in breathing apparatus, for up to

### Effects of Oxygen (O\(_2\)) Deficiency

<table>
<thead>
<tr>
<th>Concentration of Oxygen in Atmosphere</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 - 21%</td>
<td>None, normal pulse and respiration.</td>
</tr>
<tr>
<td>14 - 18%</td>
<td>Increased pulse and respiration, muscular co-ordination disturbed.</td>
</tr>
<tr>
<td>10 - 14%</td>
<td>Abnormal fatigue, disturbed respiration.</td>
</tr>
<tr>
<td>7 - 10%</td>
<td>Nausea, vomiting, collapse, loss of consciousness.</td>
</tr>
<tr>
<td>&lt; 6%</td>
<td>Convulsive movements, respiratory collapse, death.</td>
</tr>
</tbody>
</table>
Other:

Oxygen does not burn, but does support combustion.

How Depleted

Oxygen deficiency caused by humans breathing in confined space, absorption of oxygen by water, oxygen being consumed by fire, etc.

Effect on Humans

Mine air should have at least 20.94 (18 kpa) per cent oxygen. High concentration not harmful. Essential to life. Early symptoms of oxygen deficiency – buzzing in ears, rapid breathing, confusion, unconsciousness.

Treatment of Persons Affected (oxygen deficiency)

Remove to fresh air, give oxygen, artificial respiration if breathing stopped. Complete rest and treatment for shock. Seek medical aid.
16 hours a day for many days at atmospheric pressure, has caused no observed injury to man. At atmospheric pressure it is believed to have no serious effects for a continuous exposure of 24 to 48 hours.

The inhalation of pure $O_2$ at a pressure of three atmospheres (3.0 bar) is safe for a period of 30 minutes. After three hours of inhaling 100 per cent $O_2$, at more than one atmosphere (1.0 bar), neuromuscular co-ordination and the power of attention may be adversely affected.

An oxygen-enriched atmosphere is a potentially serious fire hazard. Such a situation may be created when $O_2$ breathing apparatus or other $O_2$ equipment is being used, particularly in confined spaces such as tanks, wells or enclosed rooms.

**CARBON DIOXIDE (CO$_2$)**

Carbon dioxide is a colourless, odourless gas that, when breathed in large quantities may have a distinct acid taste but is otherwise tasteless. It will neither burn nor support combustion.

Increases in CO$_2$ could cause headaches, dizziness, restlessness and disorientation, followed by paralysis of the central nervous system. Moving around or working increases the effects.

Carbon dioxide has a specific gravity of 1.53, and is often found in unventilated areas and abandoned mine workings. It is normally found in mine air but the concentration can be increased by breathing, the burning of fires, as well as explosions and blasting.

Carbon dioxide is produced by the decomposition and the combustion of organic compounds in the presence of $O_2$, and also by the respiration of humans and animals.
CARBON DIOXIDE (CO₂) – Specific Gravity: 1.53

**How Formed**
Oxidation of organic materials, rotting timber, burning wood, blasting, diesel engines, humans breathing and as a product of complete combustion of organic materials.

**Effect on Humans**
TWA = 5,000 ppm – stimulates breathing; 50,000 ppm – increases respiration 300 per cent; 100,000 ppm – can be endured for only short periods.

**Treatment of Persons Affected (oxygen deficiency)**
Remove to fresh air, give oxygen, artificial respiration if breathing stopped.
When the concentration of $CO_2$ in the air is more than five per cent, the $O_2$ content is usually considerably lower than normal, and the distinct acid taste is noticed.

**CARBON MONOXIDE (CO)**

Carbon monoxide is a colourless, odourless, tasteless gas that, when breathed, even in low concentrations, will produce symptoms of poisoning.

Carbon monoxide is one of the greatest gas hazards in underground mining. It is produced by combustion in blasting operations, the operation of diesel engines, and by mine fires and gas explosions.
It results from incomplete combustion when organic compounds are burned in an atmosphere with too little $O_2$ to carry the burning or oxidation to completion.

Carbon monoxide will burn, and in concentrations of 12.5 to 74 per cent will explode if ignited. It is only slightly soluble in water and is not removed from the air to any extent by water sprays. It is slightly lighter than air, having a specific gravity of 0.97.

The TWA of CO is 25 ppm or 0.0025 per cent, and the STEL is 100 ppm.

Carbon monoxide causes increasingly severe toxic effects as the concentration and duration of exposure increases. The effect of high concentrations may be so sudden that one has little or no warning before collapsing.

**Physiological Effects of CO**

Oxygen absorbed from the air in the lungs is normally absorbed by the hemoglobin in red blood cells and carried to the tissues where it is used.

Hemoglobin, however, has an affinity for CO 300 times greater than for $O_2$. When there is even a small percentage of CO in the air, the hemoglobin will absorb it in preference to $O_2$.

When CO is absorbed by hemoglobin, it reduces the capacity of the hemoglobin to carry $O_2$ to the tissues to a proportionate extent. This interference with the $O_2$ supply to the tissues produces the symptoms of poisoning.

A person exposed to high concentrations may experience few symptoms. The rate at which a person is overcome, and the order in which the symptoms appear, depend on the
state of the person’s health and individual susceptibility, the temperature, humidity, and air movement to which they are exposed, as well as the concentration and period of exposure.

Exercise, high temperature, and humidity with little or no air movement, tend to increase respiration and heart rate and, consequently, result in more rapid absorption of CO.

The most important rules for the treatment of CO poisoning are to avoid further exposure and to keep the patient at rest.

When a person is suffering from acute poisoning, it is important that CO be eliminated from the blood as quickly as possible, thus decreasing the possibility of serious aftereffects, including death.

### Effects of CO by Percentage of Blood Saturation

<table>
<thead>
<tr>
<th>% Saturation</th>
<th>Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>None</td>
</tr>
<tr>
<td>10-20</td>
<td>Tightness across forehead, possible headache</td>
</tr>
<tr>
<td>20-30</td>
<td>Headache, throbbing in temples</td>
</tr>
<tr>
<td>30-40</td>
<td>Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting and collapse</td>
</tr>
<tr>
<td>40-50</td>
<td>Same as 30-40 with greater possibility of fainting and collapse, increased pulse and respiration</td>
</tr>
<tr>
<td>50-60</td>
<td>Fainting, increased pulse and respiration, coma with intermittent convulsions</td>
</tr>
<tr>
<td>60-70</td>
<td>Coma with intermittent convulsions, depressed heart action and respiration, possibly death</td>
</tr>
<tr>
<td>70-80</td>
<td>Weak pulse and slow respiration, respiratory failure and death</td>
</tr>
</tbody>
</table>
CARBON MONOXIDE (CO) – Specific Gravity: 0.97

**How Formed**
Incomplete combustion of organic materials. Diesel exhaust, blasting, fires.

**Effect on Humans**
TWA = 25 ppm – saturates blood so oxygen cannot be used. Early symptoms include tightness of skin on forehead, dizziness, nausea, confusion of mind, a pink colour of the skin, and unconsciousness. Absorption by blood is cumulative.

**Treatment of Persons Affected**
Remove to fresh air, give oxygen, artificial respiration if breathing has stopped. Rest and treatment for shock. Seek medical aid.

**Other:**

<table>
<thead>
<tr>
<th>Colour:</th>
<th>None</th>
<th>Burn:</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour:</td>
<td>None</td>
<td>Explode:</td>
<td>12.5-74%</td>
</tr>
<tr>
<td>Taste:</td>
<td>None</td>
<td>Poison:</td>
<td>25 ppm</td>
</tr>
</tbody>
</table>

**Colour:** None  
**Burn:** Yes  
**Odour:** None  
**Explode:** 12.5-74%  
**Taste:** None  
**Poison:** 25 ppm
As soon as the patient begins to breathe air in which there is no CO, the process of eliminating the gas from the blood begins naturally. However, this normal, unaided elimination is slow and does not always prevent serious aftereffects. It may take the body as long as eight to 15 hours to reduce the CO saturated hemoglobin to 10 per cent of the total hemoglobin. However, if the casualty inhales pure O₂, the CO will be removed from the blood four to five times faster.

**HYDROGEN SULPHIDE (H₂S)**

Hydrogen sulphide is a colourless gas that has both an acidic taste and a smell, depending on the concentration. When explosions of dust occur in blasting operations in sulphide ore bodies, the resulting gases may contain varying amounts of H₂S, along with sulphur dioxide and possibly other sulphur gases.

In low concentrations its distinctive rotten egg odour is noticeable, but in concentrations of 100 ppm or more the sense of smell is paralyzed and cannot be relied on for warning.

The gas has a specific gravity of 1.19, and may collect at low points. A concentration of 4.3 to 46 per cent of H₂S in the air is explosive. Hydrogen sulphide may also indicate the presence of methane.

Hydrogen sulphide, inhaled in sufficiently high concentrations, can produce immediate asphyxiation. In low concentrations it causes irritation to the eyes and respiratory tract and sometimes leads to bronchitis and pneumonia.

Subacute poisoning may be produced by long exposure to concentrations as low as 50 ppm. Immediate collapse usually
HYDROGEN SULPHIDE (H₂S) – Specific Gravity: 1.19

Colour: None

Burn: Yes

Odour: Rotten egg odour in low concentrations

Explode: 4.3-46%

Taste: Acidic

Poison: 10 ppm

Other:

How Formed
Burning sulphide ores, explosions of dusts from sulphide ores, hydrochloric acid on sulphide concentrate.

Effect on Humans
TWA = 10 ppm – irritates nose, eyes, throat, etc. Paralyses respiratory centre. Low concentrations cause edema of the lungs, bronchitis, pneumonia.

Treatment of Persons Affected
Complete rest and treat for shock. Remove to fresh air. Give oxygen, artificial respiration if breathing stopped. Seek medical aid and advise of suspected exposure.
results from exposure to concentrations greater than 500 ppm and death quickly ensues. The TWA for H₂S is 10 ppm and the STEL is 15 ppm.

NOTE: Regulation 833 (Nov. 5, 2010) refers to the 2009 Threshold limit Values and Biological Exposure Indices published by ACGIH. The 2010 ACGIH TWA and STEL for H₂S are 1 ppm and 5 ppm respectively.

**METHANE (CH₄)**

Methane is a colourless, tasteless, and odourless gas. It may be accompanied by an odour caused by other gases such as H₂S. Methane will burn with a pale blue non-luminous flame.

Air that contains five to 15 per cent CH₄ and as little as 12 per cent O₂, will explode, methane’s greatest danger. The flammable and explosive range of CH₄, however, is variable, and all occurrences of the gas should be considered dangerous. Where the presence of CH₄ is suspected or known, adequate ventilation to dilute the gas to a harmless percentage is important.

Under OHSA, Reg. 854, Section 35 (6):

If concentrations of flammable gas exceed 1.0 per cent in an area, all of the following precautions shall be taken:

1. All sources of ignition in the affected area shall be eliminated.
2. All electrical equipment in the affected area shall be de-energized.
3. All persons, other than competent persons necessary to measure the concentration of flammable gas and to make
METHANE (CH₄) – Specific Gravity: 0.55

<table>
<thead>
<tr>
<th>Colour:</th>
<th>None</th>
<th>Burn:</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour:</td>
<td>None. Often associated with other sulphurous gases.</td>
<td>Explode:</td>
<td>5-15%</td>
</tr>
<tr>
<td>Taste:</td>
<td>None</td>
<td>Poison:</td>
<td>None</td>
</tr>
<tr>
<td>Other:</td>
<td>Explosive in air containing as little as 12% oxygen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**How Formed**
Decomposition of organic material. Released from coal seams or some rocks when mining carried out or when diamond drilling.

**Effect on Humans**
Non-toxic but can be an asphyxiants, displacing oxygen in confined spaces.

**Treatment of Persons Affected**
Treat for O₂ deficiency if methane lowers the oxygen content.
ventilation changes, shall be removed from the affected area.

Methane, or marsh gas, is encountered in most mining districts of Ontario. The length of time the gas will flow into a mine depends on the size of the pocket tapped. It is formed by the decomposition of organic matter in the presence of water and the absence of air or O\textsubscript{2}. It can be seen in the form of bubbles in stagnant pools, hence the name marsh gas.

At a specific gravity of 0.55, CH\textsubscript{4} is lighter than air and, when found in mines, is usually near the roof or at higher elevations. The gas may be encountered issuing from diamond drill holes, in unused and poorly ventilated mine workings, or when old workings are being de-watered. It may also be caused by the decay of old timbers.

In addition to its explosive nature, methane has a toxic effect on humans. It has a TWA of 1,000 ppm. CH\textsubscript{4} may also displace the O\textsubscript{2} in the air to such an extent as to cause O\textsubscript{2} deficiency.

**OXIDES OF NITROGEN (NO\textsubscript{x})**

The oxides of nitrogen are formed in mines by diesel engines, and the burning and detonation of explosives. It is also formed by nitric oxide readily converting to nitrogen dioxide in the presence of O\textsubscript{2} and moisture.

When inhaled in sufficient concentration it causes pulmonary edema that blocks the body’s natural respiration processes and leads to death by suffocation.

The oxides of nitrogen (NO\textsubscript{x}) exist in various forms in the gaseous state: nitric oxide (NO), nitrogen dioxide (NO\textsubscript{2}) and
NITROGEN DIOXIDE (NO₂) – Specific Gravity: 1.59

Colour: None in small concentrations; reddish-brown in higher concentrations
Burn: None

Odour: Yes
Explode: None
Taste: None
Poison: 3 ppm

Other:

How Formed
Diesel exhaust, blasting with dynamite and ammonium nitrate blasting agents.

Effect on Humans
TWA = 3 ppm – corrosive to tissues of lungs and respiratory tract. Causes edema.

Treatment of Persons Affected
Remove to fresh air, give oxygen, complete rest and treat for shock. Seek medical aid and advise of suspected exposure.
dinitrogen tetraoxide ($N_2O_4$). Though all are harmful, $NO_2$ has the most profound effects on humans.

Nitrogen dioxide can appear as a reddish brown gas with a strong, suffocating odour. Inhalation can cause irritation to the nose and throat in concentrations as low as 15 to 25 ppm. In concentrations of 25 to 100 ppm more severe symptoms can occur which may include bronchitis and pneumonia.

The symptoms may develop in three stages which include: initial exposure, relief of symptoms when the casualty is removed from further exposure, and the slow development of bronchitis or pneumonia over a period of three to 36 hours.

Treatment must include removal of the patient from further exposure, $O_2$ therapy, and monitoring for a full 24-hour period.

Nitrogen dioxide has a specific gravity of 1.59, a TWA of 3 ppm and a STEL of 5 ppm.

**SULPHUR DIOXIDE ($SO_2$)**

Sulphur dioxide is a colourless, suffocating, irritating gas with the familiar strong, sulphurous odour. It is sometimes given off

<table>
<thead>
<tr>
<th>Effects of Nitrogen Dioxide ($NO_2$)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentration of $NO_2$</strong></td>
<td><strong>Symptoms</strong></td>
</tr>
<tr>
<td>15-25 ppm</td>
<td>Nose and throat irritation, coughing, headache, nausea</td>
</tr>
<tr>
<td>25-100 ppm</td>
<td>Pneumonia, bronchitis; effects can be reversible</td>
</tr>
<tr>
<td>&gt; 150 ppm</td>
<td>Pulmonary edema, progressive blockage of small airways that is potentially fatal</td>
</tr>
</tbody>
</table>
SULPHUR DIOXIDE (SO$_2$) – Specific Gravity: 2.26

<table>
<thead>
<tr>
<th>Colour:</th>
<th>None</th>
<th>Burn:</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour:</td>
<td>Strong pungent sulphur smell</td>
<td>Explode:</td>
<td>None</td>
</tr>
<tr>
<td>Taste:</td>
<td>Acidic taste, in high concentrations</td>
<td>Poison:</td>
<td>2 ppm</td>
</tr>
</tbody>
</table>

Other: Very irritating to breathe.

How Formed
Burning sulphide ores. Blasting in sulphide ores, sulphide dust explosions. Some diesel fuels.

Effect on Humans
TWA = 2 ppm – irritation of eyes, throat, lungs. Intolerable to breathe in dangerous concentrations.

Treatment of Persons Affected
Fresh air, oxygen, artificial respiration if breathing stopped. Complete rest and treatment for shock. Seek medical aid and advise of suspected exposure.
by the detonation of explosives and is produced by mine fires in sulphide ore bodies.

Sulphur dioxide is very poisonous but, owing to its irritating effect on the eyes and respiratory tract, is intolerable to breathe for any length of time. Exposure to this gas for even a short period will cause edema of the lungs and damage to any moist tissues of the body by the production of sulphurous acid.

Sulphur dioxide is a heavy gas with a specific gravity of 2.26 and has a TWA of 2 ppm. The STEL is 5 ppm.

**HYDROGEN (H₂)**

Hydrogen is a colourless, odourless, tasteless gas and a normal constituent of air. It is not dangerous to breathe but is dangerous because it is combustible in the range of 4.1 to 74 per cent in as little as five per cent O₂. It can collect in high places as the specific gravity is 0.07. In addition, during a mine fire it may unite with carbon to form explosive concentrations of hydrocarbons.

Hydrogen is found in normal air in very small quantities. It is sometimes found in higher concentrations in the mine atmosphere during or after a fire, particularly when rocks have been heated to incandescence. It is also a product of electrolytic action during battery charging.

**ACETYLENE (C₂H₂)**

Acetylene is a colourless, odourless, and tasteless gas that is used underground in oxy-acetylene welding and cutting procedures. Commercial grades have a garlic odour added for the purpose of detection.
HYDROGEN (H₂) – Specific Gravity: 0.07

Other: Highly explosive over wide range with as little as 5% oxygen.

How Formed
Electrolysis in battery charging stations. Incomplete combustion and molecular breakdown of water when rock heated to incandescence. Present in coal gas and caused by blasting coal.

Effect on Humans
Non-toxic

Treatment of Persons Affected
As for oxygen deficiency if hydrogen lowers oxygen content.

<table>
<thead>
<tr>
<th>Colour:</th>
<th>None</th>
<th>Burn:</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour:</td>
<td>None</td>
<td>Explode:</td>
<td>4.1-74%</td>
</tr>
<tr>
<td>Taste:</td>
<td>None</td>
<td>Poison:</td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colour:</th>
<th>None</th>
<th>Burn:</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour:</td>
<td>None</td>
<td>Explode:</td>
<td>4.1-74%</td>
</tr>
<tr>
<td>Taste:</td>
<td>None</td>
<td>Poison:</td>
<td>None</td>
</tr>
</tbody>
</table>
It is explosive in the range of 2.5 to 81 per cent and with a specific gravity of 0.91 is only slightly lighter than air.

Acetylene is essentially a non-toxic gas at concentrations below the lower explosive limit. At higher levels it has an anesthetic action and, if allowed to displace O₂ levels, may cause asphyxiation.

**AMMONIA (NH₃)**

Ammonia is a colourless gas with an intensely irritating odour. It can be found when blasting in backfill or cement structures underground, or it can be present in recycled underground water.

At a specific gravity of 0.60 it is lighter than air and is explosive in the range of 15 to 28 per cent.

Irritation to the respiratory tract may occur in levels as low as 20 to 25 ppm. Immediate, severe irritation to the eyes, nose and throat will occur at 400 to 700 ppm. Brief exposure to levels as high as 5,000 ppm, may cause rapid death due to suffocation or edema of the lungs.

The TWA for ammonia is 25 ppm and the STEL is 35 ppm.

Treatment for casualties suffering from inhalation of ammonia should include respiratory support and to seek medical aid.

**SMOKE**

Smoke consists of fine particles of solid and liquid matter suspended in the atmosphere. These particles are composed mostly of soot or carbon, together with tarry substances, mainly hydrocarbons. Asphyxiating and irritating gases and
vapours are usually mixed with the smoke. Hydrocarbons in sufficient concentrations may be explosive.

**GAS HAZARDS DURING AND AFTER MINE FIRES**

During and after mine fires two of the greatest hazards to life are poisoning from CO and suffocation in an oxygen-deficient atmosphere, but other dangers also exist.

- **Carbon Monoxide** – This gas is always present during or after an underground fire and there is little or no sign of its presence.

- **Oxygen Deficiency** – This condition results when $O_2$ is used up by combustion or a chemical reaction and is replaced by other gases, either poisonous or inert.

- **Smoke** – The danger from smoke is that it is irritating and obstructs vision. It may be explosive and poisonous if it contains the products of the decomposition of synthetic materials due to heat.

- **Danger of Explosions** – Hydrocarbon gases caused or generated by fire (as in smoke) may explode.

- **Methane** – This gas is not produced by mine fires or explosions, but it may cause them. Its presence may then create a hazard.

- **Sulphur Dioxide** – This gas may be present during the mining of sulphide ore bodies. Because of its irritating properties it gives advance warning when in less than toxic concentrations.
TREATMENT FOR GAS POISONING

The treatment for gas poisoning is:

1. Remove patient to fresh air as soon as possible.

2. If breathing has stopped, give artificial respiration continuously until the patient is breathing normally again.

3. Give pure O$_2$ at atmospheric pressure as soon as possible and for as long as necessary.

4. Keep the patient warm with blankets.

5. Keep the patient at rest, lying down to avoid strain on the heart.

6. Seek medical attention.
ADDITIONAL GAS HAZARDS

In fires caused in conveyor belting by friction heating, the cotton carcass is usually responsible for the ignition, but once the belting is ignited, the rubber cover allows the fire to spread. Grease, oil and other material will support the burning of the belt.

In other fires the heat may be so intense that conveyor belts, tires, ventilation tubing, and other items composed of fire-resistant plastics, polyvinyl chloride (PVC), rubber, neoprene and other materials become involved.

Many gases are produced by the decomposition and burning of conveyor belting and rubber tires, urethane foam, and plastics. For example, PVC covered belting is practically non-flammable, but when heated both PVC and neoprene, as is found in rubber tires, give off chlorine gases.

PVC contains 55 per cent chlorine by weight, while synthetic rubber and neoprene contain about 40 per cent.

Some of these gases are so dangerous that CO is among the least poisonous. Though proper respiratory protection should provide adequate control for most of these hazards, mine rescuers should be aware of them.

Chlorine (Cl₂) – Chlorine is a greenish-yellow gas with a pungent, irritating odour. The odour may be described as “bleach-like” at low concentrations.

Liquefied Cl₂ is used for water treatment or as a process chemical in mills. It may be produced by the burning of PVC-coated fabrics and rubbers (ventilation ducting or conveyor belts). Chlorinated compounds are used as components or
### Properties of Gases Described in Handbook

<table>
<thead>
<tr>
<th>Gas</th>
<th>Spec. Gravity</th>
<th>Explosive Range (%)</th>
<th>Combustible</th>
<th>Colour</th>
<th>Odour</th>
<th>Taste</th>
<th>Dangerous to Breathe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1.00</td>
<td>–</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>1.11</td>
<td>–</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>1.53</td>
<td>–</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Yes¹</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>0.55</td>
<td>5.0 to 15</td>
<td>Yes</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No²</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>0.97</td>
<td>12.5 to 74</td>
<td>Yes</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Yes³</td>
</tr>
<tr>
<td>Hydrogen sulphide (H₂S)</td>
<td>1.19</td>
<td>4.3 to 46</td>
<td>Yes</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes³</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>1.59</td>
<td>–</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>None</td>
<td>Yes³</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>2.26</td>
<td>–</td>
<td>No</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes²</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>0.07</td>
<td>4.1 to 74</td>
<td>Yes</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>0.97</td>
<td>–</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Acetylene (C₂H₂)</td>
<td>0.91</td>
<td>2.5 to 81</td>
<td>Yes</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>0.6</td>
<td>15 to 28</td>
<td>Yes</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Note:**

1. CO₂ – dangerous to breathe in fairly high concentrations, above 5%.
2. CH₄, SO₂ – are sometimes accompanied by H₂S.
3. CO, H₂S, NO₂, SO₂ – are extremely dangerous to breathe, even in very low concentrations.
4. HCN may have a pale blue colour at high concentrations.
Note:

1. CO₂ – dangerous to breathe in fairly high concentrations, above 5%.
2. CH₄, SO₂ – are sometimes accompanied by H₂S.
3. CO, H₂S, NO₂, SO₂ – are extremely dangerous to breathe, even in very low concentrations.
4. HCN may have a pale blue colour at high concentrations.
additives in many rubbers and plastics and burning these materials may produce chlorine gas.

Chlorine is a toxic gas and is very irritating. Exposure to even low concentrations will cause eye, nose and respiratory irritation. Higher exposures can cause edema of the lung and damage to the eyes and respiratory tract. Edema may not be apparent for some time after exposure. Chlorine is not flammable or explosive but is a strong oxidizer and may support fires.

The TWA for Cl₂ is 0.5 ppm. The IDLH is 10 ppm.

**Arsine (AsH₃)** – Arsine is a colourless gas with a mild, garlic-like odour. Arsenic compounds may be used as fungicidal additives in fabrics, plastics, rubbers or pressure-treated woods. Burning these materials may produce AsH₃.

Arsine is a very toxic gas. Inhalation of even low concentrations may destroy red blood cells resulting in bloody urine, headaches, weakness, dizziness, nausea, vomiting and abdominal cramps and tenderness. There may be a delay between exposure and the onset of symptoms.

Nerve damage may result from exposure and AsH₃ is classified as a potential carcinogen. Arsine is also explosive in a range of 5.1 per cent to 78 per cent, in normal air.

The TWA for AsH₃ is 0.05 ppm. The IDLH is 3 ppm.

**Hydrogen Cyanide (HCN)** – Hydrogen cyanide is a colourless gas with a characteristic bitter almond odour and taste. At higher concentrations a pale blue colour might be seen. Hydrogen cyanide can be formed during the burning of nitrile and urethane plastics and rubbers. These plastics and rubbers may be used in tires, hoses, pipes, conveyor belts,
<table>
<thead>
<tr>
<th>GAS</th>
<th>Time-Weighted Average</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PPM</td>
<td>Percentages</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>25</td>
<td>0.0025</td>
</tr>
<tr>
<td>Chlorine$^1$</td>
<td>0.5</td>
<td>0.00005</td>
</tr>
<tr>
<td>Hydrogen chloride</td>
<td>5</td>
<td>0.0005</td>
</tr>
<tr>
<td>Phosgene$^1$</td>
<td>0.1</td>
<td>0.00001</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>2</td>
<td>0.0002</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>10</td>
<td>0.001</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>3</td>
<td>0.0003</td>
</tr>
<tr>
<td>Ammonia</td>
<td>25</td>
<td>0.0025</td>
</tr>
<tr>
<td>Hydrogen cyanide$^2$</td>
<td>4.7</td>
<td>0.001</td>
</tr>
<tr>
<td>Arsine$^{1,3}$</td>
<td>0.05</td>
<td>0.000005</td>
</tr>
<tr>
<td>Phosphine$^{1,3}$</td>
<td>0.3</td>
<td>0.00003</td>
</tr>
</tbody>
</table>

1. Note the toxicity of these gases compared to that of carbon monoxide.
2. Note that 4.7 is a Ceiling exposure limit, not a TWA.
3. These gases will be found only if the carcase is impregnated with certain fungicidal or fire retardant compositions.
stopping and sprayed liners for ground control. Hydrogen cyanide may also be formed by contact between cyanide salts or solutions and acids.

Hydrogen cyanide is a chemical asphyxiant. Inhalation of HCN can cause weakness, headache, confusion, nausea, and vomiting. Exposure limits for HCN have a SKIN notation, indicating that it can be absorbed through intact skin, the eyes and moist tissues of the nose and mouth.

While there is ample human evidence of HCN being absorbed from solutions and from contact with cyanide salts, there is no information on what airborne concentration of HCN is potentially hazardous by skin absorption.

Hydrogen cyanide is also explosive in a range of 5.6 per cent to 40 per cent, in normal air.

The Ceiling exposure limit (maximum airborne concentration of a biological or chemical agent to which a worker may be exposed at any time) for HCN is 4.7 ppm (SKIN). The IDLH is 50 ppm.

**Hydrogen Chloride (HCl)** – Hydrogen chloride is a clear, colourless gas with a pungent, irritating odour. High concentrations may have a slightly yellow colour. It may be produced by the burning of PVC-coated fabrics and rubbers. Chlorinated compounds are used as components or additives in many rubbers and plastics and burning these materials may produce HCl.

Hydrogen chloride is a severe irritant. Exposure to even low concentrations will cause eye, nose and respiratory irritation. Higher exposures can cause edema of the lung and damage to
the eyes and respiratory tract. Edema may not be apparent until some time after exposure.

The Ceiling exposure limit for HCl is 5 ppm. The IDLH is 50 ppm.

**Phosgene (COCl\(_2\))** – Phosgene is a toxic, colourless gas with a suffocating “musty hay” odour. It may be produced by the burning of PVC-coated fabrics and rubbers. Chlorinated compounds are used as components or additives in many rubbers and plastics and burning of these materials may produce phosgene.

Phosgene is a severe irritant. Exposure to even low concentrations will cause eye, nose and respiratory irritation. Higher exposures can cause vomiting, shortness of breath, chest pain, and edema. Effects of exposure may not be apparent for some time after exposure.

The TWA for COCl\(_2\) is 0.1 ppm. The IDLH is 2 ppm.

**Phosphine (PH\(_3\))** – Phosphine is a toxic, colourless gas with a fishy or garlic odour. Phosphorus compounds may be used as flame retardants in fabrics, plastics, or rubbers. Smoldering, oxygen-starved fires involving these materials may produce PH\(_3\).

Phosphine is an irritant and may cause lung edema and neurotoxicity. It may also produce chest pain, abdominal or muscle pain, nausea, vomiting, or diarrhea. The onset of symptoms may be delayed. Phosphine becomes explosive when it reaches a concentration of 1.79 per cent in normal air, at higher concentrations it may spontaneously ignite.

The TWA for PH\(_3\) is 0.3 ppm. The IDLH is 50 ppm.
CHAPTER 5
DETECTING MINE GASES

INTRODUCTION TO THE MX6

The MX6 iBrid Multi-Gas Monitor is a hand-held device capable of effectively monitoring different gas concentrations in the air. For mine rescue and recovery operations, the MX6 is configured to monitor carbon monoxide (CO), methane (CH\textsubscript{4}) and oxygen (O\textsubscript{2}) concentrations.

Warnings that this apparatus is “For Use with Mine Rescue Breathing Apparatus Only” and that the “Alarms are Altered” are displayed on the storage case, indicating the equipment is for the use of mine rescue personnel only.

Non-mine rescue gas detection devices are usually set to measure methane, CH\textsubscript{4}, as a per cent of the lower explosive limit (LEL). Mine rescue units measure CH\textsubscript{4} in per cent volume. To avoid confusion and ensure proper operation for
mine rescue needs, teams should not use any non-mine rescue
gas detection device without the expressed direction of the
emergency control group.

The monitor(s) should lie on top of the other components in
the storage case, to be easily viewed to see if it is charged.

Each storage case contains:
• One or more MX6 Multi-Gas Monitor
• Calibration cup with attached polyurethane tubing (the
  other end of the tubing is attached to the top of the brass
cylinder on/off valve
• Calibration gas cylinder
• Calibration log
• Brass cylinder on/off valve (with regulator and pressure
gauge) in protective covering
• Battery charger

While the monitor(s) are in the storage case their battery
chargers must be plugged into a 120V outlet. This trickle
charges the lithium-ion battery on a continuous basis to ensure
that the monitors are always ready for use.

**COMPONENTS**

The hardware components of the MX6 are:

**Liquid Crystal Display Screen** – The LCD screen is a
graphical, colour display with a software-controlled backlight.
The display provides clear readings in all lighting conditions.
A backlight is enabled for five seconds each time a button is
pressed. Any additional button press during the five seconds
resets the timer for an additional five seconds.
When activated, the display shows gas readings as sampled by the MX6 and the battery level.

- CO is displayed in ppm. At low range (zero to 999 ppm) it is displayed in one ppm resolution and at high range (1,000 to 10,000 ppm) it is displayed in 50 ppm resolution.
- CH$_4$ is displayed in per cent volume, ranging from 0.0 per cent to five per cent in 0.1 per cent resolution.
- O$_2$ is displayed in per cent volume, ranging from 0.0 per cent to 30 per cent in 0.01 per cent resolution.
• Battery icon continuously indicates the battery’s charge status. An animated icon, moving top to bottom, indicates the battery is charging.

**Navigation Button** – The single Five-Way Navigation Button provides easy positioning and item selection from the LCD. The menu system allows the user to select different modes and actions. The navigation button has five pressure sensitive positions (Up, Down, Left, Right, and On/Off/Enter). Most navigation is controlled by a single button push, though some operating modes are only accessible by holding the button for several seconds, or by pressing the button twice.

**Sensors** – MX6 units used by Ontario Mine Rescue have sensors only for Carbon Monoxide (CO), Methane (CH₄) and Oxygen (O₂). The sensors are in the top, front portion of the device behind the sensor grid. Sensor openings in the grid permit the sensors to monitor ambient gases. A gas-permeable, gortex filter covers the sensor openings to limit the amount of dust and contaminants that might enter the internal sensor chamber and affect sensor readings. The sensors and the sensor grid area must be kept clean and clear of obstructions for the device to work and to give accurate measures.

**Audible Alarm Indicators** – A 90-decibel (dB) at three feet alarm sounds when any one of the installed sensors exceeds the alarm set point.

**Visual alarm** – Ultra-bright indicators provide a visual indication when any one of the installed sensors exceeds the alarm set point.
**I/R Communications Port** – An optical media interface is on the bottom on the MX6 and used for infrared (I/R) data transmissions to a host computer.

**Battery Charging Contacts** – A charger is used to charge the MX6’s internal batteries. A combination transformer and power cord is supplied with the charger. A Datalink charger can be used to charge the device and download data directly to a host computer.

**Rechargeable lithium-ion battery** – When fully charged this battery will operate approximately 24 hours. A depleted battery should recharge in about five hours.

While in the charger, the LCD screen will show that it is charged or that it is charging. If charging, a bar shows the existing charge as an approximate percentage of total battery life. When the display slows “Charge Complete”, the device is ready for use.

If the MX6 is charging, it is NOT ready for use. The internal battery must be fully charged before the device is used. When a battery pack starts to fail and no longer charges to full capacity, it is time for replacement.

**ALARM POINTS**

The MX6 has the following alarm points:

- CO alarm has been disabled.
- CH$_4$ alarm is set to activate a Level 1 (low alarm) at 1.0 per cent, and a Level 2 (high alarm) at 2.0 per cent.
- O$_2$ alarm is set to activate at 17.5 per cent, and at 23.5 per cent.
- A Low Battery alert commences when less than five percent of the charge remains. It is followed by several higher level alarms.

For all sensors but oxygen, the alarm level will change as the gas concentration increases or decreases. For example: if the gas reading is above Level 2 (high) alarm, the instrument sustains the alarm until the gas reading is below Level 2, then the instrument switches to the Level 1 (low) alarm until the gas reading is below Level 1 alarm. For the oxygen sensor, a Level 2 or high alarm only is indicated for both oxygen enrichment and depletion.

The device uses audible, visual and vibrating alarms.

The audible Level 1 alarm is a low frequency beep followed by a slow series of beeps. The alarm will continue to signal until either gas concentrations return to safe levels, or in the case of \( \text{CH}_4 \) reach levels initiating the high alarm.

The audible Level 2 alarm is a high frequency, dual-toned beep followed by a fast series of beeps.

The MX6 has four visual alarm LEDs beneath the translucent sensor grid at the top of the unit. During an alarm, the LEDs are activated and illuminate the upper portion of the device. For Level 1 alarms, the LEDs are pulsed on and off with a long delay between pulses. For the Level 2 alarms, the LEDs are pulsed on and off with a short delay. As well, the LCD backlight flashes as part of all alarm sequences, except for the “battery low” condition.

The visual alarm is also used as the confidence indicator which, when enabled, blinks the LEDs once every 30 seconds.
The MX6 has an optional vibrating alarm used for limit alarms and as a confidence indicator. When enabled, this alarm vibrates for two seconds approximately every 30 to 60 seconds.

Prior to the Low Battery Alarm commencing, the battery icon on the LCD display will turn yellow when only five per cent of a full charge remains.

When less than an hour of charge remains, the battery icon will flash and an audible low battery alarm will sound.

When less than 10 minutes of charge remains, the battery icon will turn red and a “Low Battery” warning is visible on the lower central part of the display.

**USING THE MX6**

Before use, the MX6 must be removed from storage fully charged. If it is not fully charged, the MX6 cannot be used.

The MX6 is easy to use and includes the following steps:

**Power Up** – The MX6 is turned on by pressing and holding the centre [ENTER] point on the Five-way Navigation Button for several seconds until the backlight turns on, the red LEDs flash, and a beep is heard.

**Startup Self-Test** – The self-test lasts for several seconds and tests all of the main components in the instrument. The results of the self-test are displayed and saved into memory. The user must acknowledge the results of the self-test by selecting OK and pressing [ENTER].

**Normal Operation Mode** – After the optional Startup Self-Test is completed, the instrument displays the Normal Operation Mode. The Normal Readings Screen is the default
screen displayed while the instrument is in Normal Operation Mode.

**Calibration** – Each gas sensor in the MX6 must be calibrated each time the device is to be used. If any sensor fails calibration the MX6 cannot be used until it has been serviced and shown to be safe for use.

**Shut Down** – To shut down the instrument, hold the centre [ENTER] navigation button until a confirmation screen is displayed to provide verification of the shutdown. Confirm or cancel shutdown by selecting the appropriate response and pressing [ENTER].

**Battery Use** – During its use, the MX6 will display a blue battery icon runtime indicator in the lower left-hand corner of the display to indicate approximately how much battery capacity remains.

After use, the MX6 must be properly cleaned before it can be stored. Cleaning consists of removing the MX6 from its carrying case, wiping the unit with a clean dry cloth and then wiping the carrying case, if required. The device is then placed into the storage case, with the battery lead attached, and stored with the battery charger plugged in so that the MX6 will be ready for its next use.
CHAPTER 6

PROTECTION FROM MINE GASES

APPROVALS FOR BREATHING APPARATUS

The Ontario Ministry of Labour only permits the use of approved respiratory protection in underground mines. The breathing apparatus referred to in this handbook are those used by Ontario Mine Rescue. The following approvals are accepted:

1. The National Institute for Occupational Safety and Health (NIOSH) in the U.S.
2. The European Norm Standard (EN Standard)

The approvals of other similar qualified authorities may also be accepted.

RESPIRATORY PROTECTION

One limitation is applicable to all respiratory protective equipment – certain gases can enter the body by means other than the respiratory tract. Ammonia, for example, in concentrations of approximately three per cent or higher can cause skin burns (particularly on moist skin). Similarly, appreciable amounts of gases, such as hydrogen cyanide, can penetrate the skin and cause systemic poisoning.

To avoid this possibility, protective clothing such as hazmat suits should be worn in addition to respiratory protection when facing such hazards. Gases such as these will not normally
be found underground, but mine rescuers must know what
dangers exist at a specific site, including the hazards posed by
the products of material combustion. Material Safety Data
Sheets (MSDS) for materials – vent tubing, conveyor belting,
etc. – that may be burning should be checked prior to any
assignment.

**RESPIRATORY HAZARDS**

There are three ways in which poisons can enter the body:

1. Through the stomach
2. Through the skin
3. Through the lungs

Of these three methods, the human respiratory system
presents the quickest and most direct means of entry. That is
because the respiratory system is closely associated with the
circulatory system, and is constantly supplying O₂ to every cell
in the body.

Respiratory hazards can be classified as:

1. Oxygen deficiency
2. Gas and vapour contaminants:
   (a) immediately dangerous to life and health
   (b) not immediately dangerous to life and health
3. Particulate contaminants (including aerosols, dust, fog,
fumes, mist, smoke and spray):
   (a) immediately dangerous to life and health
   (b) not immediately dangerous to life and health
4. A combination of gas, vapour and particulate contaminants:
   (a) immediately dangerous to life and health
   (b) not immediately dangerous to life and health

Respiratory protective devices fall into three classes:
1. Air-purifying
2. Air-supplied
3. Self-contained breathing apparatus

**SELF-CONTAINED BREATHING APPARATUS**

A self-contained breathing apparatus provides complete respiratory protection against toxic gases and O$_2$ deficiency. The wearer is independent of the surrounding atmosphere because he is breathing with a system that admits no outside air. The apparatus itself provides the O$_2$ or air needed by the wearer.

There are three types of self-contained breathing apparatus:
1. Oxygen-cylinder rebreather
2. Self-generating
3. Pressure-demand apparatus

**Oxygen-Cylinder Rebreathing Apparatus**

This type includes the lung-governed type that automatically compensates for the breathing demand of the user, the constant flow type, and combinations of the two.

The unit has a relatively small cylinder of compressed O$_2$, reducing and regulating valves, a breathing bag, face piece, and a chemical container to remove CO$_2$ from the exhaled breath.
The operating time of approved rebreathing units ranges from 30 minutes to four hours.

The rebreathing principle permits the most efficient use of the O₂ supply. The exhaled breath contains both O₂ and CO₂ because the human body extracts only a small part of the O₂ inhaled. As the user exhales, the CO₂ is removed by the chemical, and the O₂ that is left is used again.

This method of operation applies to all O₂ cylinder rebreathing-type apparatus as well as those using liquid O₂.

Each time the apparatus is used, the O₂ cylinder must be refilled and the CO₂-removing chemical replaced.

An example of rebreathers is the Drager BG4.

**Self-Generating Apparatus**

This apparatus differs from the conventional cylinder rebreathing apparatus in that it has a chemical canister that produces O₂ and removes the exhaled CO₂ in accordance with the breathing requirements of the user. It eliminates high-pressure O₂ cylinders, regulating valves, and other mechanical components.

The canister, which contains potassium dioxide (KO₂), generates O₂ when contacted by the moisture and CO₂ in the exhaled breath, and retains CO₂ and moisture. Retaining moisture is important as it aids in preventing fogging of the lens.

In some models a quick-start cartridge is included to provide an initial supply of O₂ at the beginning of use. Some models require a quick starter only at apparatus temperatures below 0°C (32°F).
Chapter 6 – PROTECTION FROM MINE GASES

Chemical O₂ apparatus have variable service times. The time is determined by the breathing rate. An example of this type of apparatus is the SSR 90 M.

Positive Pressure-Demand Apparatus

The positive pressure open-circuit demand apparatus is available from many manufacturers and in different models for specific applications. All consist of a high-pressure air cylinder, a regulator connected either directly or by a high-pressure tube to the cylinder, a face piece, and tube assembly with one exhalation valve or valves, and a frame-and-harness assembly for mounting the apparatus on the body.

The pressure-demand apparatus provides positive pressure to the face piece during both inhalation and exhalation to prevent inward leakage during inhalation.

CONDITIONING

No method of breathing protection should be considered perfect. The physiological structure of a human is such that it is impossible to manufacture a portable apparatus that will suit everyone on all occasions and for all purposes.

It is a simple matter for most people to use a breathing apparatus for a short time in familiar, safe and normal conditions. But it is a different matter to wear a breathing apparatus in an emergency where physical stress from high temperature, poor visibility and arduous work add to the emotional and psychological stress. Constant training in simulated emergencies is essential so that wearing the breathing device itself does not become part of the problem.
THE VALUE OF SLOW, DEEP BREATHING

To use gas masks or other breathing devices properly, the art of deep breathing should be practised until it becomes a habit. The value of slow, deep breathing at all times can be demonstrated whether wearing breathing devices or not. This
is best shown by doing exercise that causes panting or quick breathing.

Draw in several deep, controlled breaths slowly and evenly, inhaling as much air as possible through the nose, and exhaling through the mouth. It will be noticed that the normal rate of breathing can be resumed quickly and easily without panting.

Heat and resistance from the apparatus must be expected when breathing devices are worn. The resistance can vary from slight to as much as three or four psi, and must be overcome.

The heat may vary from normal to an intolerable temperature, depending upon the type of apparatus and local conditions.

If the apparatus wearer is breathing fast, he will be unable to overcome the resistance and obtain enough air before he starts to exhale. When this happens, the wearer begins to suffer from air hunger. This, in turn, induces a suffocating feeling, and the tendency is to remove the breathing device at all costs.

When wearing a breathing device of any make or type, it is essential to breathe deeply and slowly. The habit can be acquired only by continual practice and training.

SELF-CONTAINED RESPIRATORY PROTECTION

Self-contained protective breathing equipment may be classified by its method of operation, i.e., self-contained closed-circuit or self-contained open-circuit.

Self-contained closed-circuit apparatus used in mine rescue can be of various designs and may use compressed, liquid or
chemically produced \( \text{O}_2 \), which when breathed, is circulated through a chemical compound that absorbs \( \text{CO}_2 \) and is rebreathed. Examples of this type are the Drager BG4 and the SSR 90 M.

Self-contained open-circuit apparatus use purified compressed air, which once breathed, is passed to the outside air and not reused. An example of this type is pressure-demand apparatus such as the Drager Airboss PA 94, the Scott AirPak, and the MSA Ultralite.

**SELF-CONTAINED OXYGEN BREATHING APPARATUS**

**Physiological Effects of Breathing Pure Oxygen**

The quantity of \( \text{O}_2 \) consumed by the body varies with the amount of energy expended. A man at rest uses approximately 0.26 litres (16 cubic inches) of \( \text{O}_2 \) a minute. During strenuous exercise the consumption may increase to more than eight times that amount, but the body uses no more \( \text{O}_2 \) than it requires.

The pure \( \text{O}_2 \) breathed by the wearer of a self-contained \( \text{O}_2 \) breathing apparatus causes no noticeable ill effects, even after several successive periods of use, unless the wearer is subjected to air pressures greater than the normal atmospheric pressure of 1.0133 bar (14.7 psi), such as might be encountered in caisson work, or for continuous exposure for 24 to 48 hours.
Eliminating Dangerous Amounts of CO₂ in the Apparatus

One of the most important functions of any closed-circuit self-contained oxygen breathing apparatus is the elimination of dangerous amounts of CO₂ from the circulatory system of the apparatus.

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

A closed-circuit oxygen-producing (chemical) apparatus removes CO₂ through a chemical reaction with potassium dioxide (KO₂) resulting in the consumption of CO₂ and the production of O₂.

The Drager BG4 apparatus removes CO₂ by a refillable canister that uses soda lime.

THE BG4

General Description

The BG4 is a self-contained closed-circuit, O₂ breathing apparatus which enables the wearer to work in irrespirable and toxic atmospheres for up to four hours.

The air in the BG4 is inhaled and exhaled in a closed breathing loop. The positive pressure in the breathing loop protects the wearer by preventing contaminated atmosphere from entering the system.

Exhaled air travels from the facemask along the exhalation hose to the refillable CO₂ scrubber canister. Soda lime in the
canister removes the CO$_2$ from the exhaled air. The chemical reaction to remove CO$_2$ from the air produces heat and raises the temperature of the breathing loop. To counteract this increase in air temperature, inhalation draws the air through an air cooler, which effectively lowers the temperature of the inhaled air.

Cooled air and the addition of larger diameter exhalation/inhalation hoses help to ensure low breathing resistance and reduce the physical strain on the wearer.

Oxygen is replenished in the breathing loop whether the wearer is experiencing normal breathing or extreme breathing conditions. The wearer can also feed extra O$_2$ into the breathing loop via the manually operated bypass valve.

Performance of the BG4 is continually monitored by the Electronics system. The system generates an audible and visual alarm when residual or low pressure is reached or in the event of a malfunction.

The BG4 is lightweight (15 kg/33 lbs when fully charged) and extremely durable. The unit is able to withstand demanding applications and extreme environments.
The BG4 is comprised of four major systems:

1. Pneumatics
2. Breathing Loop
3. Electronics
4. Backplate and Harness Assembly

**Pneumatics**

The pneumatic system is responsible for the O$_2$ distribution to the breathing loop. The pneumatic system consists of the following parts:

- O$_2$ Cylinder
- O$_2$ Pressure Reducer
- Minimum (Demand) Valve
- O$_2$ Lines

**O$_2$ Cylinder** – The O$_2$ cylinder is attached to the frame of the BG4 with a pull strap which is secured using a Velcro closure and buckle.

The cylinder has a volume of two litres and is available in high-grade alloy-steel or carbon composite construction.

A fully charged O$_2$ cylinder is under a pressure of about 200 bar (2,900 psi). The cylinder contains at least 400 litres of 99.5 per cent O$_2$. Under normal breathing conditions, this is rated to last for four hours.

Each cylinder is equipped with a brass on/off valve. To prevent over-pressurization, the on/off valve contains a safety cap that will burst when the internal pressure of the cylinder reaches about 275 bar (4,000 psi).
Steel cylinders must be hydrostatically tested every five years to about 345 bar (5,000 psi) to comply with the regulations of the Canadian Transport Commission.

**O₂ Pressure reducer** – The O₂ pressure reducer is in the lower right-hand corner of the BG4. The assembly performs the following functions:

- The O₂ pressure reducer distributes high and medium pressure O₂ to the breathing loop.
- High pressure from the O₂ cylinder activates the Electronics system.
- High pressure is reduced to a medium pressure output of 4.0 bar (58 psi) to 4.4 bar (64 psi).
- A relief valve is activated at 6.0 bar (87 psi) to prevent overpressurization.
- In normal operation, O₂ consumed from the breathing loop is replaced by the constant dosage metering orifice at a rate of 1.5 to 1.9 L/min.
- When the minimum (demand) valve is activated, medium pressure O₂ is supplied to the valve at a flow rate of 80 L/min.
- A manually operated bypass valve injects O₂ into the breathing loop at a flow rate of 50 L/min.

The O₂ pressure reducer is attached to the O₂ cylinder by a hand-tightened connector.

**Minimum (demand) valve** – The minimum valve is on the right side of the breathing bag. During extreme physical effort, more O₂ may be needed than is supplied by the constant dosage system. The minimum valve is activated when the
breathing loop pressure drops to between 0.1 and 2.5 mbar. In such circumstances, deflation of the breathing bag activates the valve’s rocker arm. This opens the minimum valve and injects additional \(O_2\) into the breathing loop.

Pressure drop is induced in the breathing loop by excessive breathing demand or a leak in the system. The minimum valve utilizes medium pressure \(O_2\) from the \(O_2\) pressure reducer to provide approximately 80 L/min directly to the breathing loop.

**\(O_2\) Lines** – The \(O_2\) lines are a series of yellow, blue and clear lines that carry \(O_2\) from the pressure reducer to various components of the BG4.

A yellow medium pressure \(O_2\) line connects the minimum valve located at the breathing bag to the \(O_2\) pressure reducer.

The air cooler is connected to the constant dosage metering orifice at the \(O_2\) pressure reducer via a blue medium pressure \(O_2\) line.

A branch off the blue medium pressure \(O_2\) line connects the low pressure side of the Electronics to the pneumatic system.

A clear \(O_2\) line joins the manually operated bypass valve to the constant dosage metering orifice in the \(O_2\) pressure reducer.

**Breathing Loop**

The air in the BG4 is exhaled and inhaled in a closed breathing loop. Carbon dioxide is removed from exhaled air by the \(CO_2\) scrubber canister. Inhaled air is cooled by the air cooler and replenished with \(O_2\).
The breathing loop consists of:

- Panorama Nova Mask
- Connector Assembly
- Exhalation/Inhalation Hoses
- CO$_2$ Scrubber Canister
- Breathing Bag
- Pressure Relief Valve
- Moisture Relief Valve
- Air Cooler

**Panorama Nova Mask** – The Panorama Nova Mask is available in black ethylene propylene diene terpolymer (EPDM) and yellow silicone. Both have a double internal seal and are held in place by a five-strap, quick adjusting, head harness and neck strap.

An internal nose cup helps direct the exhaled breath to the connector assembly and helps to focus speech. The mask is equipped with a stainless steel speech diaphragm to facilitate communication while under O$_2$. 
The facemask has a curved full-view lens which allows 90 per cent of peripheral vision. It is equipped with a manually operated wiper to keep the inside surface of the lens clear.

**Connector Assembly** – The Panorama Nova Mask is attached to the breathing hoses via the connector assembly. The connector assembly consists of a plug-in connector, an inhalation valve, an exhalation valve and the main body.

The main body of the connector assembly is labelled with breathing flow indicators. The plug-in connector is equipped with a silicone O-ring connector seal and comes with a sealing cap to protect the assembly when it is not coupled to the mask. The inhalation and exhalation valves have different housing diameters so they can not be confused. The valve disks in each valve are identical and interchangeable.

**Exhalation/Inhalation Hoses** – The corrugated exhalation and inhalation hoses are identical and interchangeable. Constructed of EPDM, the hoses are flexible making it easy to don and remove the BG4.

Each hose has a long collar and short collar on opposite ends to facilitate proper union with the adjoining component. Quarter-turn bayonet rings secure the four ends of the breathing hoses to the adjoining components.

The exhalation hose is connected to:
- Connector assembly (long connector)
- CO$_2$ scrubber canister (short connector)

The inhalation hose is connected to:
- Air cooler (long connector)
- Connector assembly (short connector)
Anti-crush reinforcing rings can be placed on the breathing hoses in the shoulder area to provide constant support. The breathing hoses are secured to the shoulder straps with safety loops.

**CO₂ Scrubber Canister** – The CO₂ scrubber canister sits in a metal retaining bracket and is secured to the frame of the BG4 with a roller clamp tensioning bar. It is connected to the exhalation hose with a quarter-turn bayonet ring and to the breathing bag with a sleeve and collar connection. A safety clip is used to connect the pressure relief valve hose to the scrubber canister.

The CO₂ scrubber canister removes CO₂ from exhaled breath using soda lime. The canister can be a single-use, factory-packed style or a refillable one. Under normal breathing conditions, either style can be used continuously for up to four hours.

The components of the refillable canister are:

- Metal stabilizer disk
- Lid with quick tab lock connectors
- Neoprene O-ring seal
- Top and bottom dust filters
- Top and bottom screens

The refillable canisters are translucent and marked with a fill line to ensure proper filling. It is essential that the refillable canisters be completely filled with soda lime and packed correctly.

Under-packing the canister will not provide sufficient soda lime to effectively remove CO₂ from the breathing loop. Over-packing the canister may cause channelling in the soda lime.
Channelling interferes with the proper absorption of $\text{CO}_2$ from the exhaled air. Both under and over-packing reduce the effective operating time of the BG4.

The scrubber canister is designed for easy removal and servicing.

**Breathing Bag** – The breathing bag assembly is held in place within the frame of the BG4 by a retaining bar. The $\text{CO}_2$ scrubber canister, air cooler, minimum valve and moisture relief valve are attached to the breathing bag with sleeve and collar connectors.

The 5.5-litre breathing bag has sealed seams and is constructed from yellow puncture-resistant polyurethane.

With the aid of two large springs, the breathing bag is able to generate positive pressure throughout the entire breathing loop.

The breathing bag assembly consists of:
- Two springs
- Pressure plate
- Breathing bag

**Pressure Relief Valve** – The pressure relief valve is mounted to the frame of the BG4 at the breathing bag. Excess air is routed from the breathing loop at the scrubber canister along a clear tube to the valve.

The pressure relief valve prevents over-pressurization of the breathing loop. Too much air in the breathing loop causes the breathing bag to over-inflate. This pushes the pressure plate against the relief valve tappet, opening the valve and expelling the excess air into the atmosphere. The valve opens when the breathing pressure reaches between 2.0 and 5.0 millibars (mbar).
The internal components of the pressure relief valve are interchangeable with those of the moisture relief valve.

**Moisture Relief (Drain) Valve** – The moisture trap and valve are at the bottom of the breathing bag. They are attached to the frame of the BG4 with a retaining clip.

The moisture relief valve drains moisture that accumulates in the breathing bag. The valve opens when the pressure in the moisture trap is equal to or greater than 15 mbar. The moisture drains out at the base of the unit into the atmosphere.

A sintering filter is located at the top of the valve housing to prevent soda lime particles from entering the valve.

The internal components of the moisture relief valve are interchangeable with those of the pressure relief valve.

**Air Cooler** – The air cooler is between the breathing bag and the inhalation hose. It is secured to the frame by a roller clamp. The cooler is attached to the breathing bag with a sleeve and collar connection and to the inhalation hose with a quarter-turn bayonet ring. The molding seams on the hose connection are used to ensure proper alignment with the inhalation hose during assembly.

The air cooler is a simple heat exchanger with the ice chamber isolated from the breathing loop. The cover on the ice chamber helps keep condensate and melted ice from entering the body of the BG4.

When filled with preformed ice, the air cooler lowers the temperature of the inhaled breathing air, reducing the physical strain on the wearer.
The constant dosage system enriches the breathing loop with O₂ at the air cooler.

At a breathing rate of 30 L/min and an ambient temperature of 24°C (75°F), the temperature of the breathing air can be maintained below 37°C (98°F) for up to four hours.

Air temperature and breathing rate will affect how long the ice lasts and the air cooler remains effective. Ice packs which are small, broken up or not completely frozen will reduce available service time allowing the temperature of the breathing air to rise above 37°C (98°F).

**Electronics**

The Electronics system is comprised of:

- Sensor
- Switchbox
- Sentinel

The system continuously measures the pressure in the O₂ cylinder, indicates this pressure on the Sentinel, tests and monitors the correct functioning of the BG4, and generates alarms when residual (low) pressure is reached, as well as in the event of a malfunction.

The sensor and the switchbox are on the right-hand side of the BG4. The sensor converts the pressure reading from the O₂ cylinder into an electronic signal. This signal is transmitted through the switchbox to the Sentinel which monitors the performance of the BG4. The electronics system is powered by a commercially-available nine-volt DC alkaline battery which can be replaced quickly and easily in the Sentinel.
**Sentinel** – The reinforced cable from the switchbox to the Sentinel is secured to the shoulder strap with snap loops.

The housing of the Sentinel is designed for use in tough environments to explosion-proof standards.

The Sentinel features:

1. LCD digital display of O$_2$ cylinder pressure in psi/bar
2. LCD digital display of time remaining in minutes to first low pressure alarm
3. Icon for minutes
4. Yellow panic button to manually activate Distress Signal Unit (to deactivate press and hold the right- and left-hand buttons)
5. Right-hand button to display ambient temperature (display automatically switches back)
6. Green LED for visual operational signal
7. Tally key, a movement sensor and Automatic Distress Signal Unit
8. Red LED indicators for visual alarm signals
9. Left-hand button for LED backlight to illuminate display for five seconds
10. Analog display of O$_2$ cylinder pressure
The main function of the Sentinel is to provide the following information:

- Indicate $O_2$ cylinder pressure
- Display time remaining until first low pressure alarm
- Indicate results of the high pressure leak test
- Indicate results of the battery test
- Provide low pressure alarms
- Provide no pressure warning

The Sentinel has three alarm points:

- 1st low pressure alarm @ 55 bar (800 psi), the Sentinel beeps intermittently for 30 seconds and the red LEDs flash
- 2nd low pressure alarm @ 10 bar (145 psi), the Sentinel beeps continuously and the red LEDs flash until it switches off
- No pressure warning @ 1.40 mbar, the Sentinel beeps once and the red LEDs flash indicating that the $O_2$ cylinder is closed or empty and there is no pressure left in the system.

**Blackplate and Harness Assembly**

The ergonomic design of the backplate and harness assembly provides the wearer of the BG4 with improved comfort over the previous model.

Notable features of the backplate and harness assembly are:

- Constructed of lightweight composites
- Shaped carrying shell for ergonomic fit
- Padded harness for comfort
- Waist belt
• Shoulder straps
• No-tool design for easy harness removal and cleaning
• Carrying handle and feet for easy handling
• Flame tested to 1093°C (2000°F)

**THE SSR 90 M**

A self-contained closed-circuit oxygen breathing apparatus with a lifespan of at least 90 minutes (European Norm Standard) at a medium heavy workload is essential to rescue conscious trapped miners. This length of protection is essential because of the distances involved. The SSR 90 M is one unit that suits mine rescue needs.

The MSA/Auer SSR 90 M is a compact closed-circuit, self-contained, oxygen-generating rescue device with potassium dioxide (KO₂) as the active chemical.

Oxygen is generated when the wearer’s exhaled breath, containing CO₂ and water vapour, reacts with the chemical in the canister.

The rate at which O₂ is produced is proportional to the demand of the wearer. If the wearer is breathing deeply and filling his lungs, the O₂-generating chemical will more than satisfy his requirements. When the wearer is breathing at a sedentary rate, less CO₂ and water vapour are exhaled. Therefore, the rate at which O₂ is produced slows. If the person begins to move vigorously and to consume large amounts of O₂, the increased demand is satisfied immediately.

The total weight of the unit in the case is 6.7 kg (14.7 lbs). The unit itself weighs 4.7 kg (10.3 lbs).
Description of Parts

The apparatus consists of five main parts:

1. Facemask and mouthpiece
2. Breathing bag and breathing tube
3. Oxygen-generating canister
4. Carrying harness
5. Stainless steel carrying case

**Facemask and Mouthpiece** – The full-facemask is foldable and has a twin lens, speaking diaphragm, and threaded breathing tube connection. The mouthpiece, with threaded breathing tube connection and noseclip and goggles is included for special applications.

**Breathing Bag and Breathing Tube** – The breathing tube is connected to the valve housing on the top of the breathing bag. The valve housing contains the inhalation and exhalation check valves, heat exchanger, particle filter and connection for the internal exhalation tube. The breathing bag is made of rubber. The relief valve is on the front of the breathing bag. The breathing bag has a capacity of approximately five litres.

**Oxygen-Generating Canister** – The canister is a metal container filled with an oxygen-producing chemical (potassium dioxide – KO₂). It is connected to the bottom of the breathing bag and has a central tube that delivers the exhaled air to the bottom of the canister. Oxygen is then liberated into the breathing bag by the chemical reaction of moisture and CO₂ with the KO₂.
## Rated Service Time of SSR 90 M

<table>
<thead>
<tr>
<th>Breathing Rate</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>At rest</td>
<td>Up to 300 min.</td>
</tr>
<tr>
<td>30 litres/minute</td>
<td>90 min.</td>
</tr>
<tr>
<td>40 litres/minute</td>
<td>60 min.</td>
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</tbody>
</table>
Pulling the ring removes a pin on the bottom of the canister that activates the Quick-Start Cartridge. The cartridge contains sodium chlorate (NaClO₃) that is pressed into a candle shape. The chlorate candle is highly susceptible to moisture. Removing the pin releases a spring-loaded plunger that strikes a percussion cap causing the sodium chlorate to ignite. The primary purpose of the chlorate candle is to generate heat to make the KO₂ more receptive to activation by CO₂. The ignition of the chlorate candle results in the creation of O₂ at a rate of four litres per minute for about 2 1/2 minutes.

Since heat as high as 205°C (400°F) is produced when the cartridge is ignited, care must be taken not to touch the area around the pin after igniting the cartridge.

**Carrying Harness** – The carrying harness consists of an adjustable neck and waist strap connected to a felt canister support that insulates the wearer from heat being produced by the canister.

**Stainless Steel Carrying Case** – The unit is stored in a case made of stainless steel that can be sealed to prevent air from entering.

**General Information for Use**

The units should not be used on unconscious casualties as their breathing volume may not be adequate to ensure sufficient production of O₂. An attempt, however, may be made with one SSR 90 M. If the breathing bag does not inflate, the unit should be removed immediately.

Since after hard work the canister will produce more O₂ than will be needed, the breathing bag will become over-inflated.
The excess $O_2$ is vented through the relief valve on the breathing bag.

There are two indications that the canister is becoming expended: fogging of the lenses on inhalation and increased resistance during exhalation. These two indications will not normally appear until after 90 minutes but may become noticeable during extremely hard work.

**Maintenance**

*Reconditioning After Use* – The SSR 90 M has a chemical canister that can be changed easily and quickly without special tools. All components can be used again after being cleaned, disinfected and thoroughly dried. After a new canister has been installed, the SSR 90 M is pushed back into the case, closed airtight and resealed.

Never allow any substance, such as water, oil, gasoline or grease, to enter the neck of the canister. The chemical produces $O_2$, which may cause any flammable material to catch fire.

*Disposal of Canister* – To dispose of a canister, punch a small hole in the front, back, and bottom and place in bucket of clean water deep enough to cover the canister by at least three inches. When the bubbling stops, any residual $O_2$ will have dissipated and the canister will be expended. Neutralize the solution by adding a dilute acid. Then pour the water down a drain or dispose of it in any other safe manner and discard the canister.

*Monthly* – The exterior must be checked for damage and the condition of canister and lead seal.
Annually – The unit must be checked with a tightness tester to ensure the canister contents have not been exposed to humidity.

Three Years – Interior random sample checks must be made of three per cent of the units in service.

Ten Years – The shelf life of the unit expires and it must be rebuilt. Note that the shelf life of units exposed to mechanical vibration is only three years, after which those units must be rebuilt. The date of the last rebuild is labeled on the bottom of the canister. Rebuild dates may also be labeled on the lid of the SSR 90.

Training

For reasons of economy, Ontario Mine Rescue uses the SSR 90 M Training Unit for training purposes. This apparatus is identical to the SSR 90 M in design, weight, dimensions and use. However, it does not contain a KO₂ canister. Therefore it must not be used for training in contaminated atmospheres. The label and the breathing bag are blue to distinguish them from emergency units.

CAREvent DRA AUTOMATIC RESCUE VENTILATOR

The CAREvent DRA Automatic Rescue Ventilator was developed by Drager Safety to meet the specific challenges of underground mine rescue. These include a low O₂ atmosphere and/or potentially toxic environment, entrapment, long rescue times, distance to fresh air, performing artificial resuscitation and/or cardiopulmonary
resuscitation on a downed victim, multiple victims requiring $O_2$ therapy or resuscitation, and compromised breathing supply.

The CAREvent provides a safe and effective means of providing demand breathing or artificial ventilation to patients suffering respiratory difficulty and/or cardiac arrest. It is a portable and extremely durable unit, pneumatically powered, and effective in confined space rescue or Immediately Dangerous to Life and Health (IDLH) environments.

Patients requiring respiratory support can demand breathe from the apparatus, while those requiring ventilation support receive automatic intermittent positive pressure $O_2$. A manual override button allows the operator to control ventilations at a rate and volume they desire.

The ventilator allows the breathing patient to “demand breathe” on 100 per cent $O_2$ while their inspiratory efforts causes the automatic cycling to cease. Should the patient stop breathing the ventilator will automatically restart.

The pneumatic logic circuit can be run on either approved compressed breathing air or medical $O_2$. The unit is self-contained and only requires to be attached to a regulated $O_2$ or air supply for immediate use.
Parts

The CAREvent consists of:

- An aluminum storage case
- Two carbon fibre O₂ cylinders
- Regulator
- Air supply hose
- Resuscitator
- Facemask

The face piece is a Panorama Nova facemask of similar design to that used with the BG4. The O₂ cylinders are interchangeable with those used with the BG4.
CHAPTER 7

AUXILIARY EQUIPMENT FOR THE BG4

TEST-IT 6100

The Test-it 6100 is a sturdy, portable test device – compact in a suitcase design – intended specifically to test the functions of Drager closed-circuit breathing apparatus, including the BG4.

To operate the Test-it 6100 place the case on a flat surface next to the apparatus. Open the case and connect the unit to a power supply. Press the On/Off button to turn the device on and allow the Test-it to complete an automatic sensor offset adjustment. When the adjustment is completed, the unit is ready to be tested before use.
Chapter 7 – AUXILARY EQUIPMENT FOR THE BG4

The operating panel is clearly divided into a flow and a pressure area. An integrated display is located in the centre of the panel where either the flow or the pressure is indicated. The display indication can be switched by pushing the button below the display. If this button is pressed for a longer period, a sensor offset adjustment is carried out. The measuring scale for the flow is L/min and for pressure in which mbar, H₂O, or hPa can be selected.

The components – RD40 connector, the hand pump connection piece, shutoff valve, and pressure relief valve, are arranged on the pressure side of the operating panel. A supplied adapter is used to connect the air hoses of the BG4 to the RD40 connector.

The Test-it 6100 includes a dosing cap used to connect the flow sensor to the input of the hand pump. This design means that the BG 4 can remain connected to the unit. In addition, the flow side includes a stopwatch for time measurement. The unit also comes with a pump ball/hand pump and hose and sealing plug.

The Test-it 6100 will perform the following tests on the BG4:

• No Pressure Warning
• Inhalation Valve
• Exhalation Valve
• Moisture Relief Valve
• Positive Pressure Leak Test
• Pressure Relief Valve
• Bypass Valve
• Constant Dosage Rate
• Minimum Valve
• Low Pressure Alarm

Clean and dry the Test-it 6100 with a moist cloth. Store the device in a dry place at room temperature and keep sheltered from direct sunlight.

HIGH-PRESSURE OXYGEN BOOSTER PUMPS

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 the oxygen is possible and is very likely to result in an explosion. When using any oxygen pump, ensure good ventilation in the pumping room to dilute the concentrations of oxygen.

The following pumps are multi-valve, piston-type pumps for compressing oxygen and transferring it from one cylinder to another at a desired higher pressure. Pumps are available in either hand-operated or power-driven types.
Drager Masterline Booster

The Masterline Electric Booster Pump Model 7000A is used for pumping oxygen, allowing users to fill oxygen cylinders up to 5,000 PSI (345 bar) from low-pressure supply cylinders. The booster has a 10:1 boost ratio, is capable of quickly filling four cylinders at a time, and has an auto stop.

The booster pump operates at a low noise level and requires minimal maintenance. The booster is oil-free and uses only two low-friction dry seals. The seals can be replaced in about 20 minutes with only a few tools. The piston guides and the lower piston bushings are the only other parts that need replacement after several years of service.

Haskel High-Pressure Oxygen Booster Pump

This unit is a two-stage oxygen booster pump powered by electricity or compressed air. The pump is capable of boosting the pressure in the cylinder being charged to as high as 305 bar (4,425 psi), according to the setting of the automatic control. This is a fully portable unit that should be operated by trained personnel following the manufacturer’s operating and maintenance instructions.

OXYGEN & OXYGEN CYLINDERS

The purity of the oxygen used in rescue apparatus is very important as impurities tend to accumulate in the circulatory system of the apparatus. For this reason, any apparatus or equipment using compressed air supplied by compressors lubricated with oil should not be converted for use with oxygen without cleansing and purging.
The U.S. Bureau of Mines specifies that oxygen for use in rescue apparatus shall contain at least 98 per cent oxygen, no hydrogen, and not more than two per cent nitrogen, with traces of argon.

Drager specifies that oxygen used in the BG4 shall contain at least 99.5 per cent oxygen by volume and be tasteless and odourless.

Oxygen made by liquefaction processes conforms to this standard and contains no impurities other than nitrogen and traces of inert gases.

**Hydrostatic Test Requirements**

All cylinders used to transport oxygen and other non-liquefied gases whose pressure exceeds 300 psi (21 bar) at 21°C must comply with the requirements of the Canadian Transport Commission as to strength, and all such cylinders that are longer than 12 inches (0.3 m) must have valves equipped with an approved safety device (such as a bursting disc).

Cylinders made solely of steel or seamless unsupported aluminum with an outside diameter of two inches or more must be tested by hydrostatic pressure at 5/3 of bottle pressure at least once every five years. Such cylinders have an indefinite life expectancy.
In general, composite bottles made of multiple materials (such as an aluminum liner wrapped with filament) have a 15-year life expectancy and must be tested every three years. The fibre-composite cylinders used by Ontario Mine Rescue, however, have the TC-SU 5134 designation and have been granted an exemption by Transport Canada, to be tested every five years.

The date of testing must be marked on all cylinders as required by the Canadian Transport Commission.

The tests consist of determining the elastic expansion (total expansion minus permanent expansion) after the bottle is subjected to the specified hydrostatic pressure.

Cylinders capable of being charged to 2,000 psi (135 bar) are tested to 3,400 psi (235 bar). Cylinders charged to 3,000 psi (205 bar) are tested at 5,000 psi (345 bar).

**Deterioration of Air or Oxygen Bottles**

If moisture is introduced to the cylinders, inadvertently, this moisture will hasten oxidation of the steel of the bottle, causing scale, sediment, rust and pitting, and thus weaken the walls of the bottle.

These changes leave no visible sign on the outside of the bottle, and often, none on the inside either. The only means of positively determining the condition of the bottle is by hydrostatic testing.
CHAPTER 8
SPECIAL EQUIPMENT

eHYDRAULIC SPREADER/CUTTER/RAM

Each EDraulic or electro-hydraulic device is equipped with two lithium ion batteries and a charger unit. Each battery, when fully charged, has an operating life of approximately 60 minutes, and is interchangeable between devices. The tools may also be run on alternating current with a 110 Volt adapter to an external power supply. The battery or external power supply powers a hydraulically operated piston(s) that activate the arms of the spreader or cutter, or the extension/retraction of the ram.

All EDraulic devices are equipped with lights to facilitate work under poor operating conditions, and illuminate the work area.

The Hurst SP 310E2 Spreader has a maximum spreading force of 72,800 lbs (324 Kn), and a maximum pulling force of 9,900 lbs (44 Kn). The SP 310E2 has a maximum spread of 28.5 in. (725 mm). The spreader can be used to spread open, pinch, or pull open objects.

The Hurst S 700E2 Cutter has three distinct cutting angles, and at its maximum opens to 7.6 in (192 mm). The engineered curved blades close at the tips and then pull the object to be cut towards the point where maximum cutting force is applied.
The Hurst R 411E Ram has a retracted length of 21.5 in (545 mm) and an extended length of 35.6 in (905 mm). An optional extension accessory provides an extended length of 47.2 inches (1.2 m) when used. The ram has a maximum pushing force of 23,154 lbs (103 Kn). The ram is equipped with “claws” on both ends to ensure its safest possible use.

Field Test

1. Ensure both batteries are fully charged.
2. Check general condition and for damage (ie. tips, blades, claws, etc…).
3. Turn on device and examine for easy opening/closing (spreader/cutter) or extension/retraction (ram).
4. Listen for quiet operation/suspicious noises.
5. Ensure the ‘dead man’s switch’ stops the operation of the device.
6. Close spreader/cutter or retract ram.
7. Turn device off.
8. Report to captain.

Operating Procedures – Spreader

Before work begins, ensure the obstacle is stabilized, and that the area is cleared so that no one is unnecessarily at risk from the movement of the device or from flying fragments Never stand between the load (being pulled or spread) and the spreader.

The spreader is not designed to be used as a jack. Only in an extreme emergency may the tool be used to lift a load. The load could easily tip over because of the small surface area of the tips.
Therefore, never work under a load being lifted by the device alone. Make sure the load is blocked properly as it is lifted.

**Spreading** – The spreader is designed to do the spreading and pinching only with its tips. Never use the arms for spreading or pinching material.

Insert the tips of the spreader in the opening between the objects to be spread. If the access point is too small, spread the arms and insert only one tip. Close the arms and bend the fixed material away. Repeat this until both tips can be inserted in the opening and then start spreading.

**Pulling** – When pulling, use only the special high-tensile chain and adaptor supplied with the unit. They are to be used as follows:

- With the spreader open, connect one of the chains to the article to be pulled.
- Securely anchor the other chain to a solid object.
- Fix the adapters to the arms and make sure the hooks point upwards.
- Place the fastpins from below through the adapter and the special holes in the arms.
- Connect both the chains to the hooks on the adapters and pull.

**Operating Procedures – Cutter**

Before work begins, ensure the obstacle is stabilized, and that the area is cleared so that no one is unnecessarily at risk from the movement of the device or from flying fragments.

The blades of the cutter should be positioned at a 90° angle to the object to be cut, if possible. Higher cutting capacities can be achieved by cutting as close as possible to the blade’s pivot point.

During cutting, the gap between the blade tips (in the transverse direction) must not be exceeded, otherwise the blade is in danger of breaking.

**Operating Procedures – Ram**

Before work begins, ensure the obstacle is stabilized, and that the area is cleared so that no one is unnecessarily at risk from the movement of the device or from flying fragments.

Before using the ram, ensure that it is adequately supported and has the required substructure. Where this support is not adequate, additional supports, cylinder attachments and the use of holding straps may be required.
DARDA HYDRAULIC SPLITTER

The Darda Hydraulic Splitter is a wedge-type splitter that can achieve a splitting force of 350 tons at a maximum 7,100 psi (490 bar).

The main parts of the splitter consist of two cylinders. The upper cylinder houses the piston which moves the wedge in the lower cylinder. The control valve that extends or retracts the wedge is operated by a single lever on top of the unit.

When the control lever is turned to the forward position, the wedge advances and the two feathers are forced sideways against the wall of the hole and, with hundreds of tons of pressure, tears rock or concrete apart.

Depending on the material, a break usually occurs within 10 to 60 seconds.

Before Going Underground

Make sure you have everything you will need for the air/electric model being used:

• Splitter
• Hydraulic pump
• Air and water hoses, and fittings
• Four 1 3/4-inch diameter bits, two 48-inch drill steel and drill gear
• Lubricating grease (graphite) and extra hydraulic oil
• 36-inch measuring stick

Check the level of hydraulic oil in pump.
Before Startup

1. Check all fluid levels, hoses and power connections.
2. The air hose should always be blown free of water and dirt before connecting.
3. Check that wedge and feathers are in good condition. End of retracted wedge should be approximately 1 1/4 inch from tip of feathers.
4. Lubricate the wedge and feathers.
5. Always start power unit with lever on rock-splitting cylinder in neutral position.

Operation of the Splitter

1. The splitter is operated by a lever at the top of the unit. It has three positions:
   – Lever to left – Wedge extends
   – Lever to centre – Wedge is in the neutral position
   – Lever to right – Wedge retracts
2. Always pause in neutral when going from forward to reverse, otherwise you will damage the splitter.
3. When the splitter is working, keep an arm’s length away from the cylinder. There may be a sudden movement when the break occurs.
4. Once the rock is cracked, do not attempt to spread the rock with the splitter.
5. Never use the splitter as a prying tool.
6. Proper scaling and barring safety precautions should be taken.
Lubrication of Wedge and Feathers

1. Use only a molybdenum disulphide lubricant.

2. The wedge and feathers generate up to 350 tons of pressure. If not properly lubricated, they can freeze together and the feather tops can be pulled out of the cylinder causing damage to both feathers and cylinder.

3. Lubrication is simple:
   - Extend the wedge fully and lubricate both sides of the wedge
   - Use lubricant sparingly, but often

4. It is recommended that it be lubricated every two or three splits – under extreme conditions, every split.

5. Good lubrication means almost twice the power as compared to neglected lubrication.
Drilling Holes for Splitter

1. For efficiency, drill straight and proper-sized holes, 1 3/4 inch diameter and a minimum of 26 inches (66 cm) deep.

2. The breaking results are best when holes are drilled 30 to 36 inches (76 to 91 cm) deep.

3. The hole pattern will vary according to rock density and method of excavation. Distance between holes will vary from eight to 36 inches (20 to 91 cm).

4. Try to split with the rock grain when possible.

Controlling Direction of Break

1. This is a simple operation. Line up the handle in the same direction as the intended break.

2. The wedge and feathers will then be in the proper position for a controlled break.

Hydraulic Splitter Field Test

1. Check general condition of splitter and pump.

2. Splitter: check feathers and wedge, hose condition, caps on ends of hoses.


4. Materials required:
   - Air hoses and fittings
   - Four 1 3/4-inch diameter bits, two 48-inch drill steel and drill gear
   - Extra hydraulic oil
– Lubricating grease (graphite)
– Water hoses and fittings
– 36-inch measuring stick
5. Repack and report to captain.

**ENERPAC 1250 SELF-CONTAINED HYDRAULIC BOLT CUTTER**

The Enerpac 1250 Hydraulic Bolt Cutter is a self-contained, high-pressure cylinder with a guillotine-type cutter and a rotating head that can achieve a shearing force of 20 tons. The cutter does not actually cut the material but shears it.

**Safe Operating Procedures**

1. Wear personal protective equipment.
2. Only cut in a straight line, never on an angle.
3. Do not exceed the capacity of cutter.
4. Ensure that the cutter head is latched securely before attempting to cut.
Maximum Cutting Capacities

- Steel wire rope 1 1/4 inch
- Aluminum wire or bar 1 1/4 inch
- Copper wire or bar 1 1/8 inch
- Soft steel bolt 1 1/4 inch
- Reinforcing bar 7/8 inch
- Guy steel wire strand 7/8 inch

Using the 1250 Bolt Cutter

1. Open the jaws.
2. Insert the material to be cut.
3. Close and lock the jaws.
4. Move selector to cut position.
5. Pump handle to cut material.
6. Move selector to release position.

Hydraulic Bolt Cutter Field Test

1. Remove from case.
2. Check general condition.
3. Check all moving parts with selector in release position.
4. Check cutter blades for nicks.
5. Move selector to cut position.
6. Pump and inspect cylinder (jaw) action.
7. Move selector to release position.
8. Repack and report to captain.
DEWALT RECIPROCATING SAW

The Dewalt variable speed reciprocating saw is used for a variety of cutting applications including: vehicle extrication, conveyor belts, wood, and various types of metal and clearing debris to facilitate safe rescues. The unit is equipped with metal and wood cutting blades, and with spare battery packs allows approximately one hour of cutting.

Safe Operating Procedures

As with any tool personal safety is the priority.

- Personnel protective equipment must be worn when cutting, such as eye protection and gloves.
- The reciprocating saw must not be used in the presence of explosive gases and flammable liquids.
- The saw is fitted with a locking device on the power switch. This lock should be engaged when the saw is not in use or when changing the blade or battery pack.
• There is a variable speed trigger on the saw. Use of very slow speed is recommended only for beginning a cut. The saw cuts best at maximum speed. Prolonged use at very slow speed may damage it.
• Use clamps or other practical means of securing the item being cut if necessary.
• Do not force the saw; the correct blade will cut at the rate for which it is designed.
• When cutting metals you should spread a thin film of oil or other coolant along the line ahead of the saw cut for easier operation and longer blade life.
• The tool must be held by the insulated gripping surface if there is a chance the blade may contact hidden wiring.

**Reciprocating Saw Field Test**

1. Check seal and date.
2. Check contents:
   – saw/three batteries/charger
   – 18-tpi demolition blades (1 package)
   – 6-tpi wood blades (1 package)
   – 6-tpi 9-inch wood blades (1 package)
   – center punch
3. Check operation of saw.
4. Repack and report to captain.

**AIR LIFTING BAGS SYSTEM**

Air bag systems are multi-application, portable inflation systems used for the lifting and displacement of heavy rigid objects.
They are designed for use in emergency situations such as structural collapse and containment, vehicular extrications, industrial entrapment, and excavation collapse. Since the air bags contain no spark producing parts, they may be used in explosive environments.

Air lifting bags have several advantages over mechanical and hydraulic jacks. They have no moving parts; they are capable of lifting heavier loads; and because they are no more than an inch (2.5 cm) thick, they can be utilized in lifting situations where the use of mechanical and hydraulic jacks would be impossible.

High-pressure air bags work on a simple, yet proven, physical formula:

\[
\text{Pressure of the air being forced into the bag} \times \text{The area of the bag in contact with the load} = \text{Lifting Force}
\]

**System Components**

Systems and system components are available from various manufacturers including Vetter, Holmatro and Maxiforce.
The basic air bag system consists of six components:
1. Air source
2. Pressure regulator
3. Controller
4. Interconnecting hoses
5. Air bag
6. Safety in-line relief valve

**Air Source** – The most common air source for use with an air bag system is a compressed air cylinder, typically of the type used in self-contained breathing apparatus.

With the use of special adapters, alternate air sources may be used such as portable compressors, the mine’s compressed air system, or a hand or foot pump, provided they are capable of supplying 118 psi (8.1 bar) or more of pressure.

**Pressure Regulator** – Pressure regulators are available to reduce the supply of air pressure to a maximum 135 psi (9.3 bar) from as much as 5,500 psi (374 bar) but the standard regulator used is designed to reduce an inlet pressure of up to 3,000 psi (207 bar).

These are self-contained, direct acting, pressure-reducing, diaphragm regulators utilizing spring loading to balance the outlet pressure and thereby reduce the effect of, the decreasing of, or variations in the inlet pressure. The regulators are designed for use with an SCBA air cylinder.

**Controller** – Controllers are equipped with quick disconnect hose fittings at the inlet and outlet, a pressure gauge to monitor the pressure applied to the air bag, valves to apply and release air pressure to the bag, and a relief valve set at 118 psi (8.1 bar).
The valves may be the turn-on turn-off type, or push button or joystick “deadman” type. They may be single controllers for operation of one air bag, or dual controllers for operation of two air bags at a time.

**Hoses** – Hoses are used to convey air from the air supply to the controller and from the controller to the air bags. All hoses are equipped with quick disconnect fittings.

Hoses are available in various colours for ease of identification. When using more than one air bag, each should be connected with a different coloured hose.

All hoses should be rated for a working pressure of at least 300 psi (20.7 bar).

**Air Bags** – Air bags are available from several manufacturers. They are made from a molded “rubber” type material reinforced for strength with steel cable or Kevlar. They are equipped with the male half of a quick disconnect hose coupling.

The Maxiforce air bags used in Ontario Mine Rescue are composite units fabricated from neoprene, reinforced with six layers (three per side) of Kevlar reinforced fabric for strength and rigidity, even at their full inflation pressure of 118 psi (8.1 bar).

All air bags incorporate non-slip, molded surfaces designed for maximum friction and holding capacity. A bright yellow “X” is molded into each side to provide high visibility during pre-inflation centering.

Each bag is proof tested at twice the operating (full inflation) pressure and has a minimum burst pressure of four times the operating pressure.
Safety In-Line Relief Valve – The in-line shutoff/relief valve is designed to keep air bags fully and properly inflated:

- When the air bag is disconnected from the controller (safety relief valve and control valve)
- When excess pressure must be automatically relieved due to shifting loads and for temperature changes

The shutoff/relief valve consists essentially of an air inlet and an air outlet with quick disconnect hose fittings, a shutoff valve to isolate the associated air bag, and an internal, non-adjustable spring-loaded mechanism to relieve air bag pressure in excess of 135 psi (9.3 bar).

Preparation and Positioning

The secret to exerting maximum lifting force and achieving maximum lifting heights is to position the air bag as close as possible to the underside of the load at the start of the lifting operation.

When an object is so heavy that the largest bag will be able to move it only a short distance, build a solid-top crib that will place the deflated bag as close as possible to the underside of the load. Then build cribs as required to appropriately support the load.

Inflate the bag and lift the load just enough to add a new layer of cribbing to the two support cribs. Deflate the bag, and add another layer of cribbing to the bag support crib. Inflate the bag and add cribbing to the support cribs. Continue this sequence until the load is lifted to the desired height.
Increasing Lifting Heights and Forces

Two bags stacked one upon the other will lift only the rated capacity of the smaller bag. Stacking bags, however, will increase lifting height.

Under no circumstances should more than two bags be stacked. If two bags are stacked, the smaller of the two bags must be stacked on top, and the bottom, larger bag must be inflated first until it contacts the load. The top air bag is then inflated to achieve the desired lift. If additional lift is required, the bottom bag is further inflated.

As the bottom bag approaches full inflation, however, the stack becomes less and less stable until finally the effect is like trying to balance an object on top of two footballs. For this reason, it is good practice to never inflate the bottom bag to more than 50 to 75 per cent of capacity, thus creating a pillow for the top bag.

Lifting forces can be increased by placing two or more bags side by side and inflating them simultaneously.

At the Scene

1. Assess the safety of the area before approaching.
2. Stabilize the object in the position found before performing any work (i.e., chock wheels, set parking brake or cribbing on the sides or corners of object).
3. Build a separate crib for the lifting bags. The closer the bag is to the load, the more effective it will be.
4. As the load is raised, supplement all the stabilizing cribbing so that any drop of the load would be less than the thinnest piece of blocking available.
There may be only one layer placed on top to protect the bag.

All blocking must be stacked, cribbing style, to create a stable base which should not tip if the load shifts slightly. To ensure a stable base, blocking should not be stacked any higher than the length of the inside of the crib.

The top level of the blocking where the air bag will be located must be a solid deck or platform.

**System Operation**

An air bag system operates as follows:

- After air bags are properly positioned for a lift or displacement, the air source is turned on.
- High pressure air is reduced to 130 psi (9.1 bar). The reduced air pressure is supplied via an air hose to the controller.
- Valves on the controller are operated to permit air to flow via air hoses to either one or two bags permitting a controlled lift/displacement.
- In the line between the controller and each bag is an in-line shutoff and relief valve, designed to permit isolation from the controller, and to ensure that any excess pressure will be relieved from the air bag. The shutoff/relief valve should be located at the controller and not the air bag, to prevent damage.
- As air flows into the bag it increases in height resulting in a corresponding lift/displacement. Maximum lift/displacement force occurs at approximately one inch (2.5 cm) of inflation height (minimum reduction of the air bag cross section).
• When air bags are to be partially or fully deflated, controls on the controllers are operated to perform the function, as well as prevent any further inlet air pressure from flowing beyond the controller.

• At the conclusion of the operation the air supply is turned off, any residual system air pressure is bled off through the controller, and the system components are disconnected. All system components should be inspected before being stored for future use.

• The team member operating the controls must concentrate on the gauges, not on the lift and take direction from the captain only.

Field Test

1. Open case if not sealed. If sealed, go to Step 4.
2. Compare list of components with contents of the case.
3. Close case.
4. Check for a minimum of two full air cylinders or air line connection.
5. Select proper size lifting bag and inspect the condition of the bag and the air inlet nipple.
6. Report results to captain.

Shutdown Procedure

1. Shut off air
2. Bleed air from system
3. Disconnect hoses from system
GRIPTECH SP2 ROPE RESCUE SYSTEM

The GripTech SP2 Rope Rescue System is designed for a two-person load of 600 lb (272 kg) maximum in locations where mine rescuers require the assistance of a rope rigging system.

Basic Operating Procedures – Vertical Operation

Vertical rigging is used where an overhead anchor point exists, and where the rescue is essentially vertical and the lines will not be passing over an edge.

The advantage in rigging vertically is that raising and lowering are performed easily with no change in the system rigging.

Setup/Anchoring – Prior to use, the GripTech System must be anchored properly and the rope control handle secured to a suitable tie-off point using the handle securing rope provided.

Suitable anchorage points for the GripTech System include tripods, overhead beams, or other structures of sufficient strength. The system is anchored via the carabiner in the triangular rigging hole at the top of the head assembly.
Always ensure that the anchor point meets applicable strength standards.

**Rigging** – Various rigging advantages may be rigged for vertical operation. For most operations a 3:1 lifting advantage is sufficient. For rigging a:

- **2:1 advantage** – A single pulley is placed at the bottom and the end of the rope is connected to the rigging hole at the bottom of the head assembly.
- **3:1 advantage** – A single pulley is placed at the top and connected to the rigging hole at the bottom of the head assembly. The single pulley with becket is placed at the bottom.
- **4:1 advantage** – The single pulley with becket is placed at the top and connected to the rigging hole at the bottom of the head assembly. A double pulley is placed at the bottom.

**Haul-Lock Operation** – In vertical operation, the haul-lock, when disengaged, allows both raising and lowering to be performed.

When the haul-lock is engaged, it still allows raising to be performed, but will prevent descent between “hauls” and should the operator(s) let go of the rope control handle.

To engage the haul-lock:

1. Pull the release pin out using the key ring, allowing it to clear the retaining hole and allowing the cam to rotate so the cam teeth contact the rope on the drum.
2. Release the pin.
3. The haul-lock will hold the load between “hauls”.
After raising with the haul-lock engaged, you must first disengage the haul-lock to lower.

To disengage the haul-lock:

1. Pull the release pin and rotate the cam to line up the pin with the retaining hole.
2. Release the pin, allowing it to enter the retaining hole.

**Raising a Person** – To raise a person:

1. Grasp the rope control handle and slide the handle up the control rope with your right hand. Grasp the control rope, below the handle, with your left hand. Slide the handle up the rope, while maintaining tension on the rope with the left hand.
2. Hold the handle stationary and grasp the hand grip with the other hand. To raise, pull on the handle with both hands, pulling the handle down, while at the same time bending your legs to use your body weight to raise the person.
3. Repeat this process until the person has been raised to the desired height.

**Lowering a Person** – To lower a person:

1. Grasp the rope control handle with your right hand. Grasp the control rope below the handle, with the left hand, maintaining tension on the rope at all times.
2. Open the cam on the rope control handle by pushing up on the rear-protruding cam lever with your thumb. You are now holding the person stationary with your grasp on the control rope only.
3. To lower, SLOWLY allow the rope to slide through your left hand by SLIGHTLY decreasing your grip on the control rope. You are in full MANUAL control of the descent. NEVER completely let go of the control rope while lowering. The rope friction is totally dependent upon a tension being maintained on the control rope.

**Raising & Lowering Yourself** – To raise or lower yourself the same basic procedures are used with the following changes:

1. The rope control handle MUST be tied off to yourself to provide the same protection in the event that you release the handle. Attach one end of a three- to four-foot lanyard to the rope control handle and the other end to a suitable point on your harness or bosun’s chair.

2. To raise yourself, employ the same procedure as raising another person, pulling down in front of your chest with both hands.

3. To lower yourself, employ the same procedure as lowering another person.

**Basic Operating Procedures – Horizontal Operation**

Horizontal rigging allows you to rig a raising and lowering system when no overhead anchor point exists to allow vertical rigging. This occurs most often when you must go over the edge of a building or other structure.

The major advantage is that only a single line passes over the edge.

**Setup/Anchoring** – Prior to use, the GripTech System must be anchored properly.
Always ensure that the anchor point meets applicable strength standards.

**Haul-Lock Operation** – When using the GripTech System horizontally, remove the haul-lock lanyard by unclipping it from the haul-lock.

To engage the haul-lock:
1. Pull the release pin out using the key ring, allowing it to clear the retaining hole and allowing the cam to rotate so the cam teeth contact the rope on the drum.
2. Release the pin.
3. The haul-lock will hold the load in between “hauls”.

To disengage the haul-lock:
1. Pull the release pin and rotate the cam to line up the pin with the retaining hole.
2. Release the pin, allowing it to enter the retaining hole.

NEVER disengage the haul-lock without first locking the control rope around the lock-off bar. Rather than fully disengaging the haul-lock, you lower by holding the haul-lock in the NEUTRAL position. To do this, when lowering is required, push and hold the haul-lock cam down.

**Lock-Off Bar Operation** – To lock the control rope around the lock-off bar:
1. Bring the control rope upward, under tension, through the V-slot.
2. Following the arrows on the lock-off bar, wrap the
control rope around the lock-off bar and back between the lock-off bar and backplate.

To unlock the control rope from the lock-off bar:
1. Pull the control rope back from between the lock-off bar and backplate.
2. Unwrap the control rope KEEPING THE ROPE UP AND IN THE V-SLOT.

**Raising – Z-Rig Configuration** – When rigged horizontally, a lifting advantage is obtained by rigging the system in a “Z-rig” configuration. This is done as follows:

1. Anchor the system.
2. Connect the load end of the rope to the stretcher or person’s harness.
3. Engage the haul-lock.
4. Tension the lines by pulling the control rope tight.
5. Lock the control rope around the lock-off bar
6. Connect an ascender (i.e., Gibbs) to the main line with the arrow pointing toward the load.
7. Connect a carabiner to the ascender.
8. Attach a single pulley to the control rope and connect it to the carabiner on the ascender.
9. **DOUBLE CHECK ALL COMPONENTS.**
10. Unwrap the control rope from the lock-off bar, ensuring it is aligned within the slot in the rope guide cage.
11. Start hauling on the control rope. The haul-lock will hold the load between hauls and while resetting the Z-rig.
**Lowering** – When lowering, friction for descent control is created by the wraps of rope around the drum AND by positioning the control rope through the V-slot on the rope guide cage. This is done as follows:

1. Anchor the system.
2. Connect the load end of rope to the stretcher or person’s harness.
3. Engage the haul-lock.
4. Tension the lines by pulling the control rope tight.
5. Lock the control rope around the lock-off bar.
6. When ready to lower, hold the haul-lock in the NEUTRAL position.
7. SLOWLY unwrap the rope from the lock-off bar. When unwrapping the rope from the lock-off bar, keep the rope upward and through the V-slot.
8. SLOWLY feather the rope downward to reduce friction and begin descent, maintaining tension on the rope at all times.

**Change of Direction While Carrying a Load**

**Raising to Lowering** – When the load is being raised, in a Z-rig configuration and you wish to change to lowering:

1. Cease hauling and allow the haul-lock to hold the load.
2. Lock the control rope around the lock-off bar.
3. Disassemble the Z-rig by removing the carabiner, pulley, and ascender. (It may be preferable, in the case of a hang up, to leave the Z-rig assembled.)
4. When ready to lower, hold the haul-lock in the NEUTRAL position. NEVER disengage the haul-lock without first locking the control rope around the lock-off bar.

5. SLOWLY unwrap the rope from the lock-off bar. When unwrapping the rope from the lock-off bar, keep the rope upward and in the V-slot.

6. SLOWLY feather the rope downward to reduce friction and begin descent, maintaining tension on the rope at all times.

Lowering to Raising – When the load is being lowered, and you wish to change to raising in a Z-rig configuration:

1. Cease lowering by bringing the control rope upward fully in the V-slot.

2. Engage the haul-lock and SLOWLY feather the control rope downward as if lowering, allowing the haul-lock to take and hold the load.

3. Lock the control rope around the lock-off bar.

4. Assemble the Z-rig by attaching an ascender (i.e., Gibbs) to the main line with the arrow pointing towards the load. Attach the single pulley to the control rope and connect it to the ascender with a carabiner.

5. Double-check all components and rigging.

6. Unwrap the control rope from the lock-off bar, ensuring it is aligned within the slot in the rope guide cage.

7. Start hauling.
General Practices

A team responding to an emergency with the system will take three bags: emergency rope with head assembly, safety line, and gear bag.

The gear bag contains:
- Safety rope control handle
- Pulleys (two-inch & three-inch)
- Carabiners (large, extra large, pear shaped)
- Gibbs ascender
- Figure 8 descender
- Swivel
- Shock absorber
- Slings, tie off adapter
- Edge roller
- Rescue cradle
- Tower climbing harness
- Web rebar assembly and spreader hook
- Edge guards
- Rescue harness
- Stretcher straps
- Web runners
- Scaffold choker*
- Web rebar sling*

* Note: For restraint, deflection, and positioning purposes only. These should not be used for anchoring.
Equipment Inspection & Storage

The GripTech rope rescue system and all ropes and rope rescue gear intended for emergency use or for training purposes must be inspected after every use and sealed, and should be checked periodically if kept in storage for extended periods. This will ensure the user that the system components have been thoroughly inspected prior to their use.

The GripTech rope is constructed with a coloured outer sheath and a white inner core so that any cuts through the outer sheath will expose the white inner core and be more readily visible.

If the white inner core is visible – do not use the system. Immediately return the system to your dealer for inspection.

If the rope inspected is satisfactory, record date and sign the corresponding rope log.

To inspect the GripTech system:
1. Ensure that all components necessary to rig a 3:1 system are there. A complete system should include:
   - One grip head block assembly
   - One single pulley
   - One single pulley with becket (two ends)
   - One rope control handle c/w anchor rope
   - Three carabiners
   - 450 ft. (140 m) of emergency rescue rope
2. Ensure that the system components are clean.
3. Check the head assembly for bends or physical damage or excessive wear.
4. Check the rotation of the drum. It should rotate freely counterclockwise. It should not rotate clockwise at all.

5. Check the haul-lock. It should move freely and have no rough surfaces to wear or snag the rope.

6. Check the haul-lock pin by removing the pin. It should be straight and should hold the haul-lock securely disengaged.

7. Check all carabiners. Inspect for visual damage. Check gate hinge and screw lock.

8. Check all pulleys. Check visually for bends or damage. Make sure pulley rolls smoothly.

9. Check rope control handle for visible damage or wear and that all moving parts operate freely.

10. Check condition of rope. Wash and dry if necessary. Look and feel for wear or damage over the entire length, paying particular attention to the used section.

11. Record, date and sign Apparatus Inspection Log.


**MSA THERMAL IMAGING CAMERA**

The MSA Evolution 5200 Thermal Imaging Camera (TIC) is designed to assist mine rescuers in low and poor visibility situations created by smoke and darkness.

The hand-held unit detects thermal energy radiated and/or generated by surrounding objects and converts this energy into a visual image on a large screen, high definition display that allows multiple personnel to view the image.

- Hot objects appear white.
- Cold objects appear black.
The camera can be used in:
• Search and rescue situations
• Initial and followup scene assessment
• Locating the seat of the fire
• Determining entry, exit and ventilation points

Parts

The system includes:
• The thermal imaging camera
• A rechargeable lithium-ion battery
• Carabiner attachment
• Charger kit

Operation

To operate the TIC:
1. Ensure the battery is fully charged.
2. Press and hold the green power button on the handle for one second.
3. Wait about five seconds for the camera to self-test.
4. Verify the camera is working by aiming at an object or person until the thermal image appears in the viewer. Do not point the camera at the sun.

To activate standby mode, press the green power button until the display shuts off and the system status LED flashes green.
To return to normal mode, press the green power button until the display reactivates without warmup, and the system status LED turns solid green.

To turn the camera off, press and hold the green power button for four seconds.

The camera is capable of withstanding conditions of heat, waterspray and impact experienced during mine emergencies, but care should be exercised not to run the camera for extended periods in high-heat conditions.

It should not be relied on as the sole means of navigation during use in dark, smoky environments. The user could become disoriented or lost, if the system becomes inoperative.

The TIC is NOT rated as intrinsically safe, and should not be used in environments where static or sparks may cause an explosion.

**On-screen Indicators**

The high-definition display monitor provides rescuers with valuable information.

The **Low Sensitivity Mode Indicator** – the letter L in the lower left corner of the display – is activated when the camera senses an environment above 320°F (160°C). The TIC’s dynamic range increases in this mode to make a better distinction between objects and people.

The **Shutter Indicator** – a green square in the upper left corner of the display – alerts the user that the camera is “shuttering” or refreshing the focal plane for proper operation. Shuttering freezes the image temporarily for about a second and occurs more frequently in high heat conditions.
The **Quick-Temp Indicator** – a central on-screen spotter and a vertical bar on the side of the display – indicates the approximate temperature of objects located in the spotter.

The **Over Temperature Warning** – a red LED at the bottom left corner of the monitor – is normally off, but turns flashing red when the TIC has exceeded the recommended operational thermal limits.

The **System Status Indicator** – a single LED, in the bottom central part of the monitor – shows the TIC’s operational status. Green indicates the camera is on and fully operational. Flashing green indicates the camera is on and in power-saving standby mode.

The **Battery Status Indicator** – three coloured LEDs at the bottom right corner of the monitor – shows the remaining battery capacity. Green indicates full or near full capacity. Yellow indicates marginal capacity. Red indicates battery warning and 15 minutes or less of capacity remaining. Flashing red indicates shutdown is imminent, in about one minute.

The **Heat Seeker Plus Indicator** adds shades of colour to objects to allow some details to be seen for easier identification.

In High Sensitivity Mode, the colour of objects reaching 275°F (135°C) will be yellow, starting with lighter shades changing to darker shades, then moving to lighter and then darker shades of orange as the temperature increases. Once objects reach a temperature of 297°F (147°C), they become red starting with lighter shades and changing to darker shades up to 320°F (160°C).
In Low Sensitivity Mode, the colour of objects reaching 842°F (450°C) will be yellow, starting with lighter shades changing to darker shades, then moving to lighter and then darker shades of orange as the temperature increases. Once objects reach a temperature of 914°F (490°C), they become red starting with lighter shades and changing to darker shades up to 1040°F (560°C).

The **System Fault Indicator** – all five LEDs – will flash if a system fault is detected by the camera’s internal computer.

**Maintenance**

After each use the camera should be inspected for:

- Structural, heat and/or chemical damage
- Loose parts and screws
- Cracks and breaks in the lenses
- Intact warning labels

The camera should be cleaned by wiping it with a solution of mild detergent and water and then dried with a dry, soft, lint-free cloth.

The battery must be recharged.

**Field Test**

1. Check general condition of the camera.
2. Turn on the camera and check battery for full charge.
3. Verify operation by viewing image.
4. Turn off camera and remove battery.
5. Install second battery.
6. Turn on camera and check battery for full charge.
7. Turn camera off.
8. Attach the carrying strap (carabiner to the camera).
9. Take spare battery.
10. Report results to captain.

**THE KED**

The KED, or Kendrick Extrication Device when used in conjunction with a cervical collar, helps to immobilize a casualty’s head, neck and spine in a neutral position, and prevent additional injury during extrication from a seated position or from a confined space.

Made of heavy duty vinyl-coated nylon, the flexible KED wraps and secures the casualty’s head, back, shoulders and upper torso in a semi-ridged embrace. Colour-coded, sewn-in securing straps and snap-lock buckles allow for quick, easy use on a casualty and help provide vertical rigidity for maximum support of the spine, neck and head.

Adjustable, fold-back sides permit easy access to the casualty’s chest, while built-in handles enable rescuers to get a firm grip on the casualty and KED as one unit.

**Field Test**

The KED will be inspected for contents only if it is required for a mission.

**Operation**

1. Stabilize head
2. Apply cervical collar
3. Slide KED behind casualty
4. Check that KED is properly aligned
5. Apply Straps: middle, bottom, legs, head, top
6. Recheck and tighten straps
7. Loosen chest and leg straps when casualty is horizontal

THE KESTREL

The Kestrel 3500 Pocket Weather Meter is a lightweight environmental measuring device used by Ontario Mine Rescue to assess a team’s heat exposure during operations.

The Kestrel display has an aviation green electroluminescent backlight. The device is powered by a long-life, lithium button-sized battery. Should the display dim or disappear, the battery must be replaced. The Kestrel is factory calibrated and requires no addition on-site calibration.

The Kestrel is capable of reading:

- Time
- Wind speed (SPd)
- Maximum gust (SPd MAX)
- Average speed (SPd AVE)
- (Dry bulb) Temperature (dEG)
- Wind chill (chill)
- Relative Humidity (r.h.)
- Heat Stress Index (H.I.)
- Dewpoint (d.P.)
- Wet Bulb Temperature (bulb)
- Barometric pressure (bAr)
- Altitude (ALt)
For mine rescue purposes, however, only the temperature (dry bulb) indicated by “dEG”, and wet bulb temperature indicated by “bulb” on the Kestrel, are measured, monitored and recorded.

**Temperature** – The Kestrel provides the instantaneous temperature of the thermistor, located at the end of the long coiled leads in the open cavity below the impeller. The exposed thermistor will respond quickly to changes in temperature when air flows past it. For the fastest response wave the unit side to side for 15 seconds.

**Wet Bulb Temperature** – WBT is calculated based on temperature and relative humidity measurements, as a measure of evaporation rate. If the wet bulb temperature is close to the air temperature, the air is humid.

The key parts of the Kestrel are:
- The cover
- On/Off button
- Left and right scroll buttons
- Display
- Impeller
- Thermistor
Field Test

The No. 2 man will be responsible for field testing, carrying and using the Kestrel. To field test the Kestrel 3500:

1. Examine the cover for cracks and/or damage.
2. Slide off the cover and examine the device for cracks or damage.
3. Turn on the Kestrel by pressing the centre button.
4. Ensure the backlight stays on for about 10 seconds.
5. Turn the Kestrel off by pressing the centre button for several seconds.
6. Slide the cover on.
7. Report the results to the captain.

Operation

To use the Kestrel:

1. Slide off the cover.
2. Press the centre button to turn on the device, the backlight will activate.
3. Use the right or left arrow buttons to scroll through the measurement modes.
4. Record the (dry bulb) Temperature, indicated by “dEG”, and the Wet Bulb Temperature, indicated by “bulb”.
5. Ensure the readings are C (Celsius).
6. Turn off the Kestrel by pressing and holding the centre button.

Note that the Kestrel will automatically turn off in 45 minutes if no buttons have been pressed.
CHAPTER 9
GENERAL EMERGENCY PRACTICES

RESCUE TEAM GUIDELINES

All mine rescue team personnel should report ready to work and fully equipped with suitable clothing. For example: during assignments that may involve firefighting, coveralls must meet National Fire Protection Association standard – NFPA 2133, and light, breathable undergarments are adviseable on assignments involving heat exposure.

All members of rescue teams sent underground should have had adequate training in such work.

In order that rescue team personnel may keep physically fit during mine rescue and recovery operations, the following arrangements should be made and adhered to:

1. No one should be permitted to work in irrespirable air with breathing apparatus without having been examined and found physically fit by a physician or, in the absence of a physician, by the most competent person present. Personnel with colds or other ailments affecting their breathing are not permitted to go underground in breathing apparatus.

2. No member should remain on shift longer than six hours. During this period no one should be permitted to remain
under $O_2$ longer than two hours, except in an extreme emergency.

3. No one should be permitted to undertake a second shift until they have had at least six hours rest. Personnel exposed to extreme heat, and worked under the time limits of the Ontario Mine Rescue Heat Exposure Standard, must have 24 hours rest.

4. Plain, well-prepared food, not too rich in sugar and fats, should be eaten in moderation. No food, including candy, should be eaten for one hour before taking an active part in rescue and recovery work.

5. Plenty of potable water should be available before and after assignments to keep rescue team personnel well-hydrated.

6. Comfortable, clean sleeping quarters should be provided, where necessary, for rescue team personnel.

In the event of a long emergency, doctors should be available 24 hours a day and every team member being used should be examined by the doctor at least once a day, more often if any indication of weakness, nausea, stomach or mental disorder appear.

Should it be necessary to call mine rescue personnel from home, care should be exercised so that men who have been drinking alcohol are not permitted underground in apparatus.

Consideration might be given to the methods used in getting team members from their homes to the mine. Mine rescue personnel proceeding to a mine emergency do NOT have emergency vehicle status and must obey all traffic laws.
OBJECTIVES OF RESCUE AND RECOVERY WORK AND EXPLORATION

Careful consideration should be given to the method and extent of the exploration plan and whether it is justified by the possible results.

Can the plan be carried out without danger to the rescue teams, and will it increase the possibility of saving lives?

The four main objectives of mine rescue and recovery work, both fire and non-fire, are:

- To ensure the safety of mine rescue and recovery teams
- To find trapped or missing miners and bring them to surface
- To respond to and resolve fire and non-fire emergencies
- To examine the mine for dangerous concentrations of any noxious gases that would prevent normal operations in any part of the mine
When making plans, the On-site Official in Charge should consider:

1. The probable conditions, including possible heat exposure, in the part of the mine to be explored
2. The route of travel
3. Visibility
4. Familiarity of the teams with the location
5. The number of trained personnel available
6. The limitations of the mine rescuers and apparatus

During emergencies the On-site Official in Charge may have to make decisions concerning the welfare of both personnel and the mine. These decisions vary from one situation to another and require input from many sources of information, both on-site and off-site.

Rescue teams may be able to fight mine fires at close range and direct the streams of water so as to extinguish the fire quickly.

When a mine fire cannot be fought directly, due to size or conditions, teams can put in seals or barricades to restrict ventilation or allow high-expansion foam generation.

When a sealed area is opened, teams with suitable breathing apparatus may explore it and evaluate the fire before the ventilation is restored.

**NUMBER OF PERSONNEL REQUIRED FOR MINE RESCUE AND RECOVERY WORK**

Oxygen breathing apparatus should be used only when there are enough trained mine rescuers available to form a five-member team to perform the assigned work.
To begin the team organization at the fresh air base, 15 trained mine rescuers are needed. They could be assigned as follows:

1. Five rescuers constitute a standard mine rescue team for work in irrespirable atmospheres.
2. Five rescuers, in apparatus but not under oxygen, should remain at the fresh air base as a standby team.
3. Five rescuers, acting as a backup team in reserve, may be used as assistants at the fresh air base until they are needed as the standby team.

Although this organization is the ideal to be strived for, during the early stages of the emergency, the deployment of the five-member teams is dictated by the urgency of the situation or the danger to human lives. It is also noted that one standby team can support two teams underground, depending upon the emergency situation. In situations, however, where heat exposure is a limiting factor, two standby teams are required.

Within six hours additional mine rescue teams must be on site, and for extended operations, a six- to nine-team rotation will be required.

**FRESH AIR BASE**

Fresh air bases are used as the headquarters from which rescue and recovery work in irrespirable atmospheres is conducted, or as an advanced staging area.

A Mine Rescue Officer/Consultant or a suitable designee, with the necessary assistants, should be stationed at the base.
This arrangement is made up to a maximum force of six teams and allows for six hours on duty and six hours complete rest. As more teams become available, and if the emergency indicates an extensive operation, a nine-team arrangement is advisable, whereby the team members would have a 12-hour rest period.

<table>
<thead>
<tr>
<th>Team No.</th>
<th>Description</th>
<th>Date:</th>
<th>Time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Active</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Stand by at F.A.B.</td>
<td></td>
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<tr>
<td>3</td>
<td>Reserve</td>
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<tr>
<td>4</td>
<td>Active</td>
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<td>5</td>
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<tr>
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<td>Reserve</td>
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</table>

**Figure 43: Rotation of Mine Rescue Teams in Event of an Underground Emergency (Six-Team Arrangement)**

<table>
<thead>
<tr>
<th>Team No.</th>
<th>Description</th>
<th>Date:</th>
<th>Time:</th>
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<tbody>
<tr>
<td>1</td>
<td>Active</td>
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<tr>
<td>2</td>
<td>Stand by at F.A.B.</td>
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<tr>
<td>3</td>
<td>Reserve</td>
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<td>4</td>
<td>Active</td>
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</tbody>
</table>

**Six-team rotation**
This arrangement is made up to a maximum force of six teams and allows for six hours on duty and six hours complete rest. As more teams become available, and if the emergency indicates an extensive operation, a nine-team arrangement is advisable, whereby the team members would have a 12-hour rest period.

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<tr>
<td>1</td>
<td>Active</td>
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<td>2</td>
<td>Active</td>
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<tr>
<td>3</td>
<td>Reserve</td>
<td>2 Hrs.</td>
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<td>4</td>
<td>Reserve</td>
<td>2 Hrs.</td>
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<td>5</td>
<td>Reserve</td>
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<td>6</td>
<td>Reserve</td>
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<td>7</td>
<td>Reserve</td>
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<td>8</td>
<td>Reserve</td>
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<td>9</td>
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</table>

Figure 43: Rotation of Mine Rescue Teams in Event of an Underground Emergency (Six-Team Arrangement)

<table>
<thead>
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<th>Team No.</th>
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</thead>
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<tr>
<td>1</td>
<td>Active</td>
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<tr>
<td>2</td>
<td>Active</td>
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<td>3</td>
<td>Stand by at F.A.B.</td>
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<td>4</td>
<td>Stand by at F.A.B.</td>
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<td>Reserve</td>
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<td>6</td>
<td>Reserve</td>
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<td>7</td>
<td>Reserve</td>
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<tr>
<td>8</td>
<td>Reserve</td>
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<tr>
<td>9</td>
<td>Reserve</td>
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</table>

Figure 44: Rotation of Mine Rescue Teams in Event of an Underground Emergency (Nine-Team Arrangement)
If there is more than one base, it may be necessary to set up a general headquarters.

The base may be on surface or underground, as conditions require, and should be as near the scene of operations as possible. The essentials of a fresh air base and an advance staging area are:

1. An assured supply of fresh air
2. An assured travelway for men and materials to surface in fresh air, if the base is underground
3. Communication with headquarters on surface by telephone or messenger
4. The best illumination possible
5. Enough room to permit efficient work without confusion

The fresh air base should be equipped with tables, benches for the reserve teams, benches for overhauling rescue apparatus, tools and repair parts for maintaining the apparatus, and the necessary tools and supplies for carrying on the work at hand.

There should be enough staff to direct the work and maintain operations on the fresh air side of the base.

Advanced staging areas may be established in refuge stations and other suitable locations.

**TIME LIMITS FOR RESCUE TRIPS**

All watches should be synchronized – team members’ with that of the briefing officer, the briefing officer with that of the Control Room. Any instructions regarding time limits must be strictly followed. For returning to the fresh air base, a team should ordinarily allow twice the time used on the ingoing trip.
If the O₂ in the apparatus bottle worn by any team member has been reduced to twice the amount used on the ingoing trip, the whole team shall return to the fresh air base immediately.

An exception may be made when extensive exploration or gas testing has been done on the way to the objective. Only the time or O₂ required for a direct return trip to the fresh air base need be considered.

Intermediate time limits will be set by the briefing officer for a rescue team to travel to a destination and for work to be done. The briefing officer and team captain must use strict realistic time limits that must not exceed 30 minutes without a report. Exceptions may be necessary if there is a problem with communications.

In situations where the team is exposed to high operating temperatures, or incidents creating high temperatures, more severe time limits may be required under the Ontario Mine Rescue Heat Exposure Standard.

If a rescue team is overdue in returning to the fresh air base, the standby team shall be sent to assist, even at the cost of delaying operations.

**BRIEFING A TEAM**

A team should be briefed by the designated briefing officer as soon as the specific assignment or task for the team has been determined.

If possible, the briefing should be done in a quiet room where questions may be answered and the work to be done by the team explained thoroughly without confusion and distraction.
All pertinent instructions should be issued in writing to the team captain. The time limits of the trip should be understood and watches synchronized.

Each team underground should have its own briefing officer.

**BRIEFING OFFICER**

The briefing officer is essential to any situation that may arise. He is the liaison between the control group and the team. He is ultimately responsible for the team while they are underground. Any decisions made must be made with the team’s safety in mind at all times.

It is his responsibility to:

1. Maintain communications with the working rescue team and the control room
2. Follow the team’s progress on the mine map and mark findings on the map as the team reports them
3. Co-ordinate and oversee the activities of all personnel at the fresh air base, including the advisory committee

Many things must be done during any emergency. It is the responsibility of the briefing officer to obtain all information about the area affected that a team may encounter. This information, listed following, will assist the emergency control group and is given to each team through the briefing officer.

- Mine fire procedure and up-to-date maps showing the location of:
  - Refuge stations
  - Communications
  - Garages
- Fuel storage
- Fire hoses
- Fire hydrants
- Electrical installations
- Hot zones or potential hot zones
- Potential rest or cooling areas that may assist the team in recovery from heat exposure

• Information about the mine’s equipment such as:
  - Ventilation and fans
  - Mining methods
  - Ground conditions
  - Timbered areas
  - Equipment used
  - Other hazards
  - Type of hoist
  - First aid equipment
  - Mine rescue equipment
  - Other equipment

• Information about the emergency:
  - Type of emergency
  - Location of the emergency
  - Missing personnel
  - Availability of mine rescue personnel
  - Special skills required by mine rescue team

These three basic responsibilities consist of a number of tasks, some of which may be done by the briefing officer.
Some tasks may be delegated to other individuals, but it is the briefing officer’s responsibility to see that they are completed.

Every briefing of a mine rescue team should include:

1. Information available
2. Persons missing, location and any trained persons
3. Action taken so far
4. Whether the incident is a potential heat exposure incident (fire, explosion, loss of ventilation, unknown nature, etc…)
5. Intention
6. Fresh air base location and standby teams
7. Communications
8. Installations such as air, water, electricity
9. Refuge stations
10. Route of travel
11. Conditions on route of travel
12. Potential rest or cooling areas for relief from heat exposure
13. Ventilation
14. Visibility
15. Mine rescue equipment available
16. Firefighting equipment and hydrants
17. First aid equipment and stretcher
18. Tools and supplies
19. Time limit
20. Written instructions

Should the incident involve a mobile equipment fire, the briefing officer must also advise the team:

- The location of the fire on the mobile equipment
- The source of the heat
- The intensity of the heat
- How long the tire(s) have been heated
- The amount of smoke from the tires
- If there were any sparks
- If the equipment became electrified, whether there was any arcing

After the team is underground, communication is vital. Information to and from the briefing officer must be specific and to the point so the control group may decide on the best course of action the team should take.
The briefing officer must inform the control group before a team passes a hazard as it may compromise the safety of the team, such as a fire area or fall of ground.

If the incident involves heat exposure, the briefing officer must monitor temperature and time exposures, as well as work/rest regimens, as reported by the team captain, and report this information to the control group.

On exploration the team must report all conditions as found with the exception of items that are normal to mining operations (doors, fans, air flow and team condition). These should only be reported if they are different than expected. Conditions need not be reported if they are the same as the initial exploration.

The conditions the team encounters must be recorded in the captain’s log and must coincide with the briefing officer’s report that is turned into the control group after the team has completed its assignment.

**DUTIES OF A RESCUE TEAM CAPTAIN**

The team captain shall take charge of, and be responsible for, the discipline, general safety and work performed by his team. He should take orders only from the briefing officer.

**Preparatory to Going Underground**

Prior to going underground the team captain should:

1. Ascertain that team members are in fit condition, including adequately hydrated, to undertake the job.
2. Make sure that each team member inspects and completes the field test on the apparatus he is about to wear.
3. Check or have team members field test the team’s standard equipment. It is suggested that:
   – No. 2 member field tests the MX6.
   – No. 3 member field tests the first aid kit. If the kit is sealed, it does not need to be opened.
   – No. 4 member field tests a SSR 90 M as a backup for the team.
   – No. 5 member field tests the captain’s equipment.

4. Check or have team members field test any additional equipment – e.g., CAREvent, stretcher – to be taken underground.

5. Understand the instructions clearly and discuss them with the team so that each member will understand what he has to do.

6. Note the time the team has been allowed for the trip and synchronize watches with that of the briefing officer.

7. See that the necessary tools, portable communication devices, guidelines, and materials, if required, are on hand, including firefighting equipment, if there is a fire burning. It is important that these items are distributed equally among the team members so that each member will carry his share.

8. Make sure that he has level plans, notebook, pencil and chalk/spray paint to take underground.

9. Ensure the hoistman is contacted to confirm availability of the cage.
Shafts and Ramp Entrance

When a Mine Rescue team enters a mine during a fire via a shaft or a ramp several precautions must be taken including:

1. Note if the shaft is upcast or smoke is present.
2. As the hoistman in an internal shaft or on a tower mounted hoist is the link between surface and underground, a second hoistman should be available as backup. A SCBA must be used for protection if there is a possibility of exposure to contamination. Where possible, this person should be checked to ensure a proper facemask seal and the apparatus is functioning correctly.
3. Ensure sprinklers are functional if the shaft is timbered.
4. Get under $O_2$ in fresh air outside the headframe or portal entrance. The captain should inspect the team’s breathing apparatus and other equipment as follows:
   a) Inspect head straps and buckles for twists
   b) Inspect facemask for correct position and tight seal
   c) Try main bottle valve
   d) Observe gauge reading and record pressures
   e) Check overall condition of man (by sign or verbally)
   f) Vice-captain to make similar check of captain’s apparatus
5. It is not required to take conditions and report to the briefing officer until the portal entrance or headframe is entered.
6. The air quality and air flow at shaft collar or ramp entrance must be determined.
7. A trial run must be performed of the hoist and cage if more than two hours have elapsed during a fire situation, especially if the location of the fire is unknown.

8. Contact the hoistman and request that the cage be left near the level when it is released to minimize response time.

**After Going Underground**

After going underground the team has many procedures it must follow to ensure its safety. The conditions teams encounter will dictate the procedures they will have to follow.

It is understood that the captain is responsible for the team and must:

1. Discourage excessive talking but keep the team informed of the plan of action after talking to briefing officer.
2. Have a team member take MX6 air quality tests at the shaft stations or levels. Note fire hoses, fans, or any other installations. All mine rescue equipment used should be returned with the team, if possible. Mark all obstructions and unusual conditions on the level plans. Bear in mind that the team will have to overcome the same obstructions and unusual conditions on the return trip.

3. Designate a team member to check an area provided the area is explored and the team is not split. As long as the captain has care and control of the team (such as visual contact, signals with rope, radio, whistles, voice, fire hose, contact with the TIC) in all situations at all times it is not a team split.

4. Consider an area explored if a responsible person, such as a shift boss or a mine rescuer, informs the captain that they have travelled the area. The team’s line of sight is also considered explored. The captain will make the decision about explored territory after consulting the team.

5. Maintain contact with the surface by utilizing either radio or telephone communication, setting strict time limits and destinations.

6. Rest and check the team after strenuous work or during exposure in hot environments, giving additional rests as often as conditions warrant. During halts, observe gauges and function of the apparatus. If the rescue of personnel is involved, speed may be necessary but should be governed by conditions and common sense.
7. Before allowing any team member to remove his breathing apparatus underground, be certain the air is safe to breathe. The captain must be certain that the MX6 functions normally and the CO level is zero.

8. Remember that it will be just as necessary to halt, rest and check apparatus when retreating as when advancing. Keep the team from becoming disorganized if anything should happen to a member or if an apparatus should fail to function properly. If necessary, have the team return to the fresh air base as quickly as possible. It is important to note that a team member in distress is priority over any other assignment.

9. Whenever possible, maintain communications with surface or report frequently, at least every 30 minutes.

10. Give consideration to turning off an auxiliary fan if it is blowing contamination into an isolated area.

11. Not alter main ventilation unless approval is given by the control group.

15. While proceeding to the shaft station with a casualty, call the briefing officer and have additional equipment brought to the team for a return trip into the mine. The equipment brought to the team by anyone, including the cagetender, must be examined.

16. An acetylene cylinder must be moved to the return air side of a fire if it is leaking or damaged. Caution should be taken if the cylinder is hot.

   In case of fire, allow the gas to burn if the flow cannot be shut off immediately. Apply water from a safe distance
to cool the container and protect the surrounding area. When the cylinders are moved, do not drag or roll them. Use a suitable hand truck for cylinder movement.

17. Ensure the team follows all mine rescue procedures.

18. Carry out the orders given by the briefing official. Bring the team back to the fresh air base on time, even if the work assigned has not been completed.

19. On return to the fresh air base, get the team out of oxygen. The captain should get out of oxygen first, and then give the order for the team to get out of oxygen.

20. Make a report to the briefing officer.

The success or failure of mine rescue and recovery operations depends a great deal on the ability of captains to lead their teams.

**Team Checks**

1. A team must perform 20-minute team checks to ensure each apparatus is functioning correctly and allow members to rest periodically. The team must check and report their cylinder pressures and condition to the captain, who must record the findings in the log. It is not necessary to squeeze hoses.

2. When a team first enters contamination, members must squeeze hoses, and report their cylinder pressure and condition. The captain will record each member’s pressure and condition in the log.
TRAVELLING UNDERGROUND

Rescue Team Guides

In a major fire or non-fire emergency it will generally be necessary to bring in rescue teams who are not familiar with the mine workings. To facilitate the necessary work, mine rescue personnel familiar with the mine should be assigned to each team.

Order of Travel

In mine rescue, as in any other teamwork, discipline is essential to efficiency. This discipline must be maintained, both in training and in actual operations.

The captain or No. 1 person will always lead, whether the team is advancing or retreating. The No. 5 man assumes the responsibilities of vice-captain.
The rate of travel cannot be laid down by any hard and fast rules. It will be governed by:

1. Visibility
2. Obstructions to travel
3. Mental and physical condition of the team members
4. Amount of O₂ in the bottles
5. Anything that may be applicable to local conditions

Travelling ‘under oxygen’ on ladders should be done only after the captain has considered carefully whether the value of doing so outweighs the dangers.

Fastening Team Members Together

When travelling in strange territory or in atmospheres where visibility is limited or may become so, the members of the rescue team are fastened together by means of a link line.

In emergencies, where the link line is liable to become an additional hazard (e.g., when carrying a stretcher or patient) the lines may be disconnected as long as there is some means of keeping team members together.

The following terms have been standardized for mine rescue work:

A guideline consists of a line or telephone cable stretched from the fresh air base or shaft station to the working face in such a manner that a team may guide itself through strange territory or dense atmospheres.

A link line is a lanyard suitable for linking the team together and as fall restraint protection provided the lamp belts used by Ontario mine rescue teams are turned to the back.
The team does not need to be linked together when conducting a fire hose drill.

**Passing a Team through Ventilation or Fire Doors**

A captain should make certain that all doors are left as found unless he has received definite instructions, preferably in writing, to the contrary. To ensure that this is done the captain should:

1. Halt the team and disconnect the link line.
2. Examine door for damage, air flow, heat, and position.
3. Determine if there is anyone behind the door.
4. Open and hold the door open.
5. While at the door, advance the team through the door until the last man is through.
6. When the last man is through, halt the team.
7. Leave the door as found, take his place at the head of the team, fasten the link line and give the signal to advance.

Air quality should be tested if the conditions are different once the team has proceeded through the door.

**Travelling in Smoke**

When travelling in smoky atmospheres team members will find it helpful to carry their electric cap lamps in their hands and use a probe stick to feel for obstructions and hazards.

If the smoke is very dense it is better to have the lamp as near the ground as possible, letting it hang by its cord so that light is directed toward the feet. The probe stick must be used.
There is a disadvantage in carrying the light on the hat as the reflection cast back by the solid particles of smoke close to the member’s face tends to be blinding.

**Recording Route of Travel**

Routes of travel can be recorded by three main methods:

1. Radio communication, using leaky feeder or phones, is subject to strict time limits and require specific destinations to allow for monitoring of the team’s progress. This method allows for greater mobility and requires strict controls. Caution should be used when relaying information to the briefing officer due to the fact that radio communications are not secure, and proper radio etiquette should be practised (no foul language, limit personnel names, maintain team discipline during radio communication).

2. Guidelines installed in areas of zero visibility will save a great deal of time for team movements and will allow a team to find its way to fresh air again. If more than one team is required to advance the guideline, as each team completes the installation of its allotted section of the guideline, the captain should mark the place where the line ends with an obstacle across the drift. This may be a pile of rocks, boards, timber or anything that can be identified by touch. On reaching fresh air, the captain should describe each obstruction clearly in his report.

3. At a turnaround point, radio communication will suffice if the turnaround point can be identified by a distinctive landmark, such as a refuge station, shop, garage, electrical
substation, etc. If radio communications is not possible or no distinctive landmark exists, a turnaround point consisting of three vertical lines, time, date, team number and the captain’s initials, must be clearly marked at the farthest point of advance into any drift or heading. All times are recorded using the 24-hour clock. A turnaround point must be cancelled only if the same team is advancing past the point that was marked.

When visibility is at zero, the sense of touch must be relied on. If the team is travelling into drifts or crosscuts where track is laid, it is simple to follow the track by sliding one foot along a rail. When a switch is reached it should always be left so that it makes a continuous track to the fresh air base that can be followed by a retreating team. If there are no tracks, much time can be saved by having several teams, in apparatus, install a guideline to the emergency scene.

**Use of Vehicles for Transportation**

The conditions teams encounter will dictate the procedures they will have to follow. The regulations for the use of motor vehicles in mines are the basis for the use of vehicles by the team.

The team captain and the briefing officer shall note the normal walking speed on the mine plans. This will give some indication how far the team would travel on foot if the vehicle needed to be abandoned.

It is not recommended to drive a vehicle in heavy smoke but there may be times in which teams may have to drive a vehicle in light smoke.
The following must be adhered to:

1. The vehicle must be equipped with good lights and the necessary emergency equipment and tools.
2. The horn must be sounded often.
3. If the vehicle is abandoned, it should be parked at the side of the roadway to maintain a clear roadway for other vehicles. The engine must be turned off. Warning reflectors or signals should be left to warn other teams.
4. Control doors may need to be opened manually, in which case they will have to be held open while the vehicle passes through. The captain will be responsible for the correct positioning of the doors.

**COMMUNICATIONS**

**Between Fresh Air Base and Team**

It is essential that communications be established between the fresh air base and teams working ahead of the base. When breathing apparatus is worn, communication may be conducted by radio or by telephone, either permanent or portable battery-powered.

Radio communication is the ideal method as the briefing officers are in constant touch with active teams should an unexpected hazard or new information become known.

When a team is on an exploration trip, radio and/or telephone communications must be checked for proper operation and to ensure backup communications. If there is more than one phone in an area, only one phone need be
checked. Radios may be used at any time an unexpected hazard is encountered or new information is to be relayed.

When a team is on a return trip or when a casualty is being transported, life-threatening or not, a sense of urgency must be demonstrated. A time limit longer than 30 minutes may be given to the destination for the return trip. All other communication points may be bypassed. If there is a hazardous location that must be evaluated during retreat and if conditions of the hazard have changed, the briefing officer must be contacted as soon as possible.

Information to and from the briefing officer should be specific and to the point. When the team is on an exploration trip, they must report conditions as found. If conditions haven’t changed when they return to that location, the conditions may be reported as the same. It is not necessary to repeat the specifics – CH₄, doors, fans, flow and team condition – if they are the same as already noted.

Information on items and conditions found during exploration by a team must be recorded by the captain and must coincide with the briefing officer plans to be included with the final report.

Conditions recording and reporting will be required when:

• Conditions along the route of travel change, otherwise conditions along the route of travel will NOT be recorded or reported
• Entering a head frame or adit
• Entering a level
• Reaching assignment area where the team does work
If radios are not being used, it is advisable that a team never pass a refuge station without phoning the briefing officer. He may have new information for the team.

When establishing a refuge station, if the standards are met, conditions do not have to be recorded or reported. The captain need only report that the refuge station has been established.

The captain does not need permission to fight a fire, nor does the captain need permission to pass a hazard – e.g., fire area, fall of ground – during exploration, if the area is assessed as safe by the team.

**Between Team Members**

Although team members may talk to one another, it is essential that conversation be limited. Whistle signals are used for team travel from one point to another and other team movements. The Code of Signals is as follows:

1. Stop
2. Advance
3. Turn Around
4. Attention or Emergency

When the captain gives a signal given by a mechanical means, such as a whistle or horn, the vice-captain repeats the signal. The Attention or Emergency signal need not be repeated.

Whistles are used for team travel from one point to another. They are not required for the hose drill, while extinguishing a fire, or work performed in close proximity to each other such as loading the cage, building a barricade, pushing a vehicle or other local movement.
STANDARD MINE RESCUE PROCEDURES

Electrical

Some situations during mine fires will require switching the electricity off/on. It is highly recommended that an electrician be placed on the team when such assignments arise. The following procedures must be followed:

1. The control group must inform the briefing officer what the results of switching the power off/on will be before throwing the switch and the team must then be informed to turn power off/on.

2. The whole team must stand back while the switch is being thrown.

3. The person turning the power off/on must stand to the side of the switchbox, pull the switch, and avert eyes to avoid possible flash. The main objective is to avoid having one’s body being directly in front of the switchbox when the power is being turned off/on.

4. The team must follow standard lockout procedures when necessary.

Use of Burning and Welding Equipment

The danger of burning and welding while under $O_2$ must be emphasized as there is the possibility that hot slag will burn into the oxygen-enriched breathing apparatus through the rubber parts of the apparatus and then erupt into flames. The recommended emergency procedure is:

1. A competent person is selected for the operation and must be trained in mine rescue and be properly equipped
for burning and welding, working under the supervision of the captain at all times.

2. The appointed person will be an extra man, not part of the mine rescue team.

3. This person must be equipped with self-contained air breathing apparatus, preferably a pressure-demand apparatus for connecting to a supplementary air supply with an extension hose. Care should be taken to ensure that the recharge hose is in a safe place.

4. The team must bring a water hose, nozzle, or a water-type fire extinguisher.

5. The area must be wetted down before welding or burning commences.

6. The area must be wetted down after burning is finished. The area should be checked periodically.

7. When the assignment is completed, the person should be returned to fresh air immediately.

**Rescue Operations in High Temperatures**

When mine rescue teams conduct operations in areas with high temperatures and/or humidity levels, they must follow the missions limits as determined by the Ontario Mine Rescue Heat Exposure Standard.

The standard, adopted by Ontario Mine Rescue, was developed by the Institute of Occupational Medicine (IOM) for Mine Rescue Services Ltd. in the United Kingdom. IOM has determined the standard is suitable for mine rescuers using the Draeger BG4, the apparatus used by Ontario Mine Rescue.
Cross-referencing the Wet Bulb and Dry Bulb temperatures indicates the maximum time exposure in minutes. Exposure limits include time for entry, exit and rest breaks. Exposure limits must not be exceeded.
This standard accounts for the four principal variables in heat exposure – workload (all mine rescue activities are ‘heavy work’), temperature, relative humidity (factored in difference between dry and wet bulb temperature) and the time exposed.

The standard cross-references dry and wet bulb to determine the maximum mission time limit in minutes.

The time limit includes:
- Time spent entering and leaving
- Time spent at rest

The maximum time limits must be strictly followed.

The heat exposure standard will apply whenever a team is exposed to a **Hot Zone**, a **Potential Hot Zone** and/or a **Heat Exposure Incident**.

A **Hot Zone** is a location or area in a mine where, under normal operating conditions, heat exposure is an issue and control measures are required.

A **Potential Hot Zone** is a location or area in a mine where heat exposure may be an issue if normal operating conditions and controls, such as ventilation, fail or are inoperative.

A **Potential Heat Exposure Incident** is an incident involving fire, explosion, loss of ventilation, or other factor that could result in a heat exposure hazard. Incidents of an unknown nature should be considered potential heat exposure incidents.

During such assignments, the team captain will ask for and record Temperature and Wet Bulb Temperature, when:
- The team approaches and enters an identified hot zone
- The team approaches and enters a potential hot zone
• The team approaches and enters a potential or real heat exposure incident

• The captain experiences or is told by a team member that the member experiences an unexpected increase in the ambient temperature

The time the measurement is taken, and the exposure time limit, if any, must be recorded and reported to the briefing officer.

Other control measures, such as extended rest breaks, if possible in ‘cooler’ areas, and more detailed team checks, should also be undertaken during such operations.

**FIRST AID**

To minimize the effects of gases or injuries on casualties:

1. In contaminated air it is not recommended that untrained personnel carry the stretcher. The team could use their link lines to link personnel to stretcher so they do not wander away.

2. The team may remove their masks to reassure casualties being evacuated in fresh air.

3. Team members must rotate clockwise around the stretcher, two positions at a time.

4. When first sighting a casualty, evaluate the history of the accident, check the area for hazards, remove casualty from danger if it is present always ensuring the safety of the team.

5. When dealing with conscious casualties, team members should consider the history of the casualty. Airway and breathing should be checked verbally, while circulation
should be checked visually for gross bleeding, and the pulse with permission.

6. A CAREvent is to be used on an unconscious person or a conscious person in breathing distress, e.g., stopped breathing, heart attack, stroke.

7. Triage cards must be completely filled out by team members when treating casualties and must be turned over to medical aid.

8. A stiff-neck cervical collar, head restraint and towel are provided in each first aid kit to immobilize the casualty.

9. Be sure to cover over and under the casualty to prevent or minimize shock.

10. To avoid placing further stress on a casualty, it is not recommended to put equipment on a casualty while in the stretcher.

11. Avoid standing, walking or passing equipment over a casualty.

12. Casualties who have been unconscious must continue to be carried after they become conscious.

13. While casualties are being protected, the air quality at the scene must be measured and the briefing officer informed of the level of exposure involved.

14. There may be times in which the team finds a casualty with a beard, burnt or bleeding face. If the casualty is conscious, you may use the mouthpiece, nose clip and goggles of the SSR 90 M rescue unit. With unconscious casualties, the team will have to seal the facemask of the CAREvent as best they can.
15. It may be necessary to leave a casualty while another is evacuated. If so, evacuate the casualty with the least protection or most serious condition.

16. The team may leave casualties in a refuge station if there is someone qualified available. Instructions should be given to monitor the casualty closely and remove the mask should complications occur. If not, the casualties must be evacuated to the shaft.

17. When an injured casualty wearing a SSR 90 M must be left alone, always place them in the recovery position.

18. Should there be several casualties and the team does not have sufficient equipment for protection, the casualties must be placed in the recovery position, treated for shock, and area ventilated as soon as possible.

19. There may be occasions when a team has two unconscious casualties protected with O$_2$ breathing apparatus, and one must be left alone. The apparatus left with that person should be kept out of harm’s way. It is vital that the team not leave the level and go to surface if a casualty is alone wearing an O$_2$ breathing apparatus as the team may be delayed in returning. In the case of a casualty being placed with qualified personnel in fresh air (e.g., refuge station, fresh air raise) then a team may leave the level to take another casualty to surface.

20. Captain must monitor the casualty while the team is at rest or during a team rotation.

21. Briefing officer must make sure that medical assistance is available for casualties when the team gets to surface.
‘Load and Go’

‘Load and go’ means dealing with any life-threatening injuries, then loading and transporting the casualty immediately without conducting a secondary survey other than a pulse and respiration count.

Though the decision to ‘load and go’ must be made early when a casualty is encountered, it does not mean ‘do nothing, just go’. A prompt attempt must be made to treat or correct the life-threatening injury, and all actions, including the decision to ‘load and go’, must documented on the casualty card.

Examples of ‘load and go’ situations include (this list is not all-inclusive):

- Any airway problem in which there is a risk of loss of the airway
- Cardiorespiratory arrest or chest pain
- Any head injury no matter the level of consciousness
- Anaphylaxis
- Abdominal evisceration
- Major fractures
- Fractured femur or pelvis
- Uncontrolled hemorrhage
- Partial or complete loss of a limb
- Critical burns
- Spinal injuries
- Multiple casualties
- Deteriorating vital signs
REFUGE STATIONS AND SAFE AREAS

When the way of escape is cut off, but the local atmosphere is free of contaminating gases, personnel may be required to establish a safe area supplied with compressed air for trapped miners by erecting a fresh air tent, a portable refuge station, or building barricades using materials at hand.

Garbage bags, plastic sheets, vent tubing, tools, timber, canvas, water, dinner buckets, and anything else that might be useful should be collected. A suitable place should be chosen and construction started without delay, as deadly gases often travel quickly.

To provide a maximum quantity of air, as much area as possible in drifts and crosscuts should be included in the barricaded area, regardless of the number of people in the party. If possible, barricades should be erected in such a location that a valve in the compressed air line will be inside the barricade.

Refuge Station Procedures

There are procedures that teams must follow when dealing with Refuge Stations and Barricades.

1. Assuming there is contamination outside a refuge station or barricade, there are questions that a team must ask when first encountering people inside a refuge station or barricade who have not been in communication with surface:
   – Knock on the door
   – Identify as mine rescue
1. Determine the number of personnel inside, if they are trained in first aid or mine rescue, and if anyone has a beard
   - Ask if people are alright and if there are any injuries
   - Determine if they have self-rescuers and whether they have been used
   - Ask about missing personnel or information on fire
   - Ask if the compressed air is blowing and the door is sealed
   - Ask if the phone is working
   - Tell the people to stay inside

2. Where people inside a refuge station or other safe location are without communication with the surface, a team captain must ask the appropriate questions, and relay the information to the briefing officer.

3. If the people inside a refuge station or other safe location have contact with the briefing officer, the team is not required to ask for all the information the briefing officer should know, nor leave a mark on the outside of the people inside.
4. When the team knocks or calls out and receives no response it is imperative to enter immediately with the stretcher, turn on compressed air, check air quality in the area, and contact the briefing officer, thus establishing it as a refuge station. No mark is required outside the refuge station.

5. Should it become necessary to enter an occupied refuge station, instruct the individuals to move to the back of the refuge station and turn the compressed air on fully while the team enters quickly. If there is no compressed air, treat as a barricade.

6. A telephone outside the refuge station is ideal for communicating with people inside and to the briefing officer. However, if it is not available, the team must not enter as it would expose the people inside to contamination unnecessarily. Someone inside could phone the briefing officer on the team’s behalf and relay messages. Because information is received from other parts of the mine, it is important to wait for a reply from the briefing officer before continuing with the original assignment.

7. The captain may use the phone in a refuge station with the team remaining outside providing the air outside is not contaminated. The door must be kept open to maintain contact with the team. The whole team must enter if there is contamination outside and the captain wishes to use the telephone.
8. There may be circumstances when it is necessary to get out of $O_2$ underground, whether it is the team or casualties in refuge stations. It is essential to test the air quality.

9. The team must take precautions to minimize contamination of a barricaded area if no compressed air is available. Consideration should be given to:
   - Size of area
   - Amount of contamination
   - Number of personnel, injuries and if they are willing to stay
   - How long they have been there
   - If self-rescuers are available and, if so, have they been used?
   - Determine information on the fire or missing personnel

10. Circumstances may dictate that the team enters a barricaded area to remove personnel with suitable apparatus. If so, the area must be ventilated or the amount of contamination allowed to enter must be restricted.

11. A barricade that has been built to seal off a fire should not be unsealed unless the On-site Official in Charge has given definite orders to do so.

**BG4 EMERGENCY PROCEDURES**

Ontario Mine Rescue acknowledges that the following emergency procedures for the BG4 are not recommended
by the manufacturer, but may be required under extreme circumstances, including:

1. Entrapment procedure
2. Team member in distress
3. Use of the BG4 as a rescue unit
4. Gradual loss of oxygen pressure

**Entrapment Procedure**

Before using this procedure in an emergency situation mine rescue teams must consider all other available options, be informed of the hazard of hypoxia, and be able to demonstrate knowledge of the entrapment procedure.

**Hypoxia** – Hypoxia literally means deficient in oxygen. When the body doesn’t receive the required amount of $O_2$, it results in a low $O_2$ content in the blood. This leads to Hypoxic hypoxia. The major causes of Hypoxic hypoxia are high altitude climbing, inadequate ventilation, or heart mechanism failure.

Hypoxic hypoxia may occur while performing the entrapment procedure with the BG4 when the $O_2$ cylinder is off. The concentration of nitrogen and carbon dioxide in the breathing circuit may increase. The high nitrogen concentration together with low oxygen may be fatal.

**Signs and Symptoms** – Hypoxia is difficult to recognize in its onset. The signs and symptoms can be different for every person and may not occur in the same progression.

Signs and symptoms include:

- Cyanosis
- Poor coordination
• Lethargy/fatigue/tiredness
• Executing poor judgment
• Air hunger
• Dizziness
• Headache
• Mental and muscle fatigue
• Nausea
• Hot and cold flashes
• Tingling sensation
• Visual impairment
• Euphoria

**Entrapment** – The following procedure requires **strict discipline and careful monitoring** on the part of team members. **One team member will always be under oxygen** on an alternating basis when this procedure is being performed.

Mine rescue teams should consider all options such as retreating to fresh air, using installations such as garages or electrical substations as a fresh air location, travelling to another level via a manway or ramp, or using cached self-rescuers before using this procedure.

If the entrapment procedure is used in the first half-hour of BG4 use, the breathing circuit will need to be flushed of nitrogen by using the bypass valve to fill the breathing bag several times.

A mine rescue team member who weighs 75 kilograms (165 pounds) requires approximately 0.5 litres of O₂ per minute at rest. A BG4 with a cylinder pressure of 100 bar would contain
200 litres of $O_2$. At 0.5 litres per minute, 200 litres would provide $O_2$ for the user for 400 minutes or 6.5 hours.

A BG4 that has been in use for 30 minutes and has 150 bar with 300 litres of $O_2$ remaining would provide oxygen to the user for approximately 600 minutes or 10 hours.

**Procedure:**

1. The captain will select a safe site where the team can sit together comfortably.

2. Team members will remove each others’ BG4 cover so the breathing bags can be monitored.

3. The BG4 harness can be loosened for comfort.

4. The captain will record cylinder pressures and condition of team members initially and every 10 minutes thereafter.

5. The captain will remain under oxygen for the first rotation of the procedure to check team members’ alertness and observe breathing bags. The buddy system should also be used to observe breathing bags and condition of team members.

6. Another team member or captain will push the bypass valve and **ensure the breathing bag is not overfilled**.

7. Team members will turn off their $O_2$ cylinders and breathe in slow controlled breaths. The time the cylinders are turned off should be noted by each team member. Breathing difficulty may be noticed as the breathing bag empties and bottoms out on inhalation.

8. Team members will turn on the cylinder every 10 minutes, or sooner if a breathing bag is empty or a team member is in distress.
9. The #2 man will remain under oxygen to check team members’ alertness and observe breathing bags for the second rotation of the procedure. This step will be repeated until everyone has had a turn with their cylinder left on. The cover of the BG4 should be on when the cylinder is left on.

10. Another team member or captain will push the bypass and ensure the breathing bag is not overfilled.

11. Team members will turn off their O₂ cylinders and breathe in slow controlled breaths.

**Team Member in Distress**

There may be times when a team member experiences breathlessness, exhaustion, anxiety or collapse. This may be a result of overexertion, hyperventilation, or exposure to high heat and humidity.

Mine rescue teams may avoid having a team member in distress by working at a slow even pace, and breathing slowly and deeply while wearing a BG4.

There may be occasions when the inspired air temperature in a BG4 becomes hot. This can be avoided if mine rescue teams take rest breaks that are long enough for body cooling and recovery to occur. Cooling stations such as fresh airways, air conditioned refuge stations, or mobile equipment can also be used during rest breaks.

Excessive use of the emergency bypass valve should be discouraged. **The emergency bypass valve should not be used to cool the inspired air or provide additional oxygen.**
Team members should be informed of the factors that contribute to heat stress, the dangers posed by heat stress, and precautions a mine rescue team can use to prevent heat stress. This information can be found in Appendix A of this Handbook.

If a team member experiences distress, the team should return to surface immediately.

**Procedure for Team Member in Distress:**

1. Remove BG4 cover of the team member in distress to monitor breathing bag
2. Check cylinder pressure and function of apparatus
3. Check facemask seal using hands
4. Push the bypass valve to fill the breathing bag with oxygen. Ensure the breathing bag is not overfilled.
5. Have the team member in distress breathe slowly and deeply
6. Observe the breathing bag
7. Repeat Steps 4 to 6 until the team member recovers

**When team member is unconscious:**

8. Place team member in the stretcher in the recovery position
9. Loosen harness

**BG4 as a Rescue Unit**

The BG4 could be used on conscious casualties when there is not enough SSR 90 Ms to rescue everyone requiring evacuation or if the service time of an SSR 90 M is not sufficient to
transport people to fresh air. It is not practical to use a BG4 in all rescues because of its size and weight. Untrained people should not perform work while wearing the BG4.

The BG4 shall not be used on unconscious casualties as it cannot be used without twisting or turning the breathing hoses or facemask to prevent kinking.

**Procedure** – If the BG4 is used as a rescue unit, perform the following procedure:

1. Place facemask and hoses over BG4 cover
2. Assist patient with donning and adjusting harness for fit
3. Place facemask and hoses over patients head
4. Have patient take a deep breath
5. Ensure head straps are folded over the lens and position mask on the face
6. Slide head straps over the patients head and adjust
7. Check for a facemask seal by squeezing breathing hoses
8. Turn $O_2$ cylinder on fully back 1/4 turn
9. Check cylinder pressure
10. Report to Captain
11. Reassure patient to breathe normally
12. Captain to check facemask seal and record bottle pressure

**Gradual Loss of Oxygen**

A team member may experience a gradual loss of oxygen during a mine rescue response. A gradual loss of oxygen is usually caused by a small leak, poor facemask seal, excessive use of the bypass valve or high oxygen flow. When the loss
of oxygen is caused by a small leak or poor facemask seal the minimum valve will be heard with each breathe, regardless of the work being performed. The captain may also note a team member’s oxygen supply is being consumed at a higher rate than other team members when 20-minute team checks are compared.

When the captain notes a gradual oxygen loss the team member affected should recheck his facemask seal. The team member’s apparatus should be inspected for obvious problems. If the cause of the leak is not found the team should return to fresh air.

If the team member runs out of oxygen before reaching fresh air the team should consider applying an SSR 90 M or using an O₂ cylinder from a CAREvent.

The team member with the leaking apparatus should not perform any work, such as carrying a stretcher.
CHAPTER 10
UNDERGROUND FIRES

THE NATURE OF FIRE

Fire is the chemical reaction that occurs when a material unites with oxygen so rapidly that it produces heat and light energy in the form of flame.

The nature of fire, from its ignition through the complete burning process, is entirely predictable. This well-defined pattern is a chemical reaction called combustion.

Whenever oxygen, in any form, combines with fuel a chemical reaction known as oxidation occurs. In combustion, material is oxidized rapidly, causing a release of energy in the form of heat and light, or fire.

This chemical reaction is characterized by a four-sided geometric figure called a tetrahedron which consists of four elements.

**Oxygen** – Normal air has about 21 per cent oxygen. Fire needs an atmosphere of at least 16 per cent oxygen.

**Fuel** – Fuel can be any combustible material: solid, liquid, or gas. Most solids and liquids become a vapour or gas before they will burn.

**Heat** – Heat is the energy necessary to increase the temperature of the fuel to a point where sufficient vapours are given off for ignition to occur.
Chemical Chain Reaction – Oxidation, a chemical chain reaction, can occur when the other three elements (oxygen, fuel and heat) are present in the proper conditions and proportions. Fire occurs when rapid oxidation, or combustion, takes place.

These four elements are referred to as the fire tetrahedron. Fire can be prevented or extinguished by removing any one element of the tetrahedron.
CAUSES OF MINE FIRES

Most fires occurring underground can be classified according to their cause:

1. **Diesel-powered equipment** – mobile, locomotive or portable equipment
2. **Electrical** – battery locomotives, power cables, trolley wires, motors, electric heaters, and even electric light bulbs
3. **Burning and welding** – use of compressed gases, electrical welding
4. **Friction** – conveyor belts, drive units, brakes and clutches, gear boxes
5. **Spontaneous combustion** – sulphide ores, tailings backfill, accumulation of combustible materials
6. **Smoking or open flame** – Either deliberate or accidental

The causes of fires are listed in order of their occurrence in recent years. Almost 70 per cent of all fires involve diesel equipment. Also high on the list are fires caused by electrical equipment and burning and welding, which account for another 20 per cent.

CLASSES OF FIRE

Since not all fires are the same, fires are classified based on the fuel that feeds them so that an appropriate method of safely and efficiently suppressing or extinguishing them can be used.

The four classes are:

- **Class A** fires involve ordinary combustible materials (such as wood, cloth, paper, rubber and many plastics) and require
the heat-absorbing (i.e., cooling) effects of water or water solutions, or the coating effects of certain dry chemicals that retard combustion.

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 circumstances of the fire.

Class C fires involve live electrical equipment where safety to the extinguisher operator requires the use of electrically non-conductive extinguishing agents. Dry chemical, carbon dioxide, and de-ionized water mist extinguishers are suitable. Because foam, water and water-type extinguishing agents conduct electricity, their use can kill or injure the person operating the extinguisher, and cause severe damage to electrical equipment. (Note: when electric power is disconnected, Class A or B extinguishers may be used.)

Class D fires involve certain combustible metals (such as magnesium, titanium, zirconium, sodium and potassium) and require a heat-absorbing extinguishing medium that will not react with the burning metals. Specialized techniques, extinguishing agents, and extinguishing equipment have been developed to control and extinguish fires of this type. Normal extinguishers should not be used on metal fires as there is danger of increasing the intensity of the fire because of a chemical reaction between some extinguishing agents and the burning metal.
Portable Fire Extinguishers

It is well known that most large fires could usually have been extinguished easily if they had been discovered in the early stages and if suitable equipment, such as portable fire extinguishers, had been readily available. This applies to both surface and underground fires.

Fire extinguishers are typed or rated based on the class of fire on which they are effective, and are further rated on their size and/or duration. Some extinguishers are of value primarily on one class of fire only. Some are suitable on two or three classes. None is suitable for all four classes of fire.

**Water extinguishers (Type A)** use the simplest firefighting medium available. The water may be pumped or stored under pressure in suitable containers. Water-type extinguishers are effective and safe on Class A fires only. They must not be used on Class C fires.

**Carbon dioxide extinguishers (Type BC)** are safe to use on Class A, B and C fires, but are only moderately effective on Class A. They are available in different sizes and in larger mobile models. The extinguishing agent is carbon dioxide, liquid while in the extinguisher, but discharged in a gaseous form. It extinguishes fire by excluding or diluting oxygen. They are preferred on Class C fires because they do not leave a chemical residue.

**Dry chemical extinguishers (Type BC)** are safe to use on Class A, B, and C fires, but are highly recommended for Class B and C fires. The extinguishing agent is sodium bicarbonate or potassium bicarbonate in dry powdery
# Know Your Fire

## Extinguishers

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
</table>

## Pressure Types

<table>
<thead>
<tr>
<th>Pressure Type</th>
<th>Water Type</th>
<th>Carbon Dioxide</th>
<th>Dry Chemical</th>
<th>Multi-Purpose</th>
<th>Multi-Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored Pressure</td>
<td>Yes</td>
<td>Yes</td>
<td>No (but will control small surface fires)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Water Pump Tank</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-Purpose</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

## Usual Operation

<table>
<thead>
<tr>
<th>Operation</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright Squeeze Handle or Turn Valve</td>
<td>Upright and Pump Handle</td>
<td>Upright and Pump Handle</td>
<td>Rupture Cartridge Squeeze Nozzle to Release</td>
<td>Rupture Cartridge Squeeze Nozzle to Release</td>
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</table>

## Range (Feet)

<table>
<thead>
<tr>
<th>Range</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-40</td>
<td>30-40</td>
<td>3-8</td>
<td>5-20</td>
<td>5-20</td>
</tr>
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</table>

## Discharge Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Seconds</td>
<td>13 Seconds</td>
<td>20 Seconds</td>
<td>35 Seconds</td>
<td></td>
</tr>
</tbody>
</table>

## Notes

- This specialized classification includes fires in combustible metals such as magnesium, aluminum, sodium, potassium and other. A special extinguishing powder usually with a sodium chloride base.
form, to which has been added an ingredient to repel moisture and maintain a free flow. The powder is expelled under pressure, produced either by compressed air stored in the extinguisher or by carbon dioxide stored in a small cartridge attached to or confined within the extinguisher. The action of dry chemical in putting out a fire is believed to be due to the fact that the fine particles of powder hit the unburned gases rising above the fire and prevent them from igniting. This is called a chain-breaking reaction or flame interrupting.

**Multi-purpose dry chemical extinguishers (Type ABC)** are safe and effective on Class A, B, and C fires. The extinguishing agent is mono ammonium phosphate. This agent, when heated, decomposes to form a molten residue that will adhere to heated solid surfaces (Class A fires), thus excluding oxygen from the fire.

**Wheeled Fire Extinguishers**

Dry chemical wheeled extinguishers are available in sizes ranging from 75 lbs to 350 lbs (34 to 159 kg).

They can be used on Class A, B or C fires depending on the extinguishing agent used.
Wheeled fire extinguishers offer a combination of mobility and one-person operation. They can be used in places where large fires may occur and water is not readily available.

**Ratings and Classifications**

Underwriters Laboratories of Canada devised a rating system to indicate the effectiveness of portable fire extinguishers.

This system is based on extinguishing pre-planned fires of determined sizes. The user needs only to consult the rating on the label to determine the fire-suppression ability of the extinguisher.

For example a 10 lb multi-purpose dry chemical extinguisher has a U.L.C. rating of 4A, 40B, C. This extinguisher’s rating is based on use by a non-expert.

The 4A refers to the equivalent firefighting capability of four Imp. gallons of water (4.8 U.S. gal, 18 litres). The 40B refers to a Class B fire 40 square feet (3.6 m²) in area, and the C rating indicates that it is also safe to use on a Class C fire.

**WATER FOG**

**Water fog** is a firefighting device for Class A and B fires. Water fog is composed of fine particles of water expelled through a special high-pressure nozzle. As the very fine spray hits the fire, it cools and quenches the heat. The water turns to steam, cutting off the oxygen and extinguishing the fire.

Water fog may be useful as a heat barrier for rescue teams advancing towards the fire. It also causes much less water damage than solid stream nozzles.
Fire Hose Drill

The fire hose drill is designed for the worst case scenario. It will assist the teams to ensure that there is no damage to the hose and that it is rolled out without kinks.

1. It is vital that electrical power is off before using water.
2. The stretcher must be placed in a location to ensure it does not get wet.
3. The captain will have a team member flush the pipeline to ensure clean water, and hook up the hose to the water header while another team member holds hose.
4. The captain will lead the team in the opposite direction of the fire, while a team member unrolls the hose. Once the hose is half unwound, the captain will turn the team and proceed back to the water header.
5. A team member will flush the hose to ensure there are no leaks. The line will be charged once the nozzle has been connected. The team then advances with the nozzle on the appropriate setting.
6. The nozzle is to be left on the wide pattern setting after the fire has been extinguished to ensure the fire does not reignite.

FOAM

Foaming agents are effective in controlling and extinguishing Class A and B fires.

The foaming agents, consisting of biodegradable fluorocarbon and hydrocarbon surfactants, are diluted with water, and discharged in a mass of bubbles containing air or a
non-combustible gas. The water content cools the fire as the foam holds steam, smoke and oxygen-deficient atmosphere around the fire, sealing it and preventing fresh air from reaching it.

Foam's effectiveness depends on the rate of application, the expansion ratio and the stability of the foam. Low-, medium- and high-expansion foams are produced through the use of a foam generator system or a fire hose with a pickup eductor and foam concentrate.

**Aqueous Film-forming Foams (AFFF)**

Low-expansion foam, or Aqueous Film-forming Foams, usually have an expansion of 10:1, and are recommended when there is close access to the fire without undue risk to team members. It is best used on two-dimension fires, such as fuel spills, and has limited effectiveness on three-dimensional Class A fires.

AFFF can be used in both aspirating and non-aspirating mechanical foam hardware.

Aspirating nozzles are specifically designed to entrain air in certain
proportions into the diluted foam-water solution to produce a fully aspirated foam extinguishing agent.

Non-aspirating type foam hardware is designed primarily for the application of water in the appropriate stream setting.

The system used by Ontario Mine Rescue consists of the Elkhart model 241 eductor and the Akron Turbojet nozzle, model 1715 and the model 766 foam tube.

The eductor uses the venturi principle to introduce a proportional amount of liquid concentrate into a water stream. When water at high pressure, 200 psi (13.8 bar) exits the venturi (the constricted portion of the waterway near the eductor inlet), it creates negative pressure to siphon concentrate through a metering device, like a straw, and into the waterway.

The flow of concentrate through the metering device will remain constant. The flow of water, however, will vary with inlet pressure. The higher the inlet pressure the lower the solution of concentrate. The lower the inlet pressure, the higher the solution of concentrate.
Current 361 litres (95 U.S. gal, 80 Imp. gal) per minute eductors have detachable metering valves with five notched settings marked 0, 1/2, 1, 3 and 6 per cent. The “0” position is a positive shutoff for the concentrate supply. The other four positions are calibrated for the precise metering in per cent of most types of concentrate.

To change meter setting, push meter knob in and turn to align slot in knob with desired percentage number, then release the knob.

It is important to flush the system with clear water after use to ensure that dried concentrate does not clog the metering device and cause the ball check valve to stick closed. This valve is in the metering device immediately inside the nipple which connects the pick-up tube assembly to the metering valve.

By removing the clear plastic hose from the nipples, the ball can be visually inspected in the nipple opening. If it is stuck, it can be dislodged with a pencil or blunt tool.

The Akron turbojet nozzle is an adjustable nozzle from 115 to 475 litres (30 to 124 U.S. gal, 25 to 105 Imp. gal) per minute with the maximum operating pressure of 200 psi (13.8 bar).

As with any water-based firefighting, this nozzle must never be used in fighting electrical fires. It is important to open and close the valve slowly. Rapid opening will produce a sudden thrust. Rapid opening or closing can cause water hammer.

When using the nozzle do not use the shutoff valve to throttle back water pressure with an eductor in line as doing so can cause the eductor to shut down.
Procedure for AFFF

The use of low expansion foam is recommended when there is close access to the fire area without undue risk to the team members.

1. The team should perform a field test on all parts before proceeding underground (eductor, nozzle, foam tube, concentrate, and sufficient hose).
2. The electricity must be turned off.
3. The system must be assembled according to manufacturer’s instructions.
4. The foam should be sprayed indirectly towards the fire to ensure a high quality blanket of foam covers the entire material that is burning.
5. Shut off the nozzle to allow foam to act as a blanket to exclude oxygen and cool the material.
6. The area must be checked for hot spots and more foam reapplied if necessary.

Compressed Air Foam Systems

When the supply of water is limited or non-existent, or where the use of large quantities of water is not advisable, compressed air foam systems, such as the Rapid Response Unit (RRU) Foam Tote Series used by Ontario Mine Rescue and a growing number of Ontario mines, use compressed air or nitrogen to deploy a foam solution.

Compressed air foam systems consist of a water tank (up to 100 Imp. gal, 120 U.S. gal or 455-litre capacity), a compressed air/gas cylinder, a foam reservoir (up to four Imp. gal, 4.8 U.S. gal, or 180-litre capacity).
gal, or 18-litre capacity), a water-powered proportioner, and a dispensing hose. The system may be operated on a vehicle, trailer or skid.

When air/gas is released from the cylinder, the air/gas enters the water tank and simultaneously enters the foam solution. The pressurized water tank forces water through the water-powered proportioner, which pulls in foam concentrate from the reservoir and mixes it with water. The solution exits the proportioner and air/gas is injected to create foam.

To operate the system:
1. Release and remove the hose from the tray, pulling it clear of kinks, and hold the nozzle valve off.
2. Open the cylinder safety cap.
3. Open the cylinder valve to pressurize the water tank.
4. Close the cylinder safety cap.
5. Open the master valve to activate the system and charge the hose.

6. Open the nozzle valve as fully as possible to project foam.

Foam will be expelled immediately when the nozzle valve is opened. The factory settings of about 20:1 foam-water ratio projects foam about 12 to 15 metres (40 to 50 feet).

When deploying foam, move quickly. To attack a fire, shoot foam at its base and work up. To fight a fire or protect a fuel spill from fire, broadcast foam indirectly to no more than two inches in depth. Be prepared to monitor the extinguished fire for foam touch up or re-application.

If the system is not to be used for three or more minutes, it should be shut off at the master valve to prevent pressure buildup. (There are pressure relief valves to prevent excessive pressure.)

**High Expansion Foaming Agents**

High-expansion foaming agents, with expansion ratios ranging from 100:1 to 1,000:1, are suited for flooding three-dimensional Class A and B fires, particularly where close access to the fire is not possible. A mass of in-depth foam can provide an insulation barrier for exposed materials not on fire, preventing the spread of the fire.

The foam is a mass of bubbles generated mechanically by the passage of air or other gases through a net, screen, or other porous medium that is wetted by an aqueous solution of surface-active foaming agents.
High-expansion foam is a unique vehicle for transporting wet foam to inaccessible places, for total flooding of confined spaces, and for displacing vapour, heat and smoke.

Tests have shown that under certain circumstances high-expansion foam, when used in conjunction with water from automatic sprinklers, will provide more control and extinguishment than either extinguishing agent by itself.

Optimum efficiency in any one type of fire depends on the rate of application and the expansion and stability of the foam.

High-expansion foam has several effects on fires:

1. When generated in sufficient volume, it can prevent air, necessary for continued combustion, from reaching the fire.

2. When forced into the heat of a fire, the water in the foam is converted to steam, reducing the oxygen concentration by diluting the air.

3. The conversion of the water to steam absorbs heat from the burning fuel. Any hot object exposed to the foam will continue the process of breaking down the foam, converting the water to steam and thus being cooled.

4. Because of its relatively low surface tension, the solution from the foam that is not converted to steam will tend to penetrate Class A materials. However, deep-seated fires may require further control.

5. When accumulated in depth, high-expansion foam can provide an insulating barrier for protecting exposed materials or structures not on fire, thereby preventing the spread of the fire.
When foam is generated from the gases of combustion it becomes toxic and no one should attempt to enter a space filled with foam without self-contained breathing apparatus. The foam mass also obscures vision and link lines must be used if entering it.

Most Ontario mine rescue stations are equipped with diesel-powered, high-expansion foam generators capable of producing 170 m$^3$ (6,000 cu. ft.) per minute of high-expansion foam with a ratio of 1,000 parts of air to one of water.

The water supply required at the foam generator inlet is 456 litres (120 U.S. gal, 100 Imp. gal) per minute at 50 psi (3.4 bar) minimum.

The unit uses 190 to 266 litres (50 to 70 U.S. gal, 42 to 58 Imp. gal) of water and 2.6 litres (0.7 U.S. gal, 0.6 Imp. gal) of foam concentrate a minute.

The foam generator consists of a fan, a one-cylinder diesel engine, a plenum chamber, a bank of spray nozzles, and a knitted terylene net on which the foam is formed. Water is fed into the unit through a 1.5 inch hose, and an ‘in-line’ proportioner, which should be set at one per cent and draws foam concentrate through a metering orifice into the water stream.

A mixture of foam concentrate and water is sprayed through the nozzles onto the terylene net creating a constant spray pattern for equal wetting of the net. The foam, created by air passing through the netting, is delivered through tubing.

**Operation of Diesel-Powered Foam Generator**

The water hose is connected to a hydrant or pipe valve in a line capable of supplying 456 litres (120 U.S. gal, 100 Imp. gal)
of water per minute at a minimum pressure of 50 psi (3.4 bar). The water should be reasonably free of dirt or scale that might clog the inlet strainer.

The reading on the water pressure gauge should remain constant, even though the supply pressure varies. If the pressure reading falls below the mark on the gauge dial, the pressure is too low or the inlet strainer is plugged with dirt.

The stainless steel pickup tube is fitted with a fine screen to keep foreign material out of the metering orifice.

The proportioner and pickup tube should be flushed with clear water after use. Check the screen on the pickup tube for cleanliness, run water through the nozzles to be sure they are not clogged, and check the screen at the hose inlet. Foam detergent will corrode metal.

It is important that members of mine rescue teams become proficient in the use of the high-expansion foam machine.

A trained operator can vary the quality and quantity of foam being generated.

**Procedures for Using the Foam Generator**

The following procedures will assist the team when using the foam generator.

1. As with other equipment used in Mine Rescue, the foam generator must be field tested before taken underground.
2. A second foam generator should be made available as a backup.
3. The electrical power must be off where foam is applied as it largely consists of water.
4. A team should take extra fuel, oil, foam concentrate, and disposable tubing with the foam generator to ensure the assignment can be completed without interruption.

5. The opening in a barricade must be at least 36 inches (90 cm) to accommodate the barrel of the generator.

6. The foam generator should be set on a platform to elevate the unit.

7. It is highly recommended to get the ventilation to move the foam. A good supply of air will ensure that the foam machine will operate efficiently. An air hose may be used to direct air from the pipes to the air breather of the generator when the atmosphere is deficient in oxygen.

8. When investigating the status of a fire, a team must always have a charged water hose and nozzle. The team must ‘knock’ the foam down by using water spray. The area must always be checked for loose ground created by the fire.

9. The foam machine may be used as a fan when there are instances when the ventilation is not sufficient to clear area of smoke.
10. The stretcher can be left at a strategic location to be picked up later, if the team is required to transport the foam generator.

**Water-Powered Foam Generators**

Ontario Mine Rescue has water-powered units available that range in size from 21 to 565 m³/min. (750 to 20,000 cu. ft/min.). Most water-powered foam generators will produce low-, medium-, or high-expansion foam. The high-expansion foam agent, used with diesel-powered foam generators, is compatible with water-powered foam generators.

Water-powered units can be hand-held for advancing on a fire or set up to push foam beyond a barricade. The water-powered foam generators can be used where portability or a quick response is required.

**Fire Attack with High-Expansion Foam**

The tremendous volume of foam being discharged into an area seals it and prevents fresh air from reaching the base of the fire. Once the fire has been reached, the foam continues to exclude fresh air and holds the steam and oxygen-deficient atmosphere around the fire.

When the water film of the bubble wall approaches a fire, radiant heat vaporizes the water in the foam front.

The one-part water in 1,000 parts air expands 1,700 times in forming steam.

The resulting mixture of steam and air has an oxygen content of around 7.5 per cent, well below the level required to support combustion.
Large volumes of the steam formed in this way displace additional hot gases and tend to create inert areas above the fire and limit its speed.

Bubbles cannot exist in contact with a dry surface. As a result, high-expansion foam wets everything it touches and limits the spread of the fire. The surface tension of the water in the foam is quite low and penetration is thus deeper than with the same amount of plain water.

Since a fire is cooled and extinguished best by a high steam atmosphere, the generator should be operated to produce foam at as high a rate as possible.

After the burning material has been covered, the foam covering should be maintained to cool the hot material.
Travelling Through High-Expansion Foam

During training people wearing self-contained oxygen or air breathing apparatus may travel safely through the foam, even if they are submerged in it. Care should be taken that all team members are fastened closely together, and that they travel only where it is known there are no hazards.

In a fire situation, foam will be diluted with water and knocked down to ensure that a team is not exposed to the fire.

TIRE FIRES

Underground mobile equipment or vehicles can catch fire under a range of circumstances. In some cases there is potential for the tires to become heated or catch fire. Whenever excess heat is applied to a tire, it can initiate a process within the tire called pyrolysis. This can cause a buildup of flammable gases and pressure within the tire, which may rupture or explode.

During a mine fire involving heated tires, mine rescuers should approach the site with extra caution to assess the situation before commencing operations. In assessing a mobile equipment fire, mine rescuers should:

- Use a thermal imaging camera. If external tire temperatures are higher than 95°C evacuate the area and isolate the equipment
- Determine the location of the fire on the equipment and whether the tires are involved
- Evaluate the intensity of the fire
- Determine what the equipment/vehicle was transporting
• Determine other potential hazards, such as nearby electrical power, fuel, oil, grease or explosives
• Evaluate contamination levels, temperature and ventilation flows

To determine if a tire has exploded, as opposed to just having ruptured, mine rescuers should look for:
• A charred patch on the liner
• Soft tacky patches on the liner, or tacky fragments in the tire
• Rupture in the casing opposite the point of heating
• An identifiable heat source in most cases
• An eyewitness report of a fireball

**Extinguishing Tire Fires**

Rubber-burning fires are difficult to extinguish. The initial attack should be with foam for an extended period. Water should be used as a last resort as it poses the potential of spreading molten rubber.

Hand-held extinguishers are ineffective and expose personnel to extreme risk from the fire, potential explosion and smoke. Without breathing apparatus there is also the risk of harm from the respiration of toxic fumes given off by the burning tires.

If attempts are made to bury the tire while still mounted, it should be done using a haul truck to back up and tip a load. This still leaves the operator at risk of flying debris if a tire explodes. Care should be taken to use only fine particulate fill material to prevent large fill material from being projected if the tire explodes.
The vehicle should be isolated for 24 hours after removing the source of heat from the tire.

**PERSONAL PROTECTIVE EQUIPMENT**

Whenever a mine rescue team is sent on an assignment that may involve firefighting, their personal protective equipment must include coveralls that meet the National Fire Protection Association standard – NFPA 2113.
APPENDIX A

HAZARD AWARENESS

Mines and mining plants pose a unique environment to those men and women who provide emergency services in Ontario. Mine rescuers need to be constantly alert to their surroundings and aware of all potential hazards while responding to an emergency. Several of these hazards have been the focus of growing attention among mine rescue organizations around the world. This information is presented in the interests of increasing that awareness but does not prescribe practices either for individuals or operations.
HEAT STRESS

The nature of mine rescue work and deeper, hotter mines place mine rescuers at a greater risk of heat stress than any other job within the mining industry.

Recognizing the factors that contribute to heat stress, understanding how the body responds to heat, knowing the dangers posed by heat stress, and taking preventive measures, should not only safeguard the individual, but also the team, and allow the best opportunity for a successful mission.

Factors in Heat Stress

Heat stress is the heat burden on the body from the combination of environmental sources, the body’s metabolism as determined by workload, and clothing requirements, as well as exposure time.

Environmental Factors – Air temperature, relative humidity, air movement, and heat sources such as auto-compression and powered-equipment, play a role in creating heat stress.

Mine Rescue Factors – During mine emergencies mine rescuers can face extreme heat loads not only due to environmental factors that will be less than ideal, but also to their work conditions and requirements.

In an emergency situation, existing engineering controls may have limited effectiveness or no longer work. Environmental factors may be subject to new influences, such as fire, that pose increased variables and dangers.

Mine rescuers may travel long distances on foot over uneven terrain at extreme depths, wearing a cumbersome breathing
apparatus and other personal protective equipment. They usually carry heavy loads, and do physically and often psychologically demanding work.

Mine rescuers may already have put in partial or full work shifts when called to action, contributing to fatigue and dehydration. During rescue operations, they have little ability to drink fluids to rehydrate their bodies and rest conditions are often less than ideal.

**Exposure Time** – The longer a person is exposed to heat, the higher level of heat stress he or she will experience. Researchers have developed often complex formulas to measure heat stress and establish safe work level/time exposure guidelines.

The Ontario Mine Rescue Heat Exposure Standard was developed by the Institute of Occupational Medicine (IOM) for Mine Rescue Services Ltd. in the United Kingdom. IOM has determined the standard is suitable for mine rescuers using the Draeger BG4, the apparatus used by Ontario Mine Rescue.

**Physiological Response to Heat**

Normal core body temperature of 37°C (98.6°F) must remain relatively constant for the body to work well. Variations in this temperature indicate that the body is under stress. As body temperature rises, the body automatically takes a combination of steps to cool or lose heat to maintain a relatively constant temperature.

**Vasodilation** – The circulatory system—blood vessels, heart—acts as a human radiator. Blood vessels and capillaries near and in the skin increase in size and the heart beats faster to increase blood flow. This encourages heat dissipation and
body cooling. As blood warmed by the metabolic rate nears the skin surface, it transfers heat to the skin. If the air is moving and skin exposed or lightly covered, body heat passes more easily to the environment than if the air is still and skin more fully covered. When air temperature exceeds body temperature, vasodilation ceases to cool the body.

**Sweat** – As blood circulation to the skin fails to adequately cool the body, the body produces sweat for evaporative cooling, the body’s most effective cooling mechanism. The rate of cooling depends on the rate of evaporation based on temperature, humidity, and skin exposure. When relative humidity exceeds 70 per cent, the air has a limited ability to absorb moisture and cooling is minimal. The body, however, will continue to sweat until it is dehydrated. Dehydration reduces the blood volume in the body, resulting in lower blood pressure and increased strain on the heart.

**Decreased heat production** – Meanwhile inside the body, the increased blood flow to the skin, as much as 25 per cent of the cardiac output, and a rising body temperature causes blood flow to internal organs to decrease and produce less heat. The diminished blood flow, however, places the internal organs and the brain at risk.

**Heat Stress Disorders**

When the heat burden overcomes a body’s ability to cool itself, heat stress disorders result. These disorders can be considered a progressive spectrum of health issues from mild to severe, with potentially fatal results as the body attempts to control a rising core temperature.
• **Heat Rash** – Red, bumpy rash with severe itching. Though uncomfortable, heat rash does not pose a danger to life and health.

• **Heat Cramps** – Painful cramps in arms, legs, or stomach that occur suddenly. Though painful, heat cramps do not pose a danger to life and health.

• **Heat Syncope (fainting)** – Suddenly passing out while doing or after doing physical work in a heated environment. Cool, moist skin; weak pulse.

• **Heat Exhaustion** – Heavy sweating; cool moist skin, body temperature over 38°C (100°F) weak pulse; normal or low blood pressure; fatigue; person is weak, clumsy, upset or confused; is very thirsty; panting or breathing rapidly; vision may be blurred.

• **Heat Stroke** – High body temperature over 41°C (106°F) and any of the following: the person is weak, or acting strangely; has hot, dry, red skin; a fast pulse; headache or dizziness. In late stages, a person may pass out, have convulsions and die.

Standard treatment for heat disorders includes moving the patient to a cooler environment, cooling the body, drinking water, and in severe cases seeking medical aid and monitoring vital signs.

**Prevention**

Early prevention of heat stress incidents begins well before any exposure to the hazards and focuses on individual preparation for working in hot, humid environments.
Nutrition – A regular, balanced diet can help prevent the depletion of salts that could lead to early heat stress. If the majority of meals are dry or dehydrated, the risk of dehydration is greater. A diet of junk food, high fat and caloric foods can also increase the risk of dehydration.

Fitness – Fitter individuals tolerate work and heat better. Their bodies have higher water content, use energy more efficiently, and are better able to stay hydrated. Heavier, less fit individuals reach their maximum level of activity more quickly than their lighter, fitter counterparts, and experience an increased susceptibility to heat stress disorders.

Health – Health problems, large and small, can compromise the body’s ability to cool itself. Even temporary acute problems—mild fever, runny nose, hangover, constipation—can compound and be compounded by heat stress. Healthy individuals tolerate work and heat better.

Rest – Adequate rest prior to heat exposure, during exposure, and between work periods allows the body to cool and recover.

Acclimatization – The more an individual works in the heat, the better his or her body becomes at keeping cool. A body requires one to two weeks of acclimatization to adjust to work in a hot environment.

Precautions – Precautions are measures that should be taken by teams and personnel prior to, during and after a mine rescue emergency.

Before exposure:
• Be rested
• Be properly hydrated
Appendix A – HAZARD AWARENESS

- Avoid drinking coffee
- Not have consumed a significant quantity of alcohol in the past 24 hours
- Be in good health (i.e. not have a cough, cold, or any other infection or sign of infection)
- Be reminded of the signs and symptoms of heat stress

During the assignment:
- Work at a slow, even pace with a minimum of movement
- Take frequent rests, long enough for cooling to occur
- Watch each other for signs of heat stress
- Immediately notify the captain at the first sign of heat stress, in one’s self or someone else

After exposure:
- Cool down slowly by resting
- Wait to shower until sweating ceases
- Drink fluids, water is best
- Rest, avoid heavy work or driving long distances
- Not be called back to duty for 24 hours
GROUND CONTROL

Falls of ground and rockbursts are a significant hazard underground, and one of the most serious dangers faced by mine rescue teams.

Both natural and man-made factors cause ground support problems. Over thousands of years, natural cracks called “joints” have formed in rocks. Putting an opening into a rock mass changes the stresses on the rock. Time and gravity start to work. Blocks of rock separate along their joints and “relax” toward the opening.

Geological formations like dykes, faults and shear zones may increase the risk of rock movement. Mining activities can also lead to blast or stress induced fracturing. Other factors such as rock type, depth of the mine, proximity to other openings, movement of water and changes to water flow, can affect the risk of ground problems.

Warning Signs

When responding to a ground control emergency, or an incident in which ground control may be a concern, mine rescue teams should watch for:

• Deformed headings
• Intersecting structures which may mean wedges or blocks
• Sagging of back in sedimentary rock
• Bagging or gaps in screens
• Corroded screen or bolts
• Change in the shape of drill holes or offsetting of drill holes
• Deterioration or change in shape of pillars (such as an hourglass shape)
• Opening of existing cracks or fresh cracks in rock
• Cracks in shotcrete
• Change in water flow or moisture
• Excessive amount of loose rock
• Plate-like pieces or flakes of rock
• Fresh dust on the floor
• Bending of rock bolt plates
• Rings come off or closed slot on friction stabilizers
• Bolt heads popped off
• High torque readings on mechanical bolts
• Splayed (unraveled) ends on cable bolts
• High loads on Smart Cables

And listen for:
• Drummy sound when a mechanical bolt is taking weight
• Ringing sound when a bolt is taking weight
• More, or less, rock noise (snapping and cracking)
• Drummy or hollow sound when rock pieces are tapped

Any of these clues may indicate ground control problems.

**Considerations for Safety:**

• Follow the advice and instructions of the briefing officer and the control group
• Constantly check ground conditions as you proceed
• Check ground conditions in the working area before entering
• Install ground support as instructed
• Stay alert to changing conditions
• Report any changes in rock condition to the briefing officer
• Trust your instincts, if you think an area is too risky, leave
• Remember the safety of the rescue team is paramount
CRITICAL INCIDENT STRESS

Critical incidents, such as those that require a mine rescue response, can cause strong emotional reactions that overwhelm an individual’s ability to function in a normal manner at work, at home or in any other aspect of their life.

This strong emotional reaction is referred to as critical incident stress.

Factors Contributing to Stress

Anyone exposed to the incident, directly or indirectly – mine rescue team or control group member – can experience critical incident stress, though it can be more pronounced in those directly involved, particularly if the incident involved severe injury or death. Other factors that influence a person’s emotional reaction include:

- Magnitude of the incident
- Duration of exposure
- Degree of personal danger
- Individual personality and emotional stability
- Past experience
- Recent and/or current stress
- Personal acquaintance with the victim(s)
- Support of family, friends, co-workers and employer
- Training/knowledge of critical incident stress

During the incident, personnel suppress their emotions to concentrate on getting the job done. When the incident ends, and a more normal routine resumes, these repressed feelings...
begin to surface. Stress-related anxiety is normal, but if the emotions are not dealt with in a healthy, effective fashion, they can result in emotional turmoil and even harmful behaviour.

**Critical Stress Symptoms**

Symptoms may appear immediately after the incident, several days after the incident, several weeks or months, or in some instances even years, after the incident.

Symptoms can be far ranging and may include:

- **Physical** – fatigue, headaches, weakness, dizziness, muscle tremors
- **Cognitive** – confusion, nightmares, poor attention, memory problems
- **Emotional** – anxiety, guilt, anger, grief, irritability, feeling overwhelmed
- **Behavioural** – withdrawn, emotional outbursts, antisocial, change in appetite

**Managing Stress**

Most professional emergency response services now have critical incident stress management teams to help first responders deal with stress. Mine operators may have access to this type of assistance through employee assistance plans or other programs to help mine rescue team and control group personnel respond to critical incident stress.

Mine management can help individuals effectively manage critical incident stress with policies and procedures that centre on a humane, sensitive response. Management could consider designating a critical incident stress management co-ordinator
to take proactive and reactive measures to help personnel deal with stress.

Proactive measures focus on education, including:

- Making personnel aware of the hazard of critical incident stress
- Making personnel aware of the symptoms of critical incident stress
- Making personnel aware of steps they can take to cope with critical incident stress
- Making personnel aware of support services available
- Making support services available

Post-incident measures that can help mine rescuers deal with stress include:

- A full regular debriefing
- An optional defusing briefing led by a professional or trained peer
- Optional one-on-one sessions with a professional or trained peer
- Providing time to heal

Considerations for after a critical incident:

- Expect an emotional reaction
- Accept that a reaction is natural
- Maintain a good diet and exercise
- Take time for leisure activities
- Spend time with family, friends and co-workers
- Avoid excessive use of alcohol
• Avoid legal or illegal substances to numb emotional response
• Acknowledge that getting help is not a weakness
• Accept help if it is offered or recommended
TIRE EXPLOSIONS DUE TO PYROLYSIS

Underground mobile equipment can catch fire under a range of circumstances. In some cases there is potential for the tires to become heated or catch fire. Whenever excess heat is developed on applied to a tire, it can initiate a process within the tire called pyrolysis. This can cause a buildup of flammable gases and pressure within the tire, which may rupture or explode.

Common sources of heat that can cause tire pyrolysis are:

• Tires run below the specific pressure or when flat
• Overload/over speed of the tire compared to tire design
• Mechanical damage to the tire
• Contact with high voltage power lines
• Overheated brakes
• Wheel motor fires
• Welding on rims while the tire is inflated
• Oxyacetylene heating of wheel nuts
• Major vehicle fires with tire involvement

Tire explosions, resulting from the ignition of the gaseous vapours created by pyrolysis within the tire, can unleash energy many orders of magnitude greater than that of a tire blowout, often leading to significant equipment damage, serious injuries or fatalities. They pose a significant hazard during a mine emergency.

Pyrolysis-related explosions are unpredictable, and can occur immediately or up to 24 hours after initiation. A violent explosion can occur where no fire is visible and the danger area
can be as far as 300 metres (328 yards) or more from the tire. Pressures at the time of the explosion are in the order of 1,000 pounds per square inch (69 bar) or more, with the production of shock waves.

The pyrolysis or chemical decomposition of the tire, usually the tire’s inner liner, produces flammable gases, such as methane, styrene, butadiene, hydrogen and other hydrocarbons. Some canned materials used to seal punctures or leaks from the inside of the tire may also produce explosive vapours.

A tire explosion due to pyrolysis will occur if there is:
• An explosive concentration of flammable gases
• Sufficient oxygen, 5.5 per cent, to support combustion
• A source of ignition

The rubber liner of some tires will begin to pyrolyse or decompose at about 185°C (365°F). Explosions have occurred when as little as 20 grams (0.7 oz) of rubber has been pyrolysed.

Mines may inflate tires with nitrogen rather than oxygen to reduce the risk of a tire explosion. The use of nitrogen, however, does not prevent pyrolysis and should adequate oxygen be available (possibly through an inadvertent top-up with compressed air or oxygen), an explosion can still occur when a critical concentration of flammable gases is reached. Consequently, all tires known to or suspected of having been subjected to a heat source should be treated as a potential explosion hazard.

No visible flame or spark is necessary to ignite the explosive gases created by pyrolysis. Heat or energy sources can prompt
the gases to reach their auto-ignition temperature. Carbon dust, a product of pyrolysis, has an auto-ignition temperature of 200°C (392°F). During a mine emergency possible sources of heat/energy that will result in tire pyrolysis and may lead to auto-ignition include:

- Equipment contact with high voltage power lines
- Any fire, but particularly tire or equipment fires
APPENDIX B
MEASUREMENTS

The measurements in this handbook are copied from documentation provided by manufacturers. Where manufacturers have provided measurements in only one unit of measurement (e.g. metric or imperial), Ontario Mine Rescue has converted to the other unit (e.g. metric or imperial). Some rounding may have occurred.

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<tr>
<th>Measure</th>
<th>British Imperial</th>
<th>S.I.</th>
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<tr>
<td>Weight</td>
<td>1 lb</td>
<td>0.453 kg</td>
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<tr>
<td>Linear</td>
<td>1 ft</td>
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<tr>
<td>Liquid</td>
<td>1 gal</td>
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<td>Volume</td>
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<td>0.0283 cubic m</td>
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<tr>
<td>Force 1 pound-force</td>
<td>1 pound-force</td>
<td>4.448 newtons</td>
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<tr>
<td>Pressure</td>
<td>1 pound-force/sq. inch</td>
<td>6.895x103 pascals</td>
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Examples from the Handbook

Experiments have shown that a man in a confined space requires approximately one cubic yard of air (0.76 m³) per hour.

A BG4 oxygen bottle is charged to 200 bar = 2,900 psi = 20,000 kilopascals. The capacity of the bottle at this pressure is 400 litres.

A man at rest uses approximately 0.26 litres, 260 cubic centimetres or 16 cubic inches of O₂ a minute.
The BG4 is lightweight (15 kg/33 lbs when fully charged).

Cylinders capable of being charged to 2,000 psi (135 bar) are tested to 3,400 psi (235 bar). Cylinders charged to 3,000 psi (205 bar) are tested at 5,000 psi (345 bar).

Compressed air foam systems consist of a water tank (up to 100 Imp. gal, 120 U.S. gal. or 455-litre capacity), a compressed
air/gas cylinder, a foam reservoir (up to four Imp. gal, 4.8 U.S. gal, or 18 litre capacity), a water-powered proportioner, and a dispensing hose.

Ontario Mine Rescue has water-powered units available that range in size from 21 to 565 m$^3$/minute (750 to 20,000 cu. ft/min).
## Contact Us

**Sudbury Office/Mine Rescue Station**  
760 Notre Dame Ave.,  
Sudbury, ON P3A 2T4  
T: 705. 671. 6360 • F: 705. 670. 5708

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Extension</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ontario Mine Rescue General Manager</strong></td>
<td>Ted Hanley, x 337</td>
<td></td>
<td><a href="mailto:alexgryska@workplacesafetynorth.ca">alexgryska@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Executive Assistant</strong></td>
<td>Penny Pagan, x 321</td>
<td></td>
<td><a href="mailto:pennypagan@workplacesafetynorth.ca">pennypagan@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Mine Rescue Services</strong></td>
<td>Becky Barrett, x 325</td>
<td></td>
<td><a href="mailto:beckybarrett@workplacesafetynorth.ca">beckybarrett@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Mine Rescue Program Supervisor</strong></td>
<td>Charlie Burton, x 329</td>
<td></td>
<td><a href="mailto:charlieburton@workplacesafetynorth.ca">charlieburton@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Chief Mine Rescue Officer</strong></td>
<td>Shawn Rideout, x 329</td>
<td></td>
<td><a href="mailto:charlieburton@workplacesafetynorth.ca">charlieburton@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Emergency Services Specialist</strong></td>
<td>Shawn Kirwan, x 322</td>
<td></td>
<td><a href="mailto:shawnkirwan@workplacesafetynorth.ca">shawnkirwan@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td><strong>Mine Rescue Officers</strong></td>
<td>Walter Adler, x 331,</td>
<td></td>
<td><a href="mailto:walteradler@workplacesafetynorth.ca">walteradler@workplacesafetynorth.ca</a></td>
</tr>
<tr>
<td>Delaware Mine Rescue Station</td>
<td>Kirkland Lake Mine Rescue Station</td>
<td>Algoma Mine Rescue Station</td>
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<tr>
<td>28 Victoria Street</td>
<td>140 Government Road East</td>
<td>Williams Mine</td>
<td></td>
</tr>
<tr>
<td>Delaware, ON N0L 1E0</td>
<td>P.O. Box 38</td>
<td>P.O. Bag 500</td>
<td></td>
</tr>
<tr>
<td>T: 519. 652. 9809</td>
<td>Kirkland Lake, ON P2N 3L8</td>
<td>Marathon, ON P0T 2E0</td>
<td></td>
</tr>
<tr>
<td>F: 519. 652. 9824</td>
<td>T: 705. 567. 4606</td>
<td>T: 807. 238. 1155</td>
<td></td>
</tr>
<tr>
<td>Mine Rescue Officer</td>
<td>F: 705. 567. 3469</td>
<td>F: 807. 238. 1400</td>
<td></td>
</tr>
<tr>
<td>Tim Taylor – <a href="mailto:timtaylor@workplacesafetynorth.ca">timtaylor@workplacesafetynorth.ca</a></td>
<td>Mine Rescue Officer</td>
<td>Denis Leduc – <a href="mailto:denisleduc@workplacesafetynorth.ca">denisleduc@workplacesafetynorth.ca</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wayne Baker – <a href="mailto:waynebaker@workplacesafetynorth.ca">waynebaker@workplacesafetynorth.ca</a></td>
<td></td>
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<tr>
<td>Mine Rescue Station</td>
<td>Address</td>
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<tr>
<td><strong>Red Lake Mine Rescue Station</strong></td>
<td>20 Dickenson Road, P.O. Box 368, Balmertown, ON P0V 1C0</td>
<td>T: 807.735.2331 F: 807.735.2331</td>
<td></td>
</tr>
<tr>
<td><strong>Mine Rescue Officer</strong></td>
<td><strong>Grant Saunders</strong> – <a href="mailto:grantsaunders@workplacesafetynorth.ca">grantsaunders@workplacesafetynorth.ca</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thunder Bay Mine Rescue Station</strong></td>
<td>615 Squier Street, Thunder Bay, ON P7B 4A7</td>
<td>T: 807.344.8211 F: 807.344.8248</td>
<td></td>
</tr>
<tr>
<td><strong>Mine Rescue Officer</strong></td>
<td><strong>Duane Croswell</strong> – <a href="mailto:duanecroswell@workplacesafetynorth.ca">duanecroswell@workplacesafetynorth.ca</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Timmins Mine Rescue Station</strong></td>
<td>48 Shamrock Avenue, P.O. Box 477, South Porcupine, ON P0N 1H0</td>
<td>T: 705.235.4861 F: 705.235.4891</td>
<td></td>
</tr>
<tr>
<td><strong>Mine Rescue Officers</strong></td>
<td><strong>Emanuel (Manny) Cabral</strong> – <a href="mailto:mannycabral@workplacesafetynorth.ca">mannycabral@workplacesafetynorth.ca</a>  <strong>Danny Taillefer</strong> – <a href="mailto:dannytaillefer@workplacesafetynorth.ca">dannytaillefer@workplacesafetynorth.ca</a></td>
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