A report of the sub-committee to the
Technical Advisory Committee on Safety and Loss Control
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Safety and Health Association

Our vision and mission

At MASHA, we believe every worker should come home safe and healthy every day. We are convinced the mining and aggregate industry can move progressively toward this state of zero harm. We believe our vision will be realized within an industry culture that embraces a belief in safe productivity, and in which everyone contributes toward making the workplace safer and healthier.

Because MASHA is morally committed to this vision and uniquely positioned to help industry realize and sustain this state, we will:

- Identify changes needed in cultures and programs, and help companies make these changes,

- Develop industry leaders who will spearhead positive and sustainable changes in health and safety,

- Create a base of unique knowledge and expertise in matters that have the potential to jeopardize the safety or health of workers in mining operations,

- Apply our unique expertise to the development of standards and speak out on matters that are critical to our vision,

- Ensure each workplace has access to the knowledge it needs for safe productivity, and access to the know-how to apply it,

- Create hubs of collaboration that will lead to the sharing of ideas and information.

The roles MASHA fills for our members must be translated into practical action. The ways in which we traditionally serve our customers fall into four categories: consulting, auditing, training, and provision of information. To be effective within the broad scope of our vision and roles, we must focus our energies where we see the greatest need. These areas of focus for MASHA reflect the key issues and hazards faced by our member companies. We will undertake our four services to address our areas of focus:

- Leadership and safety culture
- Ground control and slope stability
- Equipment
- Health issues
- Emergency preparedness and response
- Knowledge networks
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INTRODUCTION

Refuge Stations have been part of the mining scene since the 1930s when, as a result of a disaster at the Hollinger Mine, recommendations were made to include them in the Mining Act. These provisions only covered the basics required and have not changed to any large extent over the years.

Serious incidents involving refuge stations within the Ontario mining community came to the attention of MAPAO in 1989. A sub-committee of the MAPAO Standing Committee on Safety and Loss Control published guidelines to assist the industry in establishing suitable underground refuge stations.

In 1996, a review sub-committee was established to update and revise the current document.

Sub-committee members:
- Baxter Leduc - Barrick Gold Corporation
- Tom Gunn - Inco Limited
- Bob Steele - J. S. Redpath Ltd.
- Kostic Tsoph - Falconbridge Ltd., Kidd Mining Division
- John Vergunst - Provincial Mining Specialist - M.O.L.
- Malcolm Smith - Ontario Mine Rescue - M.O.L.
- Peter Morrison - Sifto Canada Inc.
- Frank Wolt - Mines and Aggregates Safety and Health Association

The Mandate of the Sub-Committee was to:

- Establish guidelines for construction of refuge stations.
- Establish guidelines for equipment, furnishings and supplies to be provided in refuge stations.
- Recommend standard procedures for entry into and for use inside refuge stations during emergencies.
- Propose guidelines for use of portable refuge stations.
- Recommend alternate emergency actions in the event people are unable to reach a refuge station.
- Establish inspection criteria and frequency requirements for all refuge stations.

The recommendations include minimum legislated requirements and suggested standards for industry.

Note:
The sub-committee does not wish to dictate or restrict standards; only to suggest the best way to achieve consistency in refuge stations to protect workers in the event of an emergency situation underground.
REFUGE STATIONS

Occupational Health and Safety Act and Regulations for Mines and Mining Plants
Reg. 854/90 - as amended

Section 26

Where the procedure in case of a fire in an underground mine provides for the use of refuge station for workers, the refuge station shall,

(a) be constructed with materials having at least a one-hour fire-resistance rating;
(b) be of sufficient size to accommodate the workers to be assembled therein;
(c) be capable of being sealed to prevent the entry of gases;
(d) have a means of voice communication with the surface; and
(e) be equipped with a means for the supply of,
   (i) compressed air, and
   (ii) potable water.

POTABLE WATER

Section 280

(1) In underground mines cool potable drinking water shall be provided at locations that,

   (a) are reasonably accessible to a worker; and
   (b) shall be kept in a clean and sanitary condition.

(2) All potable drinking water in a mine or mining plant shall be governed by the guide imposed as a standard of Drinking Water Objectives set by the Ministry of the Environment.
MINISTRY OF LABOUR
Mining Health & Safety Branch
Information for Guidance of Inspectors
Requirements for Underground Refuge Stations

Information Sheet R.S. 24

Refuge stations should be located in all areas underground where in the event of a fire or other disaster there is a possibility that persons may not be able to reach a mine exit from the workplace in a reasonably short time. They should be located in a fresh air circuit and away from extreme hazard areas such as diesel repair stations and oil, fuel or explosives storage. All persons working in the area should be familiar with the location of the refuge station.

Requirements

The refuge station should

1. Preferably be excavated from solid host material (rock, salt, gypsum, etc.) and constructed so as to prevent the inflow of outside air; a portable type unit may be used providing it is fire resistant and reasonably airtight.

2. Be of a size that will afford all anticipated occupants 10 cubic yards (7645 litres) of air per person per 8 hours; or, be provided with compressed air sufficient to sustain the occupants for 8 hours; or, be serviced by a compressed air line.

3. Be serviced with potable water lines or have a supply of drinking water available.

4. If possible be fitted with heaters or air cooler and lights.

5. Have steel main door(s) which can be positively latched and tightly sealed. There should be a small opening to exhaust stale air that can be sealed when required. All components should be fire resistant.

6. Contain enough benches to comfortably seat the persons who will use it.

7. Have a drain which will permit escape of waste water but will stop the inflow of outside air.

8. Have a container of clay or other caulking compound kept in a condition suitable for use.

9. Have a means of communication to a point on surface which can be constantly monitored. If practical, the means of communication should be of a type where an emergency call can interrupt any other call.

10. Contain a basket stretcher, blankets and a first aid kit, all of which are regularly inspected and maintained.

11. Have a supply of emergency tools such as axes, ropes, shovels, jacks, etc., and a 10 lbs dry chemical fire extinguisher.

12. Contain a copy of the fire procedure and the procedure to be followed in the refuge station during an emergency.

13. Be routinely inspected and properly maintained for its intended uses.

DATE: April 27, 1979
Refuge Stations - Sub-Committee Report

ONTARIO MINE RESCUE MANUAL
Refuge Stations and Barricaded Areas

Refuge stations are becoming more numerous in Ontario mines, and in many cases, they are used for dual purposes such as lunch rooms and places of refuge in emergencies. This keeps the worker familiar with the location.

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:

(a) be constructed with materials that have at least a one-hour fire resistance rating;
(b) be of sufficient size to accommodate the workers to be assembled therein;
(c) be capable of being sealed to prevent the entry of gases;
(d) have a means of voice communication with the surface; and
(e) be equipped with a means of supply of,
   (i) compressed air, and
   (ii) potable water.

It should have a door(s), opening outwards, 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 valve within 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 in the event of 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 is determined by the volume of air in the stations without an additional supply of fresh air from compressed airlines. In breathing, humans consume oxygen from the air and give off an almost equal amount of carbon dioxide. When the proportion of carbon dioxide in the air of the enclosed space reaches eight percent, people breathe heavily and reach the point of complete exhaustion. However, people have lived for considerable periods in an atmosphere in which a carbide light would not burn, i.e., in air containing less than 13 percent of oxygen. A person at rest consumes less oxygen and gives off less carbon dioxide than when working. In a confined space, however, the air will finally become unfit to sustain life.

Experiments have shown that a person in a confined space requires approximately one cubic yard of air per hour (one cubic metre of air per hour). At the end of an hour, this cubic yard of air will contain about 14 percent of oxygen and 5 percent of carbon dioxide. A flame lamp or match will not burn. On the basis of one cubic yard of air per hour (one cubic metre of air per hour), an enclosed space 10 ft. x 10 ft. x 10 ft. or 1,000 ft³ (3 m x 3 m x 3 m or 27 cubic metres) will support one person for approximately thirty hours before he begins to suffer through lack of breathing air. This minimum allowance of one
cubic metre per hour per person, however, does not provide for loss of oxygen 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, 6 feet high, and 6 feet wide (9,000 cu. ft. 224 m³) kept 29 men alive for 36 hours. In the same mine another drift 130 feet long, 7 feet high, and 7 feet wide (6,500 cubic feet, 184 m³) contained sufficient air to support 6 out of 8 men for 50 hours; the other 2 men were found dead. The 6 who were alive were all unconscious, but were revived.

The value of barricades cannot be too strongly emphasized. They have been the means of saving hundreds of lives in coal and metal mines. Many additional lives may be saved if workers are properly instructed in their use.

**Opening a Barricade**

Before opening a barricade behind which people have taken refuge, the air outside should be made respirable if possible.

However, if delay in clearing the atmosphere outside the barricade should endanger the lives of the trapped people, an air lock should be constructed as close to the people's barricade as possible, and the people removed with suitable apparatus.

A barricade which has been erected to seal off a fire should not be unsealed unless the director of operations has given definite orders to do so.¹

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¹ Mine Rescue Handbook 1992
SECTION 2 - RISK ASSESSMENT/NEEDS EVALUATION

2.1 BACKGROUND

On February 10, 1928 39 miners died in an underground fire at Hollinger Consolidated Gold Mine. The subsequent Report of the Commissioner, T.E. Godson, made 15 recommendations, the most important the establishment of mine rescue stations in Ontario. (Reference (1), (2)) In 1930 the Mining Act was amended to include provisions for refuge stations where the Chief Inspector deemed necessary. Refuge stations were to "have water, air and telephone connections to surface and be separated from the adjoining workings by closeable openings so arranged and equipped that gases can be prevented from entering the refuge station".

In 1979, the Regulations for Mines and Mining Plants changed this section to its present form, mandating "at least a one-hour fire resistance rating" and to "be of sufficient size to accommodate the workers".

On May 2, 1972 a major underground fire occurred in the Sunshine Mine in Kellogg, Idaho. Of the 173 men working underground at the time, 80 escaped before the hoistman died, 2 more were rescued and the remaining 91 died, of carbon monoxide poisoning. 18 men were working on the bottom 3 levels, the only access being the shaft. The final report on the disaster stated "If a refuge was available, it is conceivable that some of the men could have been saved." (Ref. (3))

2.2 NEEDS ASSESSMENT

The primary function of a refuge station is to sustain life in the event of a major underground fire by preventing fire gases from entering and by providing a source of breathable air.

A needs assessment is required to determine how miners will be rescued in the event of an emergency. Until miners are rescued, refuge stations may be an important part of the mine's emergency procedures.

Refuge stations designed to rely on compressed air have an unlimited occupancy time. However, there have been cases where there has been an unexpected loss of compressed air. In one instance smoke was transported through a ruptured air line into a refuge station. (Ontario, 1990) (Ref. (4)) In another case the fire sucked air out of the refuge station. (Manitoba, 1989) Alert workers in both cases had the presence of mind to close the compressed air valves inside the chamber. In both cases, a fire vaporized the rubber seals in the victaulic couplings in the compressed air line.

Access could be blocked in the following situations:

- A shaft fire where this is the only access to the refuge station.
• A level where the only access to the refuge station is past a burning fuel bay.

• Where access is cut off because of a fall of ground.

In the above examples, it may take mine rescue teams a day or more, depending upon the circumstances, to reach the refuge station.

Each refuge station should be individually evaluated for these types of hazards and assigned a maximum amount of time that it could be occupied before the miners must be rescued.

The primary function of a refuge station is to sustain life in the event of a major fire underground. To accomplish this objective, the refuge station(s) must be properly located and designed to provide workers using the chamber sufficient time to be rescued.

2.3 LOCATION

Location considerations must take into account the following;

Timeliness of Installation

Most refuge stations are established once the initial development is well underway. The use of portable refuge stations or the provision of oxygen self rescuers are alternatives to establishing a permanent refuge station.

Until refuge stations are established underground, interim procedures must be in place before an emergency occurs. Once an emergency occurs it is too late.

Refuge stations should always be considered when:

• An escapeway or secondary means of egress from the mine is not available.

• Mining is taking place on a area remote from the normal access routes into the mine.

• Developing new levels.

• Developing a new mine or re-entering an old mine.
Access and Route of Travel

Refuge stations should be located:

- On main or normal routes of travel.
- A safe distance away from any hazardous areas or conditions, including:
  - explosives magazine or storage container (60 m or 200 ft.) RS 126(1)(a)(iii)
  - electrical transformers greater than 5 KVA (15 m or 50 ft.) RS 171(1)
    from an explosives magazine
  - garages or fuelling bays (placed so that in the event of a fire or explosion there will be a minimum effect RS 120(1)(b))
  - blasting operations and concussions
  - inadvertent entry of uncontrolled vehicles
- In a location that provides ready access to mine rescue teams
- In areas where the ground is safe or well supported.

Length of Time to Get to Refuge

- The station should be as close as possible to the majority of the working places in the area.
- The maximum length of time to walk to a refuge station should be less than 30 minutes.
- If the length of time to get to a refuge station is excessive, (eg +30 minutes) then the use of self rescuers should be considered for those workers.

Signage/Identification

- The location should be familiar to workers, and where possible should be used as a lunchroom or meeting room for safety talks.
- The refuge station should be easily located by employees.
- Routes to the refuge station should be clearly identified.
- The entrance to the refuge station should be well lighted and clearly marked.
- Position of refuge stations should be indicated on all ventilation and mine emergency plans as well as level plans.
SECTION 3 - DESIGN CONSIDERATIONS

3.1 - PERMANENT REFUGE STATION

Size

- to accommodate the required number of employees for up to 24 hours (with compressed air)
- multi-use considerations such as supervisor's office, crew meetings, advanced fresh air base, lunch room, first aid room, etc
- to accommodate alternate sources of respirable air

Location

- centralized in terms of travel time from all workplaces served by the refuge station
- in competent ground
- removed from potentially hazardous source areas such as shops, fuel bays, explosives magazines, etc.
- in a fresh air supply drift if possible

Mine Rescue

To be useful for a mine rescue staging area, a double entry door system (air lock) is preferred. The space between the doors must accommodate a five-member crew and a stretcher and allow them room to move around before they enter the refuge station.

Excavation (the following should be considered if required)

- The constructed bulkhead should be of sufficient size to:
  - minimize construction costs
  - minimize surface area open to ingress of toxic gases.
- Ground support, where required, should be such that the structural integrity will not be jeopardized throughout the entire service life of the facility.
- All joints, cracks or fissures with possible connection to adjacent mine openings should be sealed against the ingress of toxic gases.
- Drainage of water away from the station will enable hosing down of the floor (housekeeping and hygiene).
- The entrance area to the refuge station should not be restricted by vehicles/supplies. Flammable material should not be stored near the entrance.
5. Fabrication/Construction

- Use non-combustible materials.
- All cracks, joints, porous materials and openings for service lines should be effectively sealed against the ingress of toxic gases.
- A smooth concrete floor or consolidated material at least four inches thick and sloped for drainage should be provided. If a sub-floor drainage pipe is installed, it should have a p-trap. Alternatively if a drainage opening is provided at floor level in the constructed bulkhead, then this opening should be fitted with a quick-seal mechanism in case of emergency.
- Unrestricted doorway dimension should be minimum 36 inches wide to accommodate a stretcher and/or mine rescue personnel in full apparatus.
- Door frames should be steel-fabricated and should include a bottom sill.
- Doors should be steel-fabricated and reinforced against bending. The door should open outward to protect against damage from blasting concussion and to enable proper sealing during emergencies.

There should be an adjustable exhaust port to enable a means of controlling differential ambient air pressure across the constructed bulkhead located either in the door or the wall.
- Door hinges and latches should be steel-fabricated and of competent design.
- Service lines through the constructed bulkhead(s) should be effectively sealed, and fluid discharge piping should include p-traps to protect against the ingress of toxic gases, vents for sinks, etc.
3.2 - PORTABLE REFUGE STATION

A mobile/prefabricated unit should be considered as a portable (temporarily located) facility in which personnel can gain quick refuge from a contaminated atmosphere. It should provide the essential elements of survival, respirable air and a relatively comfortable environment, for a period of up to 24 hours (a minimum of eight hours).

Applications

- in remote areas of operating mines where travel time to a permanent refuge station is excessive.
- in areas of new development where permanent refuge stations do not yet exist.

Location

- as close as practically possible to the workplace in an area which provides:
  - protection from blasting concussion
  - protection from collision with mobile equipment
  - safe distance from flammable materials
  - compressed air, water, electricity
  - isolated as much as possible from potential fire/gases.

Design Considerations

- large enough, or in sufficient quantity, to accommodate peak number of personnel
- self-contained: i.e. requiring only external connections of compressed air, water, electricity
- safe-guarded against
  - ingress of toxic gases
  - excessive internal air pressure
- small enough, or have breakdown capability, to fit through smallest access dimension (shaft compartment, service raise, etc.)
- durability to withstand routine handling and a reasonable degree of blasting concussion
- transportability: should have skid plates, tow bar, lifting lugs, etc. to facilitate movability
- multi-use: should be able to be used for first aid station, telephone communication station, lunchroom, etc.
- housekeeping should be ongoing to ensure clean facility
- dampness must be considered in workplace environments, and steps taken to reduce excessive moisture
- structural maintenance and repair
- Life support system - oxygen generating and CO₂ removal systems are an alternative or backup to the mine compressed supply system - see following charts on comparison study.
- refer to ventilation/air quality charts for sizing and personnel accommodation limitations.
## Comparison Chart for Air Quality

**Figure 2.1**

### Factors in Designing Life Support Systems for Refuge Stations

<table>
<thead>
<tr>
<th>Important Factors for Consideration</th>
<th>Compressed Air, Piped from Surface</th>
<th>Compressed Air, in High Pressure Cylinders (300 cu.ft./cylinder)</th>
<th>&quot;REFUGE ONE&quot; Air Centre</th>
<th>Bottled Oxygen in High Pressure Cylinders (300 cu. Ft./cylinder)</th>
<th>Oxygen Candles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintains Oxygen (below 22.5% and above 18.0%)</td>
<td>Yes; however, the flow rate is critical. Minimum of 15 scfm is required.</td>
<td>Yes; however, the flow rate is critical. Minimum of 15 scfm is required.</td>
<td>Yes.</td>
<td>Yes.</td>
<td>Yes.</td>
</tr>
<tr>
<td>Controls Carbon Dioxide (not greater than 5,000 ppm (TLV))</td>
<td>Yes; providing the rate of flow is not less than 50 - 100 scfm. This is equivalent to a 15 - 25 HP compressor running to capacity at 100 psig.</td>
<td>Yes; providing the rate of flow is not less than 50 - 100 scfm. This is equivalent to a 15 - 25 HP compressor running to capacity at 100 psig.</td>
<td>Yes.</td>
<td>No. It does nothing to control carbon dioxide produced through breathing.</td>
<td>No. It does nothing to control carbon dioxide</td>
</tr>
<tr>
<td>Is the operating performance vulnerable to outside influences?</td>
<td>Yes; should the air line from the surface compressors be severed, or the gaskets melt, the air is lost.</td>
<td>No.</td>
<td>No. The system is totally self-contained. It processes the air in the refuge station, versus purging the air. As it does not need outside air, and has an internal battery and oxygen supply, it is not vulnerable.</td>
<td>No.</td>
<td>No.</td>
</tr>
</tbody>
</table>

Chart created by John Chenier, Falconbridge Ltd., Kidd Mining Division
**Figure 2.1 (continued)**

**FACTORS IN DESIGNING LIFE SUPPORT SYSTEMS FOR REFUGE STATIONS**

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes: it can be engineered so that a valve is fully opened (with no operator discretion) and the discharge purges the air out from the refuge station through the wall vents (and/or p-traps) into the drift.</th>
<th>Yes; it can be engineered so that a valve is fully opened (with no operator discretion) and the discharge purges the air out from the refuge station through the wall vents (and/or p-traps) into the drift.</th>
<th>Yes; it has been thoroughly tested in underground conditions.</th>
<th>Only for oxygen.</th>
<th>No; requires a method of determining when to “fire” the candle. (i.e. oxygen analyser)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the system simple enough to be effective?</td>
<td>Yes.</td>
<td>Yes.</td>
<td>Only for oxygen.</td>
<td>Only for oxygen.</td>
<td>Only for oxygen.</td>
</tr>
<tr>
<td>Is the system reliable?</td>
<td>As reliable as the air line from the surface.</td>
<td>Yes; proven through testing.</td>
<td>Only for oxygen.</td>
<td>Only for oxygen.</td>
<td>Only for oxygen.</td>
</tr>
<tr>
<td>What service is required?</td>
<td>Very little.</td>
<td>Cylinders (approximately 342 cylinders) need to be replaced every three months. Very labour intensive.</td>
<td>Periodic service checks as per manufacturer’s recommendations.</td>
<td>None.</td>
<td></td>
</tr>
<tr>
<td>None. (Verification’ calibration of analysers if used.)</td>
<td>None. (Verification’ calibration of analysers if used.)</td>
<td>None. (Verification’ calibration of analysers if used.)</td>
<td>None. (Verification’ calibration of analysers if used.)</td>
<td>None. (Verification’ calibration of analysers if used.)</td>
<td>None. (Verification’ calibration of analysers if used.)</td>
</tr>
<tr>
<td>Does the system contribute negatively to the refuge station atmosphere?</td>
<td>Depends what contaminants or impurities are in the air line (i.e. oil, stench gas, gas, etc.) Noise could be a problem. If the venting in the wall was not properly designed “over pressurizing” could be disastrous.</td>
<td>No; other than that they will take up approximately 300 to 400 sq. ft. of floor space.</td>
<td>A small amount of heat is generated as carbon dioxide is absorbed. Elevated heat and humidity greatly increase the chemical absorbent.</td>
<td>No.</td>
<td>Significant heat. Through the chemical reaction, a small amount of carbon dioxide is produced when generating oxygen.</td>
</tr>
</tbody>
</table>

Chart created by John Chenier, Falconbridge Ltd., Kidd Mining Division
<table>
<thead>
<tr>
<th>Factor in Designing Life Support Systems for Refuge Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Is a tightly sealed wall to the drift critical?</strong></td>
</tr>
<tr>
<td>Yes. The large flow of air (75-100 scfm) will create a positive pressure.</td>
</tr>
<tr>
<td>No. The large flow of air (75-100 scfm) will create a positive pressure.</td>
</tr>
<tr>
<td>Preferred to prevent inward migration of gases under a prolonged duration of &quot;positive&quot; pressure from the drift. System does not generate positive pressure.</td>
</tr>
<tr>
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</table>

<table>
<thead>
<tr>
<th><strong>Is the system practical for the application?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes; providing the line from the surface is not damaged, and the &quot;complete system&quot; is engineered to meet the need.</td>
</tr>
<tr>
<td>No. The number of jumbo cylinders required for 20 men for 24 hours would be 342.</td>
</tr>
<tr>
<td>Yes.</td>
</tr>
<tr>
<td>No; does nothing to control carbon dioxide.</td>
</tr>
<tr>
<td>No. It is difficult to accurately control oxygen levels, and does nothing to control carbon dioxide.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Is the system economical?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes; if compressed air is already available. Not economical if air is only brought for the refuge station (maintenance and loss too high).</td>
</tr>
<tr>
<td>No; the investment for the cylinders and manifold with 342 pigtailed will be very high. The cost of changing them every three months is also too high.</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall suitability of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Poor</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Not suitable</td>
</tr>
<tr>
<td>Not suitable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other comments</th>
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<td>The &quot;engineering&quot; of the air for; flow rate, noise, impurities is important. The wall to drift needs proper vents to prevent pressure buildup.</td>
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<td>The &quot;engineering&quot; of the air for; flow rate, noise, impurities is important. The wall to drift needs proper vents to prevent pressure buildup.</td>
</tr>
<tr>
<td>In an emergency, where &quot;power&quot; is lost, it is limited to 36 hours of operating time.</td>
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<tr>
<td>On its own, it can only maintain oxygen levels.</td>
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<tr>
<td>On its own, it can only maintain oxygen levels. Also, controlling oxygen levels will require some form of control or monitor, i.e. an oxygen analyser.</td>
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**Note:** Training on how to effectively use any of the systems should be considered as an important part of how to ensure the "engineered" system operates effectively.
SECTION 4 - EQUIPMENT, FURNISHINGS AND SUPPLIES

1. Air Line

- The air line should reach to the rear of the station with a return outlet back to the outside to enable the clearing of rust and debris from line. The interior outlet should be fitted with a muffling system to reduce the noise levels inside the station or alternatively use a contaminant removal system.

- Double entry airlock compartments should also be equipped with air outlet and valve system for flushing.

2. Water Supply

- Water line must be installed to supply potable water to the inside of the station. If no line is available, potable water containers should be kept full and ready for use within the station. This stored water should be inspected and changed regularly by specified personnel.

3. Fire/Sealing Clay

- A container of fire clay or other suitable sealing material shall be available and ready for use at all times, inside the station. Enough material should be available to seal the door and other openings in the walls/bulkhead as required.

4. Communication System

- A communication system must be installed for contact with surface and it is suggested a similar system be installed for communication through the bulkhead, to enable persons on the outside of the station to contact those inside. A suitable backup communication system should be considered. A list of emergency phone numbers must also be readily available and should be posted at each phone.

5. Lighting

- Sufficient and suitable lighting must be installed inside the station.

6. Heating/Cooling

- Sufficient and suitable heating or cooling should be installed (where required) in every refuge station (See pg. 47, Engineering Considerations - Heat)

7. Seating

- Sufficient and suitable seating must be available for all those using the station.
8. Emergency Equipment (Basic)
   - basket stretcher and backboard
   - blankets (2)
   - first aid kit (stocked as per legislated requirements)
   - fire extinguisher mounted inside on wall (suggest minimum 10 lb ABC)

9. Emergency Supplies (Should be kept in a locked box or cabinet)
   - supply of garbage bags
   - one 12" crescent wrench
   - hand soap
   - small bag of lime for emergency toilet facilities or portable unit
   - bucket or other suitable container
   - toilet paper
   - writing material (paper, pencils, etc.)
   - smoke tubes for checking airflow/leaks

10. Miscellaneous
   - A proper emergency procedure for refuge station use must be posted inside the station as well as the mine's regular emergency procedures.
   - Level drawings should be available inside the refuge stations showing ventilation flows, escapeways and other pertinent information about the area.
   - An inventory list of emergency equipment and supplies should be posted on the emergency box inside the refuge station for easy reference.
   - A checklist for inspections should be developed, designating person responsible, equipment, conditions, supplies and inspection frequency. (See Section 6, Guidelines for Inspections.)
SECTION 5 - REFUGE STATION PROCEDURES

STANDARD PROCEDURES

Each mining operation should have a set of standard procedures for entering and for using the refuge station. It is important to be consistent and ensure worker knowledge of these procedures in the event of an emergency.

The following guideline procedures have been developed for the industry to use and/or adapt to their local situation.

Basic Procedure

INITIAL ENTRY (first person in)

1. A responsible person must take charge immediately.

2. Determine if there is compressed air available.

3. When compressed air is available, follow situation procedure #1 on page 19.

4. When compressed air in NOT available, follow situation procedure #2 on page 20.

5. List all personnel who enter by name and employee number, or as per local requirement. (see copy of chart on page 18 for example)

6. Designate a person or persons to attend the door allowing people to enter the refuge station. Some personnel may need assistance due to exposure to toxic fumes/smoke.

7. FOLLOW LOCAL SITE EMERGENCY PROCEDURES
When all personnel who were working in the area of the refuge station are grouped inside, and a supervisor is not present, it is essential to name one person to take charge. This person will supervise the tasks to be carried out as per local procedures.

The most senior qualified person should normally assume the responsibilities.
<table>
<thead>
<tr>
<th>NAME</th>
<th>EMPLOYEE NO.</th>
<th>FIRST AID TRAINED (Y - N)</th>
<th>MINE RESCUE TRAINED (Y - N)</th>
<th>WORKPLACE</th>
<th>TIME OF ARRIVAL</th>
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</tbody>
</table>

1. Person in charge
2. Time first person entered refuge station
   - Time last person entered refuge station
3. Communications with Rescue Team times:
4. Communications with Control Centre times:
5. ALL CLEAR SIGNAL GIVEN time:
SITUATION PROCEDURE #1

CHECK IF COMPRESSED AIR IS AVAILABLE

When Compressed Air is Available

1. Delegate individuals to attend the door to the refuge station.

2. Close all doors.

3. Open the compressed air valve to create slight positive pressure inside the refuge station.

4. Open exhaust port in door/wall.

5. Do not seal doors with compound until all expected personnel have entered unless contamination is present outside.

6. Prepare sealing compound for use. Do not add water or open container until required.

7. FOLLOW LOCAL SITE EMERGENCY PROCEDURES

8. When called by surface fire control, report on conditions and personnel in station, including names and/or numbers.

9. Occasionally check on pressure in the station (must be positive) to ensure contaminants are not entering from outside. (Can use ventilation smoke tube, or other suitable method to check air flow).

10. Conserve mine lamps, water and food.

11. Remain in the refuge station until you receive official instructions to evacuate.

12. “NO SMOKING” at any time during the emergency.

Everyone inside the refuge station should sit down and relax in order to conserve oxygen. From time to time, individuals may move around a little to avoid muscle cramping.
SITUATION PROCEDURE #2

CHECK IF COMPRESSED AIR IS AVAILABLE

When Compressed Air is Not Available

Note:  
When compressed air is not available, extra care must be taken

1. When entering the refuge station close all doors behind you without sealing them. More personnel may be arriving.

2. If the air outside the refuge station is contaminated, close off and seal all openings immediately. Otherwise proceed to numbers three and four.

3. Delegate individuals to prepare the sealing compound and to attend the doors.

4. When the expected number of personnel are in the refuge station, seal the door. If equipped with airlock, seal outer door first followed by the inner door.

5. IF AVAILABLE --- Bottled air should be used sparingly. This will put a slight positive pressure in the chamber. Open the cylinder valve 10 second bursts, every 15 minutes or so. (Check the gauge for pressure) This compressed air is to keep the station in positive pressure. Adjust flow meter on bottles if they are so equipped. Life Support Systems - follow instructions posted on the unit.

6. Check sealed openings for possible leaks.

7. Conserve oxygen by keeping quiet.

8. Mix the air. Have one person walk around every 15 minutes or so.

9. FOLLOW LOCAL SITE EMERGENCY PROCEDURES

10. When called by surface fire control, report on conditions and personnel in station, including names and/or numbers.

11. Occasionally check on pressure in the station (must be positive) to ensure contaminants are not entering from outside. (Can use ventilation smoke tube to check air flow or other suitable method.)

12. Conserve mine lamps, water and food.

13. Remain in the refuge station until you receive official instructions to evacuate.

14. “NO SMOKING” at any time during the emergency.

Keep off the floor. The exhaled air containing CO₂ - carbon dioxide is heavier than normal air and settles to the floor.
Refuge Stations - Emergency Procedures

SINGLE DOOR ENTRY PROCEDURES

1 - Open outer door and enter.

2 - Close door behind you.

3 - Note: If door is unattended and air outside is believed to be contaminated - seal door with clay or sealant provided. Ensure compressed air is blowing inside.
Refuge Station - Emergency Procedures

AIR LOCK - DOUBLE DOORS

1 - Open outer door and enter air lock chamber.

2 - Close outer door - if air is contaminated, purge chamber with compressed air if available.

3 - Open inner chamber door
   - Enter inner chamber and close door behind you

4 - If door is unattended - and air outside is believed to be contaminated - seal door with clay or sealant provided. Ensure compressed air is blowing inside.
SECTION 6 - GUIDELINES FOR INSPECTIONS

COMBINED REFUGE STATION AND LUNCHROOM

Refuge stations with the added features and equipment of a lunch room can enhance the quality of time spent in a confined area in an emergency.

However, with full-time use, if maintenance and proper housekeeping practices are not upheld, the fitness of the facility could jeopardize the inhabitants in an emergency.

Therefore, the following guidelines should be utilized for dual purpose refuge stations. *(Items listed with an asterisk are required in a station used for refuge only in an emergency.)*

Monthly inspections should be made by a competent person.

* **Walls** - Block or concrete or equivalent (steel or other suitable material) in place and in good condition. No holes or gaps; wall painted (if block or concrete) to seal possible concrete leakages. Areas where pipe and electric cables through wall are sealed properly (See Section 3, Design Considerations).

* **Regulations** - Relevant jurisdictional regulations pertaining to refuge stations and emergency procedures posted for all employees to see.

* **Signs** - Directional signs should be posted in drifts, ramps and roadways and other required locations throughout the mine, all pointing to the Refuge Station locations.

* **Doors** - Refuge stations must be provided with suitable-sized doors that open outward and open and close properly. The doors should be of such a size to allow easy access for a rescue team to pass with a stretcher.

The doors should be built in such a manner that they can be sealed with clay or its equivalent; are equipped with a two inch exhaust port with a screw cap to control the room air pressure; and are capable of latching securely with opening mechanism on both sides of the door.

If an airlock entry system is used, consideration should be made to provide space between doors to permit a 5 person rescue team to enter. (See Section 3, Design Considerations).

* **Ventilation** - Ensure that any ventilation fan and ventilation ducting blowing through the wall into the refuge/lunch room are in good order with a capability of being readily sealed airtight in an emergency.
Refuge Stations - Sub-Committee Report

Housekeeping - All good housekeeping practices must be followed with a daily cleaning of the facility scheduled into the maintenance program.

* Air Supply - Compressed air should be within 10 ft. of the end of the refuge station and have a controlled return line to the outside for flushing. Ideally, an air line would be equipped with a flow rate gauge/meter on the valve. Air header inside the refuge station should be equipped with an air silencer/muffler.

Air locks between doors should have an air header (only refuge stations equipped with a double door entry system).

* Water Lines/Potable Water - A water line should be installed along with the air line to serve two purposes; to be used for cleaning the floor and as a supply of potable water.

Should the mine piped water not be potable, then an adequate supply for emergency use must be stored and replenished as necessary. This supply should not be used for regular daily use. (See Section 4, Equipment, Furnishings and Supplies.)

* Emergency Procedures and Level Plans - Emergency procedure must be posted inside, preferably on a bulletin board. Level plans should be posted inside the refuge station showing refuge station location and possible escape routes, as well as fresh airways.

* Fire Protection - There should be a fire extinguisher of suitable size located at the entrance door inside the station.

* Sealant/Fire Clay - Clay box and clay or its equivalent material (electrical fire sealant) stored inside the refuge station. Clay or its equivalent must be kept soft and pliable. Clay must be abundant to seal all doors and all openings as required.

Emergency Box - An emergency box with emergency tools is usually stored in selected stations that are easily accessible. Some of the tools in the emergency kit are usually jacks, hammers, first aid kit, stretchers, and blankets, etc. (See Section 4, Equipment, Furnishings and Supplies.)

* Adequate Room - The refuge station/lunch room should be designed to accommodate all possible employees and visitors that could be seeking refuge in this station in an emergency for an eight hour period. The general rule is 10 cubic metres per people per 8 hours use. (See Section 3, Design Considerations.)
**Floor** - The floor is constructed of non-combustible material (usually poured four-inch concrete); all possible joints and cracks should be properly sealed.

**Drainage** - A p-trap should be installed in the entrance floor/wall to ensure proper draining of liquids and a constant seal. Ensure that the floor is sloped to allow liquids to flow towards the entrance and the p-trap.

**Garbage Containers** - Adequate containers must be supplied. They should be metal containers with metal lids.

* **Communication System** - A communication system to the surface should be in place. It is also recommended that a system to communicate through the wall of the station to the outside should be installed. (See Section 4, Equipment, Furnishings and Supplies for further clarifications.)

* **Emergency Communication Numbers** - A list of emergency numbers must be posted at each telephone.

**Bulletin Board** - A bulletin board is usually mounted on the wall of a refuge station for communication purposes. Items posted on the board are: Refuge Station Procedures; Fire & Emergency Procedures; escape ways/fresh airway plans; emergency numbers, emergency tool box inventory list; First Aid inventory list, and other required pertinent information.

**Electrical Installations** - All electrical panels, boxes and wiring must be properly maintained and identified for emergency shut off.

* **Lighting** - Sufficient and suitable lighting must be installed and maintained inside the station.

**Heating/Cooling** - Sufficient and suitable heating should be installed and maintained (where required) in every refuge station.

**Ovens/Microwaves** - Must be adequate, the maintenance program must include the cleaning frequency of the unit.

**Appliances (if applicable)** - All appliances installed in the station should be maintained in good operational order and should not affect the integrity of the station.

**Refrigerator** - The maintenance program must include the cleaning frequency of the unit.

**Seating and Tables** - Sufficient and suitable seats/chairs must be available and maintained for all those using the station.
* **Ground Conditions** - All walls, ceilings and floors should be competent. Any joints, cracks, fissures, etc. should be properly sealed or at least capable of being sealed in an emergency.

Proper ground support should be provided as conditions require.

**Wash Basin and Soap** - Wash basins must be installed and the maintenance program should include the cleaning frequency of the unit. Soap must be supplied to ensure personal hygiene.

* **First Aid Kit** - The first aid kit must be supplied and stocked as per legislated requirements. Most dual purpose stations usually provide both an *every day general kit* and one *for emergency use only*.

**Life Support System** - In areas where compressed air lines are not available, compressed air bottles are usually supplied for make-up air. Ensure bottles are fastened securely to the wall to ensure bottles don’t fall. (See Section 8, Engineering Considerations for further clarification). Air cleansing systems are also available and are used in some stations in Ontario. Ensure that manufacturer’s requirements in maintenance and use are followed and that proper training is available. (For reference, see charts on pages 12 - 14).

* **Emergency Toilets** - Chemical or lime toilets should be available, sealed and ready for use in the event of an emergency.
## MONTHLY REFUGE STATION INSPECTION RECORD

<table>
<thead>
<tr>
<th>INSPECTION ITEMS</th>
<th>LOCATION</th>
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<tbody>
<tr>
<td>*Walls</td>
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<td>Refrigerator</td>
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<td>*Ground Conditions</td>
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<td>Wash Basin</td>
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<td>Appliances (if applicable)</td>
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<td>* First Aid Kit</td>
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<td>Make-up Air</td>
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<td>Life Support System</td>
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<td>* Emergency Toilets</td>
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Mark items OK or SUB (substandard). Explain all substandard items on reverse of page. INSPECTED BY: ____________________________ Date: ____________________________
SECTION 7 - ALTERNATE EMERGENCY REFUGE

Employees unable to reach a refuge station due to smoke, fire or other adverse conditions must retreat from the area and take appropriate action to safeguard themselves and others. Whenever possible, take food, water and a crescent wrench with you. Procedures are given for the following situations:

Case #1  - Fresh air way
Case #2  - Building a barricade
Case #3  - Use of compressed air
Case #4  - Barricade and air header not readily available

Note:
The committee does not recognize self rescuers as a substitute for refuge stations. However, self rescuers may be of assistance for workers travelling to refuge stations or emergency refuge.
CASE #1 - USE OF FRESH AIR WAY

Employees unable to reach a refuge station should retreat to a fresh air way if they are able to do so safely.

1. Advise any employee you encounter along the way of your intentions and suggest he follow you to the fresh air way.

2. If there is a phone in the vicinity that can safely be reached, call surface and give the names, numbers and location of the employees present, their refuge location and any other pertinent information. Leave a note at your work place if possible.

3. Check area for availability of compressed air lines.

4. Remain in the fresh air way until a rescue team arrives or you have been notified by management that the adverse conditions have returned to normal.

5. If fresh air flow stops or reverses, be prepared to go to compressed air lines (See Case #3 and Case #4).
CASE #2 - USE OF BARRICADE

1. When the decision to build a barricade has been made and there is a telephone in the vicinity, if time allows, call surface and give the names and numbers of employees and location of barricade site.

2. The supervisor or employee with the most construction experience should take charge.

3. Select a dead-end drift, free of smoke which will provide a maximum quantity of air. As much area as possible should be included in the barricaded area regardless of the number of people in the party. Make sure there are no other openings or connections with other workings through which gases can enter.

4. Air and water lines with valves should be in the barricaded area and checked before construction begins.

5. If smoke or contaminants are suspected in the vent system, turn off the fan if the switch is readily available, or disconnect the vent tubing as near to the fan as possible to stop smoke being pushed towards the barricade site.

6. All useful material nearby such as tools, timber, vent tubing, nails and lunch pails should be brought to the construction site. If necessary use clothing such as coats, jackets, etc. to help seal the barricaded area.

7. Erect the barricade as quickly as possible, making it as airtight as possible.

8. Leave a note outside the barricade indicating the number of people inside.

9. If compressed air is available inside the barricade, crack open the header immediately.

10. When the barricade is completed, rest as much as possible to conserve oxygen and spread out through the area.

11. Take turns at checking the barricade for air tightness and walking through the area to mix the air. Conserve food and water. Battery lights should also be conserved. Smoking is prohibited. Signal by pounding on a pipeline.

12. Remain calm inside the barricade until a mine rescue team arrives.
CASE #3 - USE OF COMPRESSED AIR LINE

The possibility exists that due to a lack of barricade building material or being caught in dense smoke, the employee is not able to construct a barricade.

1. The employee is to make his way to an air header.

2. Open the air valve slightly so that you can feel the air blowing against your face. (The smell of emergency gas might be prevalent in the air)

3. Take your jacket, oiler coat, pants, piece of vent tubing, or anything that will enable you to build a tent-like structure around the header and your head and shoulders. Even directing the flow of air into a hard hat and putting one's face into the hard hat will enable a person to remain safe in adverse conditions.

4. Remain calm. Stay in the same location and wait for rescue.
CASE #4 - WHEN BARRICADE AND AIR HEADER NOT AVAILABLE

Conditions may change so quickly that an employee is not able to barricade himself or find a source of fresh air.

1. The employee should then proceed to a dead-end heading that is free of smoke and which will provide a maximum quantity of air.

2. Take refuge at the point farthest from the entrance.

3. Sit down and remain calm. Remember, conserve your lamp battery by turning out your lamp. No smoking. Every 15 minutes walk around your immediate area to mix the air.

4. Remain calm in this location until you are rescued.
SECTION 8 - ENGINEERING CONSIDERATIONS FOR BASIC REFUGE STATION DESIGNS

Contributed by
John Vergunst, P. Eng. CIH
Sr. Working Environment Engineer
Mining Health & Safety Branch, Ministry of Labour

QUALITY OF AIR

8.1 INTRODUCTION

In the event of a mine fire the workers immediately follow the emergency procedures and go to the nearest refuge station, turn on the compressed air, close and seal the door, and remain claim and at rest. Periodically a miner will walk around the room to mix the air. It is important that the miners rest to conserve oxygen and limit carbon dioxide production.

8.2 DESIGN

Basic design considerations must take into account all background information and requirements relating to the control of the environment for the survival of people in an enclosed space when adjacent areas are unsafe. If no planned controls are provided for the physical environment within the refuge station, conditions may approach a safe state of equilibrium or become intolerable for the people within.

A progressive deterioration of the environment within the refuge station can be a very real hazard, especially if the compressed air fails.

Factors that influence the refuge station environment are:

- Number of occupants
- Duration of occupancy
- Size
- Amount and quality of compressed air provided
- Permeability of walls and other leakage paths
- Initial environment conditions
- Temperature and humidity
- Metabolic characteristics of people with respect to energy expenditure, oxygen consumption and carbon dioxide production
- Odour control
Number of Occupants

Design should be based on the maximum number of workers that are normally expected to use that refuge station at any one time; including supervision and staff.

Note:
At no time should the refuge station be posted to limit the number of people within. For example, if a group of people were touring the level when an emergency occurred they are not to be turned away because of initial design considerations.

Duration of Occupancy

This may be the controlling factor in the design of many refuge stations. A minimum 8 hour occupancy time is suggested. In other cases, this may be longer, up to 24 hours, depending on the location; for example, in the case of single access to a refuge station.

The maximum occupancy time is considered to be that time from the start of occupancy until an upper limit of 3% carbon dioxide and a lower limit of 16.25% oxygen is reached.

Size

Once the duration of occupancy for a refuge station has been decided, the size can be calculated if the maximum number of occupants is known. Where practical, size should be calculated based on dead space volume. Using the dead space volume of the refuge station assumes the worse case condition; that the compressed air has failed.

To calculate dead space volume several methods can be used.

1. U.S. Navy $T = 0.04 \frac{V}{P}$ (10)

   where: $T =$ time to reach 3% carbon dioxide, hours
   $V =$ net volume of space, ft$^3$
   $P =$ number of occupants
2. Ontario

Mine Rescue Handbook (10)

6.2 m³ (216 ft³)/person or 27 ft³/hr/man (based on 8 hrs)

MASHA Refuge Station Sub-Committee Recommendation (4)

10 m³ (353 ft³)/person or 44 ft³/hr/man (based on 8 hrs)

Actual Examples of Refuge Station Factors Currently in Use:

- **Ontario:**
  approximately 275-280 ft³/person (7.8 cu. m)

- **South Africa:**
  - Hartebeestfontein Gold Mine - 343.3 m³ (12,120 ft³) for 150 - 170 people
  = 2 m³/person (71 ft³/person) (13)
  - Douglas Colliery - 116.1 m³ (4100 ft³) for 30 people
  = 3.87 m³/person (136 ft³/person) (9)

3. NASA-NRC graph - Figure 8.1 (10)

- locate 3% carbon dioxide on the top of the graph

- draw a line vertically down from 3% until the line intersects the NO VENTILATION line

- where the lines intersect, draw a horizontal line to the point where the curve labelled 8 HOURS (32) is intersected

- at the point where the lines intersect now proceed vertically down until the axis of the UNIT VOLUME OF SPACE is intersected

- read the unit volume (ft³ per person) off the graph. Because we have used 8 hours in step (c) now read off the UNIT VOLUME as 218 ft³ per person

- multiply 218 ft³ by the number of people expected to occupy the refuge station.
Example # 1:

What is the size of refuge station if the design requires an 8 hour occupancy time with an occupancy of 10 workers? Assume no compressed or bottled air is available.

1. U.S. Navy

\[ V = \frac{TP}{hr \times \text{persons}} = \frac{2000 \text{ ft}^3}{8 \times 10} = 0.04 \text{ ft}^3 \text{ or } 57 \text{ m}^3 \]


27 ft³/hr/man x 8 hrs x 10 persons = 2160 ft³ or 61 m³

3. NASA-NRC graph - Figure 8.1

At 3% CO₂ the unit volume required per person is 218 ft³. Therefore;

218 ft³/person x 10 persons = 2180 ft³ or 62 m³

Refuge Station Size: Example # 1:

All methods give approximately the same result for dead space volume. The refuge station would have to be between 57 - 62 m³ (2000 - 2200 ft³) For a 2200 ft³ refuge station;

**Nominal Size:**

8 ft.H x 15 ft.W x 18.3 ft.L = 2200 ft³
2.4 m x 4.6 m x 5.6 m = 62 m³

**Note:**

This refuge station could not be used as an advanced FRESH AIR BASE as the floor space is less than the required 30 square metres (350 ft²).
Example # 2

For portable refuge stations the size and occupancy is fixed by the manufacturer. Therefore more than one unit may be required. As well, the capacity of the portable air supply (i.e. number of jumbo cylinders) should be calculated to reflect the occupancy time required.

If the same conditions as in Example 1 are assumed and all 10 persons could fit into the portable refuge station then the air supply would be calculated as follows:

1. Total Air Supply Required = 2180 ft$^3$

2. Portable Air Supply Required = 2180 ft$^3$ - less dead space volume of portable refuge station
   = 2180 ft$^3$ - (10'L x 6'H x 4'W)
   = 1940 ft$^3$

3. Number of Compressed Air Cylinders Required:

1940 ft$^3$ of air required. Each fully charged (2400 psi) jumbo cylinder has a capacity of 300 ft$^3$ of free air

\[
\frac{1940}{300} = 6.46 \approx 7 \text{ jumbo cylinders required} \]

Note:
The portable refuge station is normally designed to hold six people for approximately eight hours.

The manufacturer of one type of portable refuge station has the following specifications:

- Size: 10'L x 6'H x 4'W
- No. of Jumbo Cylinders: 6
- Occupancy: 6 people
- Occupancy Time: 8 hrs.

Based on the NASA-NRC curves of 3% CO$_2$ and 16.75% O$_2$, a maximum occupancy time of 12 hrs. and 45 min. can be calculated.
8.3 METABOLIC CHARACTERISTICS

Oxygen diffuses through the walls of the alveoli in the lungs into the blood capillaries, is dissolved in the blood plasma, diffuses into the red blood cells and is bound to the hemoglobin in the bloodstream. (5) The red cells are then transported to the body tissues by the blood. Where the partial pressure of oxygen is low (where the body requires oxygen), the oxygen dissolved in the plasma diffuses out of the capillaries. As the oxygen concentration in the plasma decreases it is replaced by that contained in the red blood cells. The blood is then returned to the lungs for a new supply of oxygen.

Within the tissue cells the oxygen is used for the chemical reactions that supply energy for the functions of the cell. Most of the oxygen combines to form carbon dioxide and water. The carbon dioxide is transported by the blood to the lungs and exhaled. The water is eventually excreted.

The brain is the organ most susceptible to to the effects of oxygen deficiency because it has a high metabolic rate, has no reserve store of oxygen and the cells will perish without oxygen to sustain them.

As muscular activity increases so does the rate of respiration and the volume of air exchanged at each breath. However the percentage of oxygen that is utilized decreases at heavier rates of breathing. Refer to Figure 8.2.

Figure 8.2 shows that personnel in a refuge station should rest to limit oxygen consumption and limit carbon dioxide production. It must be remembered that Figure 8.2 was NOT developed for the average person not under stress. (6)

Therefore, for design purposes a figure of 0.5 Lpm of oxygen consumption should be used. This assumes that the average miner in the refuge station is not at ease but probably consuming oxygen at a higher rate. At an oxygen consumption rate of 0.5 Lpm each person within the refuge station would be producing approximately 0.43 Lpm of carbon monoxide.

8.4 OXYGEN

Oxygen, a colourless, odourless and tasteless gas, is the most important constituent of life. At normal conditions of temperature and pressure, air is a mixture containing:

- 20.95% oxygen,
- 78.09% nitrogen,
- 0.93% argon and
- 0.035% carbon dioxide.
FIGURE 8.2
OXYGEN CONSUMPTION, CARBON DIOXIDE
PRODUCTION AND BREATHING RATES OF MAN (9)

<table>
<thead>
<tr>
<th>Level of Physical Activity</th>
<th>Rate of Breathing Lpm</th>
<th>Oxygen Consumption Lpm</th>
<th>Carbon Dioxide Production Lpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhauling effort</td>
<td>69</td>
<td>3.15</td>
<td>2.7</td>
</tr>
<tr>
<td>Strenuous work or sports</td>
<td>46</td>
<td>2.1</td>
<td>1.77</td>
</tr>
<tr>
<td>Moderate exercise</td>
<td>30</td>
<td>1.4</td>
<td>1.18</td>
</tr>
<tr>
<td>Mild exercise; light work</td>
<td>19</td>
<td>0.9</td>
<td>0.73</td>
</tr>
<tr>
<td>Standing; desk work</td>
<td>11</td>
<td>0.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Sedentary; at ease</td>
<td>7.5</td>
<td>0.35</td>
<td>0.3</td>
</tr>
<tr>
<td>Reclining; at rest</td>
<td>6.0</td>
<td>0.27</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Oxygen Deficiency

Oxygen deficiency (hypoxia) can be encountered in numerous situations such as vats, tanks and any poorly ventilated area. The air may be displaced by other gases, vapours or the oxygen may be consumed by chemical or biological reactions.

In mines, much of the oxygen in stagnant air may be removed by oxidation of minerals (ie sulphides into sulphur dioxide) and organic matter (wood) or by absorption into mine water. As well, gases such as carbon monoxide, methane and hydrogen sulphide may accumulate, sometimes to the point of making the stagnant atmosphere toxic and/or explosive. A more common method of oxygen depletion is through combustion of fuels from diesel equipment and fires. (5)

Oxygen deficiency implies an increased concentration of one or more other gases. Even non-toxic gases will endanger life by asphyxiation if they are present in sufficient concentration to cause a significant oxygen deficiency.
Partial Pressure of Oxygen

It is the partial pressure of oxygen which drives oxygen into the bloodstream from the inspired air. A minimum partial pressure of 18 kilopascals (kPa) is required to maintain a proper degree of alertness in the workplace.

One of the important characteristics of gases which do not react with each other, is that the total pressure of a gas mixture is the sum of the partial pressures. At standard atmospheric pressure of 101.3 kPa (Refer to Figure 8.3) the partial pressure of oxygen is obtained as follows;

\[ 101.3 \text{ kPa} \times 21\% \text{ O}_2/100\% \text{ Air} = 21.3 \text{ kPa of O}_2 \]

Therefore at normal temperature and pressure 18% of oxygen is roughly equivalent to 18 kPa. However, this changes with depth and altitude as shown in the following examples;

1. 17% O₂ underground \( \times 106.5 \text{ kPa} = 18.1 \text{ kPa of O}_2 \)

2. 21% O₂ at 3000 ft of altitude \( \times 90.75 \text{ kPa (normal pressure at this altitude)} = 19.05 \text{ kPa of O}_2 \)

**FIGURE 8.3**
Standard Dry Air Conditions

<table>
<thead>
<tr>
<th>Property</th>
<th>Imperial</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure *</td>
<td>29.921 in. Hg.</td>
<td>101.325 kPa</td>
</tr>
<tr>
<td>Temperature</td>
<td>70 °F</td>
<td>21.1 °C</td>
</tr>
<tr>
<td>Humidity</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Density</td>
<td>0.075 lb/ft³</td>
<td>1.2 kg/m³</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>28.9645</td>
<td>28.9645</td>
</tr>
</tbody>
</table>

**Note:** 101.325 kPa = 29.921 Hg. = 760 mm Hg. = 760 Torr

= 14.7 lbs/ft² = 1 atm. = 1013 millibar
Health Effects of Oxygen

Oxygen is only a health hazard at low concentrations as shown in Figure 8.4. The primary concern is asphyxia.

The effects of oxygen deficiency near or below sea level are the same as those of oxygen “sickness” at high altitudes. It also becomes clear that the symptoms can be considered identical and the physiological effects only depend upon the partial pressure of oxygen available. The altitudes for which various symptoms of oxygen deficiency are known (7) were converted to atmospheric pressure $P_2$ and then to partial pressure and an equivalent percent by the following formula;

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{gH}{RT}$$

where:

- $P_1 =$ atmospheric pressure at sea level, 760 mm Hg and 21.1°C
- $P_2 =$ atmospheric pressure at altitude, mm Hg
- $g =$ gravitational constant, 9.807 m/sec$^2$
- $H =$ altitude, m
- $R =$ gas constant for air, 0.287 kJ/kg*K or 287 kg m$^3$/kg sec$^2$ *K
- $T =$ absolute temperature, °K = °C + 273

The effects of oxygen deficiency are not usually detectable when the partial pressure of oxygen is greater than 21.3 kPa. Between 21.3 and 16 kPa the uptake of oxygen decreases linearly with the decrease in partial pressure. At less than 16 kPa chemical receptors in the aorta and carotid arteries detect the declining blood oxygen saturation and stimulate increased breathing. The minimum partial pressure that an unacclimatized person can tolerate is 9 to 10 kPa (9–10% at normal temperature and pressure). (5) (7) At this level of oxygen a person will require 5 to 10 minutes before becoming unconscious. (7)

However, there is considerable variation among individuals in their sensitivity to oxygen deficiency.
<table>
<thead>
<tr>
<th>Percent Oxygen</th>
<th>Symptoms of Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>At half an atmosphere can be tolerated indefinitely; 3 atmospheres is probably safe for healthy adults for one hour. (5)</td>
</tr>
<tr>
<td>23</td>
<td>Maximum level allowed in a confined space where entry is required. To minimize fire and explosion hazards. (8)</td>
</tr>
<tr>
<td>21</td>
<td>Normal oxygen content of air at standard temperature and pressure.</td>
</tr>
<tr>
<td>19.5</td>
<td>Minimum level in order to wear a NIOSH approved reusable or replacement filter type air purifying respirator. (9) This level is also cited by U.S. OSHA as an oxygen deficiency in §1910.94 of CFR 29</td>
</tr>
<tr>
<td>18</td>
<td>Concentrations greater than this required in Ontario. (18 kPa at STP) (8) Night vision may be affected. (7)</td>
</tr>
<tr>
<td>16</td>
<td>Flame safety lamp goes out. (10) Breathing and pulse rates start to increase. (1)</td>
</tr>
<tr>
<td>15</td>
<td>Fatigue and inertia after 4 hours or less. (7)</td>
</tr>
<tr>
<td>12 - 14</td>
<td>Fatigue, drowsiness, headache, and poor discernment and comprehension after 2 hours or less. (7) Muscular coordination slightly disturbed. (5)</td>
</tr>
<tr>
<td>11 - 12</td>
<td>Decreasing attention, adverse effect on vision, memory disorders, deceptive feeling of well being after 30 minutes or less. (7)</td>
</tr>
<tr>
<td>10 - 11</td>
<td>Muscles out of control, loss of memory, loss of discernment, comprehension, and of time sensation, outbreaks of excitement; after 15 minutes or less (7) abnormal fatigue upon exertion and disturbed respiration. (5)</td>
</tr>
<tr>
<td>9 - 10</td>
<td>Cramp type convulsions and unconsciousness after 5 to 10 minutes. (7) Nausea and vomiting, inability to move freely, may collapse and although aware of circumstances be unable to move or cry out. (5)</td>
</tr>
<tr>
<td>8 - 9</td>
<td>Unconsciousness after 4 to 6 minutes. (7) Convulsive movements, gasping, respiration stops and a few minutes later heart action ceases. (5)</td>
</tr>
<tr>
<td>6 - 8</td>
<td>Unconsciousness after 1 to 2 minutes. (7) Convulsive movements, gasping, respiration stops and a few minutes later heart action ceases. (5)</td>
</tr>
</tbody>
</table>
8.5 CARBON DIOXIDE

When there is no flow of air, carbon dioxide is one of the factors in limiting the length of time that workers can remain in a refuge station. The other is oxygen.

At high concentrations carbon dioxide acts as a respiratory and central nervous system stimulant. Sufficiently high exposure to carbon dioxide will lead to unconsciousness, narcosis, respiratory arrest and death as shown in Figure 8.5. Because the solubility of carbon dioxide is approximately 20 times greater than oxygen, diffusion is rapid and the respiratory and central nervous effects are experienced almost instantaneously. If the increasing carbon dioxide concentrations are accompanied by an appreciable lowering of the oxygen content, then the symptoms will be more severe.

Ontario Regulation 833/90 “Regulation Respecting Control of Exposure to Biological or Chemical Agents” is based on limiting working exposure to eight hours per day and 40 hours per week.

The Time Weighted Average (TWA) was set to provide a significant margin of safety to prevent asphyxia and metabolic effects. There is no evidence in the literature that levels below 5,000 ppm carry any increase in health risk.

<table>
<thead>
<tr>
<th>Percent CO₂</th>
<th>Symptoms of Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.035</td>
<td>Concentration in normal air.</td>
</tr>
<tr>
<td>0.06</td>
<td>Occasional complaints of indoor air quality, particularly if the ambient air temperature rises. (11)</td>
</tr>
<tr>
<td>0.1</td>
<td>ANSI/ASHRAE recommended concentration for long term occupancy of buildings where air is recirculated. This value is derived from a ventilation rate of 7.5 Lpm of outdoor air per person which is needed to dilute occupant odours to a level acceptable to 80% of visitors first entering a space. (12) Complaints are more general where there is insufficient make-up air. (11)</td>
</tr>
<tr>
<td>0.5</td>
<td>Threshold Limit Value - Time Weighted Average (TLV-TWA). The concentration for a normal 8-hour workday and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse health effects. (13) Ontario adopted limit and definition. (14)</td>
</tr>
<tr>
<td>1.0</td>
<td>Calcium phosphorous metabolism is affected over extended periods (days) and blood becomes slightly acidic. This is interpreted as indicating a mild metabolic stress. However, repeated daily exposures at one atmosphere is well tolerated on medically fit individuals. (15),(16) Maximum allowable concentration in inspired gas for open and closed circuit apparatus rated for a 4-hour service life. (e.g. BG 174) (9)</td>
</tr>
<tr>
<td>1.25</td>
<td>Level at which ventilation is considered inadequate in British coal mines. (17)</td>
</tr>
</tbody>
</table>
FIGURE 8.5 - continued
HEALTH EFFECTS OF CARBON DIOXIDE

<table>
<thead>
<tr>
<th>Percent CO₂</th>
<th>Symptoms of Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>Headaches and laboured breathing on mild exertion. (15) Respiratory minute volume (RMV) increases about 50%. (18) Maximum allowable concentration in inspired gas for open circuit apparatus rated for a one hour service time. (9)</td>
</tr>
<tr>
<td>3.0</td>
<td>Threshold Limit Value - Short Term Exposure (TLV-STE). The concentration to which workers can be exposed continuously for any 15 minute period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. (13) Ontario adopted limit and definition. (14)</td>
</tr>
<tr>
<td>4.0</td>
<td>Transient giddiness and at times the taste of ammonia were experienced by submarine personnel over a period of eight hours. (19)</td>
</tr>
<tr>
<td>5.0</td>
<td>Respiratory minute volume is approximately doubled. (18)</td>
</tr>
<tr>
<td>6.0</td>
<td>Signs of intoxication are produced by a 30 minute exposure. (15) Violent panting, headaches and fatigue to the point of exhaustion merely from respiration. (20)</td>
</tr>
<tr>
<td>7 - 10</td>
<td>Exposure produces unconsciousness within a few minutes. (15) Concentrations have been inhaled by men for periods up to one hour with no evident harmful effects. (5)</td>
</tr>
<tr>
<td>10 - 15</td>
<td>Intolerable panting, severe headache, rapid exhaustion, collapse. (20)</td>
</tr>
</tbody>
</table>

8.6 INITIAL ENVIRONMENT CONDITIONS

All the calculations have so far assumed that the initial atmosphere in the refuge station is uncontaminated. To ensure this condition, the refuge stations should be periodically checked for air contaminants, especially gases. If necessary they should be ventilated. In the event of an emergency the ventilation must be controlled from within.

In some of the uranium mines small filter units have been installed outside the refuge station and blow radon daughter free air into the refuge station. During an emergency the filter unit is turned off and the damper breaching the wall sealed.

In large refuge stations, problems may occur with stale air. Stale air is normally taken to infer 0.75% CO₂. Provisions should be made to ventilate these refuge stations.
8.7 HEAT

The design should take into account other environmental factors; in particular, temperatures, humidity and odours. Odour control should be considered for those refuge stations where occupancy time is expected to extend to 24 hours or greater.

Probably the environmental factor of most concern in this category is the effective temperature. The effective temperature (ET) is an index of relative comfort determined by successive comparison of different combinations of temperature, humidity, and air movement. The numerical value of ET for any given air condition is fixed by the temperature of slowly moving saturated air which gives an immediate sensation of warmth or coolness. It must be noted that the effective temperature has many shortcomings as an index of heat stress for the prediction of physiological strain. However, it is good for static conditions. The figures referred to in this discussion assume that all personnel have a uniform metabolic rate and that there is no appreciable airflow within the refuge station.

Figure 8.6 shows the various effective temperatures for a combination of dry bulb or ambient air temperatures and humidity. Once the effective temperature is known, the tolerance limits for personnel within the refuge station can be judged.

The common value for sedentary metabolism for adult males is taken to be 400 Btu/hr (117.2 w) which would be the total heat transferred to the environment by each occupant. (6) To estimate the temperature rise in a refuge station is a complicated procedure, but can be predicted by standard heat transfer calculations. Normally these calculations would only be carried out if personnel had to remain in refuge stations for prolonged periods of time. The air quality in a refuge station imposes the most restrictive limit on the occupancy time, not heat.

The expected length of occupancy and effective temperature have a direct bearing on the amount of potable water that should be provided to prevent dehydration (Figure 8.7). It is difficult to estimate maximum expected effective temperature, but most temperatures in underground refuge stations are generally around 21°C (70°F), because of heaters and the luminaries installed inside. Therefore, if it is assumed that men will normally spend 8 hours within a refuge station during an emergency, then a minimum of 0.8-1 quarts of water (0.8-1 litres) per person should be provided.

If water is provided in sealed containers, the seals should be checked weekly.

Temperature may become a major factor during a fire situation, when personnel in a refuge station are subjected to high heat stress. Effects of heat stress include: heat cramps caused by loss of salt; heat exhaustion caused by inadequate blood flow to the skin; and heat stroke caused by eventual cessation of sweating. (19) It may be important for Control to know the temperature within the refuge station to monitor for these conditions and prioritize mine rescue activities accordingly.

Therefore, a thermometer should be placed inside the refuge station with the emergency supplies and materials.
FIGURE 8.6
EFFECTIVE TEMPERATURE (EF) (9) *

<table>
<thead>
<tr>
<th>DRY BULB TEMPERATURE °F</th>
<th>EFFECTIVE TEMPERATURE AT VARYING HUMIDITIES</th>
<th>50%</th>
<th>70%</th>
<th>90%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>10</td>
<td>50 (10)</td>
<td>50 (10)</td>
<td>50 (10)</td>
<td>50 (10)</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>50 (10)</td>
<td>50 (10)</td>
<td>50 (10)</td>
<td>50 (10)</td>
</tr>
<tr>
<td>60</td>
<td>15.6</td>
<td>58 (14.4)</td>
<td>58 (14.4)</td>
<td>59 (15)</td>
<td>60 (15.6)</td>
</tr>
<tr>
<td>65</td>
<td>18.3</td>
<td>62 (16.7)</td>
<td>63 (17.2)</td>
<td>64 (17.8)</td>
<td>65 (18.3)</td>
</tr>
<tr>
<td>70</td>
<td>21.1</td>
<td>66 (18.9)</td>
<td>67 (19.4)</td>
<td>69 (20.6)</td>
<td>70 (21.1)</td>
</tr>
<tr>
<td>75</td>
<td>23.9</td>
<td>70 (21.1)</td>
<td>72 (22.2)</td>
<td>74 (23.3)</td>
<td>75 (23.9)</td>
</tr>
<tr>
<td>80</td>
<td>26.7</td>
<td>74 (23.3)</td>
<td>76 (24.4)</td>
<td>78 (25.6)</td>
<td>80 (26.7)</td>
</tr>
<tr>
<td>85</td>
<td>29.4</td>
<td>78 (25.6)</td>
<td>80 (26.7)</td>
<td>83 (28.3)</td>
<td>85 (29.4)</td>
</tr>
<tr>
<td>90</td>
<td>32.2</td>
<td>81 (27.2)</td>
<td>85 (29.4)</td>
<td>88 (31.1)</td>
<td>90 (32.2)</td>
</tr>
<tr>
<td>95</td>
<td>35</td>
<td>85 (29.4)</td>
<td>89 (31.7)</td>
<td>93 (33.9)</td>
<td>95 (35)</td>
</tr>
<tr>
<td>100</td>
<td>37.8</td>
<td>88 (31.1)</td>
<td>94 (34.4)</td>
<td>97 (36.1)</td>
<td>100 (37.8)</td>
</tr>
</tbody>
</table>

Note: * Assumed no measurable air velocity in refuge station

For still air effective temperature:

$$EF = [107.5 \ t_{dry} - 45.2 \ t_{wet}] / [t_{dry} - t_{wet} + 62.3] \ °F$$

TOLERANCE LIMITS FOR CLOTHED HEALTHY SUBJECTS AT REST (9)

<table>
<thead>
<tr>
<th>EFFECTIVE TEMPERATURE RANGE °F</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 - 68</td>
<td>Most people will tolerate these conditions.</td>
</tr>
<tr>
<td>68 - 72</td>
<td>Desirable range for long term comfort.</td>
</tr>
<tr>
<td>72 - 82</td>
<td>Most people will tolerate these conditions.</td>
</tr>
<tr>
<td>82 - 90</td>
<td>Physiological stresses can be tolerated by most people for several hours and some hardy individuals for 24 hours.</td>
</tr>
<tr>
<td>+90</td>
<td>Severe physiological stresses can be tolerated without injury for only a few hours.</td>
</tr>
</tbody>
</table>
FIGURE 8.7
DAILY REQUIREMENT FOR DRINKING WATER TO AVOID DEHYDRATION IN MEN AT REST (2)

<table>
<thead>
<tr>
<th>EFFECTIVE TEMPERATURE °F</th>
<th>WATER CONSUMPTION U.S. QUARTS PER DAY (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 AND LESS</td>
<td>2.0</td>
</tr>
<tr>
<td>70</td>
<td>2.5</td>
</tr>
<tr>
<td>80</td>
<td>3.5</td>
</tr>
<tr>
<td>85</td>
<td>4.0</td>
</tr>
<tr>
<td>90</td>
<td>5.0</td>
</tr>
<tr>
<td>95</td>
<td>6.0</td>
</tr>
<tr>
<td>100</td>
<td>7.0</td>
</tr>
<tr>
<td>105</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Note: (*), U.S. QUARTS x 0.95 = LITRES

8.8 QUANTITY AND QUALITY OF AIR TO BE PROVIDED

Quality of Air

While people are in a refuge station, the ventilation to be provided should ensure a healthy atmosphere for the period that they must remain inside. The refuge station must be designed so as to keep any fire gases from entering.

In addition, the refuge station should be designed to keep oxygen levels above 18% and carbon dioxide levels below 5000 ppm (0.5%). However, during a mine fire, personnel may have to endure much higher concentrations within the refuge station as a result of higher occupancy rates or longer stay times.

In general, the amount of replacement air required to prevent buildup of carbon dioxide concentration above 5000 ppm is greater than that to maintain the oxygen level above 18%. Therefore, design considerations will specify air flows to prevent the buildup of carbon dioxide as well as maintaining oxygen levels.

Ventilation: Use of Compressed Air

In the event of a fire in a mine, workers are often instructed to take shelter in a refuge station. By regulation, such locations are required to be supplied with compressed air to replace the oxygen used by the sheltering miners. Once inside the refuge station the compressed air is turned on.
The benefits of pressurizing a refuge station are obvious. As well, the same air will allow longer stay times in a refuge station.

Current procedures do not call for the flow measurement of air into the refuge station. The flow rate is determined subjectively by the occupants. Most procedures require the occupants to "crack open the air line". Experiments were performed in an equipment assembly shop (21) with a 1/2 inch ball valve on a 100 psi compressed air line. Six participants were instructed to "crack" the valve open to produce air flow as judged by a tolerable noise level, or they were instructed to "crack" the valve open because the air flow was their life support. Refer to Figure 8.8.

These flow rates are very low and without a way to measure the flow, personnel could believe that they have adequate protection when in reality they will have problems with carbon dioxide buildup and even oxygen depletion.

When ventilating with compressed air the noise levels inside can become intolerable at high flow rates. South Africa conducted tests on a refuge station with and without the use of compressed air. (22) The refuge station was normally ventilated by a 2" diameter compressed air line at 1.18 m³/s (2500 cfm) at 680 kPa (100 psi). The noise when the compressed air was on averaged 102.3 dBA with a range of 100.1 to 104.9 dBA. The peak noise measured was 105.2 dBA. When the compressed air was turned off the average noise was 59 dBA with a range of 49.4 to 64.6 dBA. Refer to Figure 8.9.

---

**Figure 8.8**
Judging Air Flow Rate (17)

<table>
<thead>
<tr>
<th>Position of Valve</th>
<th>Volume of Compressed Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lpm (cfm)</td>
</tr>
<tr>
<td>&quot;Crack&quot; the valve to produce air flow to a tolerable noise level.</td>
<td>2 - 20 (0.07 - 0.7)</td>
</tr>
<tr>
<td>&quot;Crack&quot; the valve for life support.</td>
<td>25 - 100 (0.9 - 3.5)</td>
</tr>
</tbody>
</table>
A simple manometer across the refuge station wall can be used to measure the flow rate from the compressed air source. Many refuge stations have a 2" diameter pipe through the door or wall to provide pressure relief.

The volume flowing through a pipe is related to the pressure as follows.

\[
\text{Volume (cfm)} = 4005 \times \text{Coeff of entry}(0.72) \times \text{open area (ft}^2\text{)} \times \text{pressure differential}
\]

For a 2" pipe: (I.D. = 2.067" dia.)

### Figure 8.10
Compressed Air Measurement

<table>
<thead>
<tr>
<th>Differential Pressure in, w.g.</th>
<th>Volume cfm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>47.5</td>
</tr>
<tr>
<td>1.0</td>
<td>67.2</td>
</tr>
<tr>
<td>1.5</td>
<td>82.3</td>
</tr>
<tr>
<td>2.0</td>
<td>95</td>
</tr>
<tr>
<td>2.5</td>
<td>106</td>
</tr>
<tr>
<td>3.0</td>
<td>116</td>
</tr>
</tbody>
</table>
A one-inch pressure will allow a volume of 67.2 cfm or approximately 7 cfm per person. Using the NASA-NRC graph, Figure 8.1, 7 cfm per person will mean that there is no build up of carbon dioxide and no depletion of oxygen. Therefore workers could stay in the refuge station indefinitely. However other environmental factors would then have to be considered more closely.

One paper recommends the installation of a compressed air receiver immediately adjacent to the refuge chamber in case of compressed air failure to increase the available time for rescue from five to fifteen hours. (23)

Mine compressed air supplying a permanent refuge station doesn't meet the same purity levels required by standards referencing breathing air. Normal mine compressed air contains compressor oil, carbon monoxide, antifreeze agents such as methanol or glycol, and scale; all of which the personnel within the refuge station may inhale.

It is recommended that the compressed air ventilated into the refuge station be filtered or be cleaned first by discharging the air outside.

**Ventilation: Use of Bottled Air**

Another method of extending the occupancy time of a refuge chamber is to install bottles of compressed air as in the case of a portable refuge station.

In a portable refuge station the jumbo cylinders are filled with air meeting breathing quality standards as per CSA Standard Z180.1-M85 “Compressed Breathing Air”. (24) Refer to Figure 8.11. As part of this standard, the air within the bottles must be changed out every three months. If not, then a sample of the compressed air should be taken every six months and sent for analysis.

**Ventilation: Use of Boreholes**

Direct ventilation of refuge stations through boreholes for shallow mines is common in South Africa. One paper describes a chamber at a depth of 80 m (260 ft.) which ventilated through a 200 mm (nominal 8” I.D.) pipe. The fan on the surface can be activated from the chamber and is diesel driven. (25) In another colliery, a 116.1 m³ (4100 ft³) refuge station designed for 30 occupants or 3.87 m³ (136 ft³) per person, is also vented directly from the surface. The air supply is via a surface borehole 150 mm (6” I.D.) by a 12 v. centrifugal fan (4400 Lpm at 320 Pa - 150 cfm at 1.3”wg). (22)

**Ventilation: Life Support Systems**

There is a move away from compressed air as a power source in mines, and thus there is a need to find another way of replenishing the air. In the last few years, tests have been carried out with a unit which both replenished the oxygen and absorbed carbon dioxide. (26), (27) The results of these tests are shown in Figure 8.11.

Both tests were approved by a Medical Ethics Committee and the volunteers were monitored on-site by a physician.
**Figure 8.11**

**CAN3-Z180.1-M85 - TABLE 2**

Breathing Air - Maximum Allowable Concentration of Contaminants (by Volume, Measured at 21 °C (69.8 °F) and 101.3 kPa (14.7 psig)) (20)

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>5 mL/m³ *</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>500 mL/m³</td>
</tr>
<tr>
<td>Methane</td>
<td>25 mL/m³</td>
</tr>
<tr>
<td>Non-methane hydrocarbons</td>
<td></td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>0.3 mL/m³</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>2.5 mL/m³</td>
</tr>
<tr>
<td>Halogenated hydrocarbons:</td>
<td></td>
</tr>
<tr>
<td>- Trichlorotrifluoroethane</td>
<td></td>
</tr>
<tr>
<td>- Dichlorodifluoromethane</td>
<td></td>
</tr>
<tr>
<td>- Chlorodifluoromethane</td>
<td></td>
</tr>
<tr>
<td>Oil, particulate &amp; condensate water</td>
<td>1 mg/m³</td>
</tr>
</tbody>
</table>

(a) The dew point at line pressure shall be at least 5°C (9°F) below the minimum temperature to which any part of the breathing air system is exposed at any season of the year.

(b) Under no circumstances shall the dew point exceed 53°C for systems at or above 12.4 MPa (1800 psi).

Refer to Appendix C of ACGIH Booklet

Odour

Others

* 1 mL/m³ = 1 ppm by volume

Contaminants other than those listed in Figure 8.11 shall not exceed the odour threshold or 1/10 of the current Threshold Limit Value documented by the American Conference of Governmental Industrial Hygienists (ACGIH). The threshold limit value for total combined mixtures of contaminants as documented in current Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes (see Appendix C of ACGIH Booklet) shall apply. The values used in calculating mixtures shall be as in Figure 8.11 or 1/10 of the current Threshold Limit Value as documented by the ACGIH.

**Note:** Samples being analysed must meet the purity requirements shown in Figure 8.11.
### Figure 8.12 - TESTS OF LIFE SUPPORT SYSTEMS

<table>
<thead>
<tr>
<th>Location and Description</th>
<th>Size $m^3$ (ft³)</th>
<th>No. of People</th>
<th>Time into Test min.</th>
<th>Dry Bulb Temp. °C</th>
<th>% R.H.</th>
<th>Eff. Temp. °C</th>
<th>% $O_2$</th>
<th>% $CO_2$</th>
<th>Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Lac du Bonnet, AECL</td>
<td>22</td>
<td>25</td>
<td>0</td>
<td>16</td>
<td>75</td>
<td>14.4</td>
<td>20.9</td>
<td>0.11</td>
<td>Not measured</td>
</tr>
<tr>
<td>March 4 &amp; 5 1993</td>
<td></td>
<td></td>
<td>1</td>
<td>18</td>
<td>100</td>
<td>18</td>
<td>20.2</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>19</td>
<td>100</td>
<td>19</td>
<td>20.0</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>20</td>
<td>100</td>
<td>20</td>
<td>19.8</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(777)</td>
<td></td>
<td>6</td>
<td>20.5</td>
<td>100</td>
<td>20.5</td>
<td>19.5</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Rana - Air System with 0.5 Lpm $O_2$ addition per person and $CO_2$ scrubbing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>20.5</td>
<td>100</td>
<td>20</td>
<td>20</td>
<td>20.5</td>
<td>20.5</td>
<td>19.5</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>20.5</td>
<td>100</td>
<td>20</td>
<td>20</td>
<td>20.5</td>
<td>20.5</td>
<td>19.5</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>20.5</td>
<td>100</td>
<td>20</td>
<td>20.5</td>
<td>20.5</td>
<td>20.9</td>
<td>20.5</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>3 m x 3 m x 2.5 (22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 Falconbridge Ltd.</td>
<td>240</td>
<td>25</td>
<td>0</td>
<td>22</td>
<td>78</td>
<td>20</td>
<td>20.9</td>
<td>0.07</td>
<td>21.7 Lpm/ min/m³ at 50 Pa</td>
</tr>
<tr>
<td>Kidd Creek Mine</td>
<td></td>
<td></td>
<td>1</td>
<td>24</td>
<td>88</td>
<td>23</td>
<td>20.5</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>April 1994</td>
<td></td>
<td></td>
<td>2</td>
<td>27</td>
<td>88</td>
<td>26</td>
<td>20.4</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8475)</td>
<td></td>
<td>3</td>
<td>27.5</td>
<td>88</td>
<td>26.5</td>
<td>20.4</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Rana Air System with 0.5 Lpm $O_2$ addition per person and $CO_2$ scrubbing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>29.5</td>
<td>90</td>
<td>28.4</td>
<td>20.3</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>29.6</td>
<td>91</td>
<td>28.5</td>
<td>20.3</td>
<td>0.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>30.5</td>
<td>92</td>
<td>29.5</td>
<td>20.5</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.4 m x 5.3 m x 3.6 m (23)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During the tests both carbon dioxide concentrations and oxygen concentrations were maintained at safe levels allowing the occupants to remain in the refuge station for 24 hours.

After the test results were known, questions were raised on the possible carbon dioxide concentrations that would have been present if only compressed air had been used. It was assumed that conditions would be similar to those encountered in the test.

Based on the designed oxygen consumption rate of 0.5 Lpm approximately 0.43 Lpm of carbon dioxide would be generated. Based on a theoretical analysis, the results are shown in Figure 8.13.

**Figure 8.13**

PREDICTED CO₂ CONCENTRATION

<table>
<thead>
<tr>
<th>System Used</th>
<th>Ventilation Flow Rate m³/s (cfm)</th>
<th>CO₂ After 24 Hours ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rana - Air System</td>
<td>0.075 (160)</td>
<td>2500</td>
</tr>
<tr>
<td>Compressed Air*</td>
<td>0.075 (160) 0.047 (100) 0.035 (75) 0.024 (50) 0.011 (25)</td>
<td>2650 4030 5260 7700 14800</td>
</tr>
<tr>
<td>Dead Space Volume</td>
<td></td>
<td>62500</td>
</tr>
</tbody>
</table>

**Note: (*)**

Theoretical calculations

From the above analysis the Rana - Air System performed as well as an equal amount of “fresh air” ventilating the refuge station. Unlike compressed air, this air cleaning unit does not generate any pressure inside the refuge station to keep potential fire gases out. When using this type of a system, the sealing of the refuge station becomes very important.
8.9 **Air Supply Failure**

Although the air supply to a refuge station is generally secure, failures of the air supply do occur. There have been cases where there has been an unexpected loss of compressed air. In one instance smoke was transported through a ruptured air line into a refuge station. *(Ontario, 1990)* In another case air was sucked out by the fire from the chamber. *(Manitoba, 1989)* In both cases a fire vaporized the rubber seals in the victaulic couplings in the compressed air line. Alert workers in both situations had the presence of mind to close the compressed air valves inside the refuge station.

South Africa carried out two tests on refuge stations showing what occurred when the ventilation system failed. *(22)* The refuge stations were occupied by mine workers who volunteered on the basis of informed consent. The results are shown in Figures 8.14 and 8.15.

The life sustaining potential of the Hartebeestfontein refuge station in the event of a disruption of the air supply is drastically affected by heat. It is estimated that severe discomfort would occur in 75 minutes and the occupants would collapse within four hours.

In both situations oxygen levels would be depleted to 16% within eight hours. The specific volume allowed per person in the refuge station was 2 m$^3$ and 3.87 m$^3$ versus 10 m$^3$ recommended by this committee.
<table>
<thead>
<tr>
<th>Location and Description</th>
<th>Size (m³)</th>
<th>No. of Men</th>
<th>Time into Test min.</th>
<th>WBGT (I) °C</th>
<th>Eff. Temp. °C</th>
<th>% O₂</th>
<th>% CO₂</th>
<th>Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartebeestfontein Gold Mine, South Africa</td>
<td>343.3</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Ventilation 2&quot; dia. compressed air line 1.18 m³/s (2500 cfm) at 100 psi</td>
<td></td>
<td></td>
<td>0</td>
<td>25.4</td>
<td>26.8</td>
<td>20.9</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>1.2 No ventilation</td>
<td></td>
<td></td>
<td>30</td>
<td>24.8</td>
<td>26.6</td>
<td>20.9</td>
<td>0.04</td>
<td>SF₆</td>
</tr>
<tr>
<td>L x W x H</td>
<td></td>
<td></td>
<td>60</td>
<td>31.9</td>
<td>31.8</td>
<td>20.5</td>
<td>0.36</td>
<td>v/v</td>
</tr>
<tr>
<td>36.8 m x 2.81 m x 3.32 m (12120 ft³)</td>
<td></td>
<td></td>
<td>90</td>
<td>34.8</td>
<td>34.3</td>
<td>20.1</td>
<td>0.65</td>
<td>None</td>
</tr>
<tr>
<td>hrs.</td>
<td></td>
<td></td>
<td></td>
<td>35.5</td>
<td>35.1</td>
<td>19.9</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>1.3 Estimated Critical Times at 0.3 Lpm/min O₂</td>
<td></td>
<td></td>
<td>7.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

(1) \( WBGT = \text{wet bulb globe temperature index} \)

\[ WBGT = 0.7 \times \text{wet} + 0.2 \times \text{globe} + 0.1 \times \text{dry bulb} \]

(2) \( \text{Time O}_2 \% = 53.72 + ((16-20.9)/(-0.0116)) \)

(3) \( \text{Time CO}_2 \% = 51.37 + ((5-0.005)/(+0.0089)) \)
### Figure 8.15 - TESTS SIMULATING AIR SUPPLY FAILURES (18) Borehole Supplied Ventilation

<table>
<thead>
<tr>
<th>Location and Description</th>
<th>Size (m³) (ft³)</th>
<th>No. of Men</th>
<th>Time into Test min.</th>
<th>WBGST (°C)</th>
<th>Eff. Temp. (°C)</th>
<th>% O₂</th>
<th>% CO₂</th>
<th>Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 Douglas Colliery South Africa</td>
<td>116.1</td>
<td>41</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Ventilation 6&quot; dia. borehole from surface 0.07 m³/s (150 cfm)</td>
<td>(4100)</td>
<td>40</td>
<td>19.8</td>
<td>19.8</td>
<td>20.9</td>
<td>0.05</td>
<td></td>
<td>SF₆ v/v</td>
</tr>
<tr>
<td>2.2 No ventilation</td>
<td>0</td>
<td>30</td>
<td>20.7</td>
<td>20.8</td>
<td>20.9</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L x W x H</td>
<td>7.8 m x 6.2 m x 2.4 m</td>
<td>60</td>
<td>21.7</td>
<td>21.7</td>
<td>20.6</td>
<td>0.37</td>
<td>4.55</td>
<td>10⁻⁴ ppm/min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>21.8</td>
<td>21.8</td>
<td>20.4</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>22.1</td>
<td>22.0</td>
<td>20.1</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>105</td>
<td>22.2</td>
<td>22.0</td>
<td>19.8</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 Estimated Critical Times at 0.3 Lpm/min O₂</td>
<td>hrs.</td>
<td>7.75</td>
<td>9.59</td>
<td>16</td>
<td>3</td>
<td>(2)</td>
<td></td>
<td>(4)</td>
</tr>
</tbody>
</table>

### Notes:
1. WBGST = wet bulb globe temperature index  
   = 0.7 wet + 0.2 globe + 0.1 dry bulb
2. Time O₂ % = 46.79 + ((16-20.9)/(0.0104))
3. Time CO₂ % = 45.84 + ((5-0.145)/(0.0083))
4. SF₆ (v/v x 10⁻⁴) = average of 4.55 x 10⁻⁴ ppm/minute
8.10 **EXAMPLE # 3**

The following example attempts to place into perspective the points discussed in this section.

A fire has occurred in a mine. On the level of concern a refuge station has the following dimensions - 8 ft. high x 15 ft. wide x 18 ft. long. The refuge station was originally designed to normally accommodate 10 people for 8 hours. During the fire the following information has been received.

1. 15 people in refuge station
2. refuge station sealed 9:00 a.m.
3. 12:30 p.m. refuge station has lost compressed air, manometer neutral
4. ambient inside temperature 85°F
5. 8 quarts of potable water available

As Control, you know that the fire must be put out before you can even approach the refuge station. How much time do the teams have to get to the men?

**Solution:**

1. volume of refuge station
   
   \[ 8 \times 15 \times 18 = 2160 \text{ ft}^3 \]

2. unit volume per person 144 ft³

3. use **Figure 8.1** with no compressed air

4. initial decision is to assume the men will be in the refuge station for at least 5 hrs. Calculate:
   
   \[ \text{RATIO T} = \frac{\text{time after entry (hours)}}{\text{hours}} = \frac{5}{0.035} \]
   
   \[ V \text{ unit volume per person} = 144 \]

5. Locate 0.035 on left hand side of the graph and draw a horizontal line. Where this line intersects the NO VENTILATION lines on the graph for CO₂ and O₂, draw lines vertically upwards to intersect the upper scale. Read 2.5% CO₂ and 17% O₂.

6. Repeat this procedure and interpret health effects from Figures 4 and 5. This information is summarized below.
<table>
<thead>
<tr>
<th>TIME AFTER COMPRESSED AIR LOST HRS.</th>
<th>REAL TIME</th>
<th>Oxygen</th>
<th>CO₂</th>
<th>Oxygen /CO₂ SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5:30 p.m.</td>
<td>17.0</td>
<td>2.9</td>
<td>Men experiencing headaches</td>
</tr>
<tr>
<td>9</td>
<td>9:30 p.m.</td>
<td>14.3</td>
<td>5.25</td>
<td>Men intoxicated, laboured breathing, coordination affected</td>
</tr>
<tr>
<td>12</td>
<td>12:30 a.m.</td>
<td>12.5</td>
<td>6.75</td>
<td>Men unconscious</td>
</tr>
</tbody>
</table>

As a result of this exercise, Control will set a target of 5 to 9 hours. It may be that compressed air can be restored even if the refuge station cannot be approached. After 12 hours, the men in the refuge station are unconscious so that team must bring in oxygen resuscitators. If the men are equipped with oxygen generating self rescuers, Control would order the men not to wear them until after 9:30 p.m., 9 hours after the compressed air has been lost. This will buy the teams an additional four hours.

8.11 RECOMMENDATIONS

In order to provide improved protection to workers requiring the use of refuge stations the following recommendations are made.

- The emergency underground plans should show;
  - the dead space volume of each permanent refuge station
  - the number and pressure of jumbo cylinders for each portable refuge station.

- For permanent refuge stations a manometer should be installed across the wall to allow estimation of both pressure buildup and the amount of compressed air flowing into the chamber. The range of the manometer should be such that half a cubic foot per minute per person can be estimated.

- In a portable refuge station discharge air from the manifold of the jumbo cylinders should be provided with a flowmeter. The range of the flowmeter should be such that half a cubic foot per minute per person at normal pressure can be measured.

- A means to relieve excess pressure should be installed in all refuge stations.

- All cracks in refuge station walls where leakage may take place should be permanently sealed.
• All refuge stations should have a standard thermometer mounted on an inside wall.

• As a minimum, one quart of potable water per person should be provided within the refuge station.

• All compressed air in refuge stations should be “cleaned” prior to use by either using
  - a suitable filter, or
  - a by-pass line so that the scale, oil and other contaminants are initially discharged outside the refuge station

• The discharge of the compressed air should be attenuated.
APPENDIX 1 - References


(7) Warncke, E., "The problem of oxygen partial pressure when using filter self rescuer hoods in case of fire", Drager Review, 49, Lubeck, Germany, May 1982 (Table 1: Typical symptoms of oxygen deficiency at various altitudes, after Lockheed Field Service Digest, Issue 47).


(14) Government of Ontario, "Regulation Respecting Control of Exposure to Biological or Chemical Agents", RRO 1990, O.Reg. 833, Ontario Government Publications, Toronto, ON.


(16) Source (11) also states, "NIOSH has recommended a limit of 1% carbon dioxide as a time-weighted average value, with a permissible excursion to 3% not to exceed 10 minutes duration, frequency unspecified." On August 12, 1994, Michael McCawley, Supervisor Respiratory Disease Studies, Environmentals Branch, NIOSH stated that this recommendation has been taken out of context from an older NIOSH report. NIOSH has an official list of recommended limits, but this level is not on this list. The quote will be discussed with the ACGIH.


**APPENDIX 2 - Bibliography**

"PATTY'S INDUSTRIAL HYGIENE AND TOXICOLOGY", Third revised edition, volume 2C: Toxicology, John Wiley & Sons, 1982


CONSTANCE, J.D., "CONTROLLING IN-PLANT AIRBORNE CONTAMINANTS", Marcel Dekker, Inc., N.Y., 1983
Information contained in this report was made available by the following sources:

- ALGOMA ORE
- GEORGIA - PACIFIC, CALEDONIA MINE
- FALCONBRIDGE LTD., KIDD MINING DIVISION
- INCO LTD.
- J.S. REDPATH
- BARRICK GOLD CORPORATION
- MINES AND AGGREGATES SAFETY & HEALTH ASSOCIATION
- MINISTRY OF LABOUR - MINE RESCUE, WORKING ENVIRONMENT SECTION
- PLACER DOME, CAMPBELL MINE
- WILLIAMS MINE OPERATING CORP.
- SIFTO CANADA, GODERICH MINE

Various Suppliers
REFUGE ONE Air Centre

In underground mining operations, standard emergency procedures require miners to take refuge in a safe area in the event of a mine fire or explosion. In these refuge stations, excavated out of the actual rock close to where the miners are working, which are usually utilized as lunch rooms, miners are required to seal themselves in and to turn on a compressed air line to supply suitable air for breathing. There have been instances, recently, where the compressed air line has failed. It has been burned out as part of an equipment fire and there is belief that it can be destroyed by rock bursts and falls. Therefore, an alternate means of supplying suitable breathing air has been developed.

Now, let's go back to the mine fire. The miners have sealed themselves into the refuge station and have immediately commenced to consume oxygen (O2) and exhale carbon dioxide (CO2). Unless there is a new source of O2 and a system for scrubbing the CO2, these gasses would reach levels which would be immediately dangerous to life and health. (IDLH) The REFUGE ONE Air Centre is a new life saving device developed for exactly this type of situation.

The REFUGE ONE Air Centre was developed and manufactured by Rimer Alco North America in Morden, Manitoba, a firm which manufacturers on-site hospital oxygen production plants. It is sold and serviced by MSA Canada Inc of North York, Ontario, the Canadian arm of the largest manufacturer and distributor of Occupational Health and Safety equipment in the world, Mine Safety Appliances Company of Pittsburgh, PA.

Before we get into how it works, let's look at the historical development of the REFUGE ONE Air Centre.

Recently, emergencies have occurred in hard rock mines where compressed air lines, supplying life supporting breathing air, have been damaged or destroyed. In one instance, smoke, and other products of combustion, were actually transported through a broken air line into a refuge station (Ontario 1990). Some mines, particularly soft rock mines, eg. salt, gypsum, potash and coal, do not have compressed air underground and as more and more of the mine production is performed without compressed air, the need for self-contained life support systems becomes a paramount issue.

The Mines Accident Prevention Association of Manitoba (MA-PAM) and the Manitoba Department of Labour in cooperation with the Ontario Ministry of Labour, Mine Rescue Division, decided that an imitative was necessary to decide what type of protection could be made available in the event of a mine fire.

Operation "Tommyknocker I" was performed at AECL's underground research laboratory at Lac Du Bonnet, Manitoba, in 1993, wherein 6 volunteers were sealed into a simulated refuge station at the 785 foot level for 24 hours with the REFUGE ONE Air centre as their only source of clean breathing air. This monitored action proved that the O2 levels can be kept between 19.5% and 20.9% while keeping the CO2 levels at less than 2300 ppm.

In April, 1994, a second study of the REFUGE ONE Air Centre took place at the 5200 foot level of Falconbridge Ltd., Kidd Creek Division Mine at Timmins, Ontario, wherein 25 Mine Rescue volunteers were asked to spend 24 hours in an operating Ontario mine refuge station, again, with the REFUGE ONE Air Centre as the only source of clean breathing air.

The objectives of "Tommyknocker II" were:

1. to evaluate the REFUGE ONE Air centre in a real underground refuge station
   Containing a relatively large group of miners,
2. to test an improved prototype of the system for ease of operation as per the first study, recommendations and to verify the systems ability to maintain safe levels of O2 and CO2,
3. to use external monitoring of gasses in the refuge station in order to duplicate realistic conditions wherein personnel inside have to make the decisions as to whether or not change the CO2 scrubber system using only the scrubbing material indicator (colour change),
4. to determine the potential applications of the REFUGE ONE Air Centre in underground emergency situations.

The REFUGE ONE Air Centre met and, in some respects, surpassed the expectations of the test participants. As far as meeting the objectives of the Project, it can be safely stated that:

1. the REFUGE ONE Air Centre performed well in a realistic refuge station emergency situation and results were consistent with data collected in the first study, Operation "Tommyknocker I",
2. the prototype was easy to operate and the participants agreed that the instructions were clear. The system can be started up in less than 10 minutes, which includes filling 2 drawers with the chemical to adsorb the CO2. The system provided safe CO2 levels (average of 2500 ppm) and maintained O2 levels within an acceptable range (20-2% to 20.6%), (See Figures I & 2.)
3. external monitoring of the CO2 and O2 levels was used to verify the fact that the scrubbing chemical colour indicator can be used by inside participants in order to make the decision to change the chemical scrubber,
4. the study provided data and information which will be useful in formulating the requirements needed in order to be able to apply this new technology in underground situations.

Upon completion of the field tests and after reviewing the study data, the "Tommyknocker II" Planning and Coordinating Committee collectively recognized that the REFUGE ONE Air Centre concept had the potential to greatly improve the safety of underground workers and the system could be used underground as part of a comprehensive mine emergency response program. The first 4 REFUGE ONE Air Centres went into service at mine #3 at Falconbridge Ltd., Kidd Creek Division in Timmins, Ontario, in March of 1995.

RIEFUGE ONE Air Centre Process and Operation

The REFUGE ONE Air Centre consists of two integrated processes; an O2 supply and a CO2 scrubber system. The performance characteristics, for example, for 20 people are: a) O2 supply — more than 30 hours; b) CO2 adsorbing capacity — more than 30 hours; c) battery power supply — (fully charged) about 36 hours.

To supply O2, three 244 cu/ft Medical O2 cylinders with O2 stored at 2200 psig are cascaded together and regulated down to accurately set the required flow of 0.5 L/min per person in the refuge station. This is achieved with a single stage O2 serviced regulator and a rotameter. Based on available research on human consumption of O2, the system is designed to supply O2 to 20 workers for 30 hours. In actual extrapolation, 20 workers consuming O2 at a rate of, 5 L/min per person would get approximately 34 1/2 hours out of a full 3 cylinder O2 system (732 cu/ft or 20,728 L).

CO2 is removed by circulating refuge station air through 2 separate scrubbing drawers full of soda lime using 2 battery powered fans, each operating at 2260 L/min (80 cfm). The principle of CO2 scrubbing utilizing soda lime involves a series of chemical reactions whereby the gas diffuses into the water layer surrounding the soda lime granules. The scrubbed air is then discharged on opposite sides of the console of the REFUGE ONE Air Centre in order to enhance air circulation in the refuge station - As the soda lime
becomes saturated with CO2, it changes in colour from white to blue or purple. When the colour reaches a graduation line on the observation window of the drawers, it becomes time to change the chemical. Latest thinking however, states that the soda lime should be changed at prescribed times and colour indicators should only be used as a back up.

The electrical power for the fans is 120 VAC (normal Canadian application — other services are and can be made available) supplying "smart" chargers which, in turn, supply 12 VDC long life lead acid batteries.

The dimensions of the REFUGE ONE Air Centre are approximately as follows; height — 65.5"; length — 55.0"; width — 3 1.0". The weight with the O2 cylinders is approximately 1230 lbs. and without the cylinders about 780 lbs.— (It should be noted that the vendor, MSA Canada Inc, does not supply the O2 cylinders. It is the responsibility of the purchaser to supply the O2.)

In our advertising and sales literature as well as our sales presentations, we have repeatedly stated that the REFUGE ONE Air Centre is easy to operate and that anyone with minimal training will be able to read the instructions printed on the side of the control panel. There are only 5 basic steps for the people in the refuge station to take.

1. Turn on the O2.
2. Set the O2 flow according to the number of people in the station.*
3. Fill the drawers with soda lime and put them in place.
4. Start the CO2 blowers.
5. Relax and wait for the Mine Rescue Team who will come to take you out.

* The setting of the rotameter is based on the number of people in the station who will consume O2 at a rate of 0.5 L/min; eg. 12 people in the station calls for a setting of 6; 15 people would require a setting of 8 as we always read uneven numbers by adding one digit to make them even.

A recent addition to the line is the result of an agreement among Rimer Alco North America, J. S. Redpath Group and MSA Canada Inc. We are pleased to announce that MSA Canada Inc is the sales and service centre for the Portable Refuge Station complete with the self-contained REFUGE ONE Air Centre.

The Portable REFUGE ONE Air Centre is a skid-mounted, fiberglass structure, designed for use in a mining environment. It's dimensions are: length — 10'6"; width — 4'2"; height — 6'11.5"; and the weight without the O2 cylinder (as in the REFUGE ONE Air Centre MSA Canada Inc does not supply the O2 cylinder) — about 1600 lbs. The source of power is similar to the REFUGE ONE Air Centre at 120 VAC supplying a "smart" charger which keeps 2 12 VDC long life lead acid batteries at full charge to supply power to the 80 cfm blower.

Designed to seat 6 workers comfortably (with standing or floor room for about 4 more), this system will protect 6 workers for about 36 hours. Extrapolating the numbers would indicate that 9 workers would be protected for about 25 hours and, if one were to assume that the hard wire electrical sourced power would prevail, three workers would be protected for about 72 hours.

We, at MSA Canada Inc., are now in a position to supply the REFUGE ONE Air Centre for semi-permanent refuge stations, the Portable REFUGE ONE Air Centre for the smaller mining operations on development sites, and for those employers who feel that compressed air is both suitable and appropriate, the Redpath Portable Refuge Station.
The following figures will show the monitoring of the CO₂ (Figure 1), O₂ (Figure 2), and ambient temperature and relative humidity (Figure 3) during the "Tommyknocker II" test. Figure 4 is an Air Flow Schematic of the REFUGE ONE Air Centre.

MSA Canada Inc. would like to thank the people of CANMET, Mining Research Laboratories; The Ontario Ministry of Labour, Mine Rescue Division; and the Mines Accident Prevention Association of Manitoba, for allowing us to quote directly from the "Tommyknocker II" report.

For further information, please call MSA Canada Inc. at 1-800-267-0672.

Gerry W. Smith
Sales Director, Special Assignments
MSA Canada Inc.
ABOUT THE AUTHOR

Gerry W. Smith was born in Halifax, Nova Scotia, and attended St. Mary's University in that city. Joining MSA Canada Inc in 1965 as a District Sales Representative, he was appointed Central District Sales Manager in 1977 and National Sales Manager in 1982. In 1990 he accepted the challenge of becoming Sales Director, Special Assignments, with special emphasis on the marketing of underground mining products, the position he currently holds. He resides with his wife, Barbara, in Aurora, Ontario.
Fig. 1. Carbon dioxide concentration in the center of the refuge station.

Fig. 2. Oxygen concentration at the REFUSE ONE outlets.
Tommyknocker II
Ambient Temperature and Rel. Humidity

Fig. 3 Ambient temperature and relative humidity.
"REFUGE ONE" AIR CENTRE

ANNEX #1: AIR/OXYGEN FLOW DIAGRAM

- Refuge Station Air
  - CO₂ Elevated
  - O₂ Depleted

- Processed Air
  - CO₂ Removed
  - O₂ Added

- Oxygen Supply

- Refuge Station Air
  - CO₂ Elevated
  - O₂ Depleted
FEATURES

- Maintains $O_2$ and $CO_2$ levels within standard TLV limits without external power or compressed air
- Simple and easy to use
- Security-sealed, removable two-piece waterproof top cover
- All controls accessible when top cover removed
- Auto-charge battery system complete with audiovisual low battery alarm
- Heavy duty steel base accommodates a fork lift
- Ten year underground life expectancy

DESCRIPTION

In underground mines, mine regulations and standard emergency procedures require miners to enter a specially constructed refuge station in the event of a mine fire or some other emergency that may potentially result in contaminated atmospheres. Once miners have entered a refuge station under such or similar conditions, they are required to seal themselves within that station until relieved. Under these conditions, however, exhaled carbon dioxide and depleted oxygen will rapidly reach a concentration that would be hazardous to health.

The REFUGE ONE Air Centre is a new life-saving device for use in underground Mine Refuge Stations for exactly this type of situation. Developed by Rimer Alco North America and distributed by MSA Canada Inc., the REFUGE ONE Air Centre is the first device of this type to be tested successfully in an underground refuge station under simulated operational conditions. The underground tests were monitored by CANMET Mining Research Laboratories and Atomic Energy of Canada Limited. The REFUGE ONE Air Centre processes the air contained in a sealed Mine Refuge Station and removes potentially harmful carbon dioxide while replenishing the oxygen that has been consumed. The REFUGE ONE Air Centre is a compact, easy to use, self-contained breathing air reprocessing system. Just install the carbon dioxide scrubber, start the oxygen flow, turn on the blowers and the REFUGE ONE Air Centre is in operation. Battery powered blowers draw the room air and pass it through the scrubber system where the carbon dioxide is reduced. The processed room air then has the oxygen replenished to maintain normal oxygen-in-air concentrations.
**SPECIFICATIONS**

**Physical Dimensions:**
- **Width:** 31 inches
- **Length:** 55 inches
- **Height:** 65.5 inches
- **Weight:**
  - Less oxygen cylinders: 1,155 lbs
  - C/w oxygen cylinders: 1,545 lbs

**Charger**
- **Input Voltage:** 120 VAC/60 Hz
- **Back Up Power Supply:** 12 VDC/400 AH Battery Stack

**MINIMUM PERFORMANCE CHARACTERISTICS**

For 20 people:
- **Oxygen:** 32 Hours
- **Carbon Dioxide:**
- **Adsorption:** 34 Hours
- **Battery Capacity:** 36 Hours

**APPROVALS**

All required electrical connections are CSA certified.

**OPERATING INSTRUCTIONS**

The **REFUGE ONE Air Centre** has been designed to be easy to operate under stressful conditions. The start-up instructions are simple and easy to follow:

1. Break the Security Seals and remove the covers.
2. Install the Carbon Dioxide Absorber Chemical.
3. Start the Blowers.
4. Turn on the Oxygen.
5. Set the Oxygen flow rate according to the number of occupants in the Refuge Station.

The **REFUGE ONE Air Centre** can be relied upon to maintain a safe, breathable atmosphere for periods in excess of 24 hours in an occupied sealed Mine Refuge Station without any need for connection to compressed air or electricity. The system uses components with long life ratings and has a ten year underground life expectancy. All switches and operational controls remain securely covered until the security seal is broken and the covers removed. Portability, convenience and safety - a winning combination for any mine manager.

**TEST REPORT**

The **REFUGE ONE Air Centre** has been tested under realistic conditions. To obtain a copy of the CANMET's Mining Research Laboratory test report please call the MSA Office nearest you or contact your local MSA Sales Representative.

**ORDERING INFORMATION**

- **212347** REFUGE ONE Air Centre
- **200000** REFUGE ONE Air Centre only, Modular for installation into Mobile Safety Base
  - **Accessories:**
    - **212905** Screwdriver, Security
    - **212857** Replacement Parts:
      - **Chemical Absorber:** Sofoline 797
    - **212885** Gasket, Chemical Absorber Tray
    - **212886** Hopper, Black
    - **212887** Blower, 12 VDC
    - **212888** Toggle ON/OFF Switch
    - **212889** Indicator Lamp, Blower
    - **212890** Indicator Lamp, System
    - **212891** Indicator Lamp, Alarm
    - **212892** Buzzer, Audible Alarm
    - **212893** Lamp, Reading
    - **212894** Battery, 12VDC, 100 AH
    - **212895** Battery Charger Assembly
    - **212896** Fuse (F1-F4)
    - **212897** Fuse, Charger
    - **212898** Cap, Aux. Oxygen Inlet
    - **212899** Bypass HP Hose Assembly CGA 540
    - **212900** Pigtail Assembly, 24 inch, Stainless Steel
    - **212901** Pigtail Assembly, 18 inch, Copper
    - **212902** Flowmeter Assembly, Oxygen Covers, Fibreglass Set of Two
    - **212903** Cover Latch Assembly
    - **212904** Security Seal

**MSA**

Data Sheet 26-95-01

MSA 1995

Printed in Canada
**FEATURES**

- Self-contained unit with water supply, lighting, oxygen replenishment and carbon dioxide reduction systems
- Sized for six seated miners with standing room for four more
- Rugged, waterproof components for quick and easy clean-up
- Auto-charge battery system complete with audiovisual low battery alarm
- Steel skid for rigid support
- Ten year underground life expectancy

---

**DESCRIPTION**

Work on a development heading is both difficult and potentially dangerous. Experience dictates that accidents, mine fires or the sudden release of toxic or other gases can all occur at any time and without warning. Prepare for the unexpected with the **REFUGE ONE Mobile Safety Base**.

Jointly developed by The Redpath Group and Rimer Alco North America, and distributed by **MSA Canada Inc.**, this multifunctional portable mine safety base has been designed to act as both a shelter and a source of respirable air for emergencies in and around development headings. Normally acting as a communications centre, a portable lunchroom, first aid and comfort station, the **REFUGE ONE Mobile Safety Base** will become a shelter during an emergency situation providing breathing air for up to ten individuals. The unit will maintain up to 24 hours of safe breathable air by reducing potentially harmful levels of carbon dioxide and then replenishing the oxygen that has been consumed. Made of special fire retardant high strength moulded fibreglass, this skid mounted refuge station can quickly be connected to mine water and electrics. However, as the **REFUGE ONE Mobile Safety Base** is entirely self-contained, it can be used independently of mine power and water systems. Only the battery and the water system require periodic recharging or refilling. The complete system can be shipped either pre-packaged for slinging in a 5' x 5' shaft, or fully assembled for immediate underground use.
**SPECIFICATIONS**

Physical Dimensions:

- **Width:** 4' 2 inches
- **Height:** 6' 11 3/4 inches
- **Length:** 10' 6 inches

**Total Weight:** 2,200 lbs

**MINIMUM PERFORMANCE CHARACTERISTICS**

For six people:

- **Oxygen:** 36 Hours
- **Carbon Dioxide Adsorption:**
- **Battery**
- **Capacity:** 36 Hours

**APPROVAL**

Electrics Hydro approved and CSA certified for electric shock and fire hazard.

**OPERATING INSTRUCTIONS**

The REFUGE ONE Mobile Safety Base has been designed to be easy to operate under stressful conditions. The start-up instructions are simple and easy to follow:

1. Break the Security Seals and remove the cover.
2. Install the Carbon Dioxide Absorbent Chemical.
3. Start the Blower.
4. Turn on the Oxygen.
5. Set the Oxygen flow rate according to the number of miners in the Mobile Safety Base.

The REFUGE ONE Mobile Safety Base & Air Centre can be relied upon to maintain a safe, breathable atmosphere for periods in excess of 24 hours without any need for connection to Compressed Air or Electricity. The System uses components with long life ratings and has a ten year life expectancy. All switches and operational controls remain secure until the security seal is broken and the cover removed. Portability, convenience and safety - a winning combination for any mine manager.

**TEST REPORT**

The REFUGE ONE Air Centre has been tested under realistic conditions. To obtain a copy of the CANMET Mining Research Laboratory test report please call the MSA Office nearest you or contact your local MSA Sales Representative.

Note: This Data Sheet contains only a general description of the REFUGE ONE Mobile Safety Base. While uses and performance capabilities are described, under no circumstances should the products be used except by qualified, trained personnel, and not until the instructions, labels and other literature accompanying them have been carefully read and understood and the precautions therein set forth followed. Only they contain the complete and detailed information concerning these products.

**ORDERING INFORMATION**

- **212853** REFUGE ONE Mobile Safety Base
- **200000** REFUGE ONE Modular Unit for Installation into Existing Safety Base

For more information on the REFUGE ONE Air Centre please refer to MSA data sheet 26-95-01.

**Accessories:**

- **212905** Screwdriver, Security

**Replacement Parts:**

- **212857** Chemical Absorbent, Sofnolime 797
- **212885** Gasket, Chemical Absorber Tray
- **212886** Hopper, Black
- **212887** Blower, 12 VDC
- **212888** Toggle ON/OFF Switch
- **212889** Indicator Lamp, Blower
- **212890** Indicator Lamp, System
- **212891** Indicator Lamp, Alarm
- **212892** Buzzer, Audible Alarm
- **212894** Battery, 12VDC, 100 AH
- **212895** Battery Charger Assembly
- **212896** Fuse Controls
- **212897** Fuse, Charger
- **212900** Pigtail Assembly, 24 Inch, Stainless Steel Flowmeter Assembly, Oxygen
- **212902** Cover Latch Assembly
- **212904** Security Seal
- **212906** Security Seal

MSA Canada Inc. 148 Norfinch Drive, North York, Ontario M3N 1X8
Tel: (416) 667-9400 Fax: (416) 663-5908 Toll Free 1-800-267-0672

Branches: Halifax - Montreal - Toronto - Winnipeg - Saskatoon - Edmonton - Vancouver

Data Sheet 26-95-02 MSA 1995 Printed in Canada
## FEATURES

- Steel skid for rigid support
- Dimensioned for six seated miners with standing room for four more
- Rugged, waterproof components for quick and easy assembly and clean-up
- Piped and wired for quick and easy hook-up to the on-site water, electric and compressed air systems
- Ten year underground life expectancy

## DESCRIPTION

Work on a development heading is both difficult and potentially dangerous. Experience dictates that accidents, mine fires or the sudden release of toxic gases can all occur at any time and without warning. Prepare for the unexpected with the **MOBILE SAFETY BASE**.

Developed and manufactured by **The Redpath Group** and distributed by MSA Canada Inc., this multifunctional mobile mine safety station has been designed for use in tough underground conditions. Suited for regular use as an underground lunchroom, communications centre, or even as a first aid station, the **MOBILE SAFETY BASE** has ultimately been designed to provide emergency life support for up to 10 occupants. Made of special fire retardant high strength moulded fiberglass, this skid mounted safety station can be shipped either prepackaged for slinging in a 5' shaft or fully assembled for immediate underground use. Since the **MOBILE SAFETY BASE** has been equipped with standard refuge station equipment, it can quickly be connected to regular mine water, electric and compressed air systems.

## SPECIFICATIONS

<table>
<thead>
<tr>
<th>Physical Dimensions:</th>
<th></th>
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<tbody>
<tr>
<td>Width: 4' 2 inches</td>
<td>Height: 6' 11 1/2 inches</td>
</tr>
<tr>
<td>Length: 10' 6 inches</td>
<td>Weight: 1,500 lbs</td>
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**ORDERING INFORMATION**

212854 MOBILE SAFETY BASE

Note: This Data Sheet contains only a general description of the MOBILE SAFETY BASE. While uses and performance capabilities are described, under no circumstances should the product be used except by qualified, trained personnel, and not until the instructions labels and other literature accompanying them have been carefully read and understood and the precautions therein set forth followed. Only they contain the complete and detailed information concerning these products.

**MSA Canada Inc:**
Halifax - Montreal - Toronto - Winnipeg
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Call Toll Free 1-800-267-0672

MSA Data Sheet 26-95-1
Printed in Canada 1991
INDUSTRIES’ FIRST INFLATABLE
PORTABLE RESCUE/REFUGE CHAMBER
“PATENTED POSITIVE PRESSURE FRESH AIR BASE”

The Portable Rescue Chamber (PRC) is designed as a positive pressure refuge, "Fresh Air Base", for use in tunneling and mining operations or any job application where an emergency refuge chamber is needed. Grade-D positive pressure breathable air is continuously supplied to the chamber from the filter/storage cart assembly which is attached to an outside compressed air source.

The tent chamber fully inflates in under 4 minutes. A unique air-lock system is used to allow entry and egress to the chamber without contaminating the worker's air inside or losing positive pressure. The basic PRC pictured below is designed to hold a maximum of 8-10 workers. The chamber is constructed of all fire retardant materials.

Manufactured by:
AIR SYSTEMS INTERNATIONAL
821 Juniper Crest
Chesapeake, Virginia
(804) 424-3966
(804) 424-5346 (1)
1-800-866-6100 (toll free)
e-mail: airsystem1@aol.com
Our catalog is available on the World Wide Web.
http://www.safetyonline.net/airsynon

Call us for detailed information.
Air Systems International, Inc.

Distributed by:
LEVITT-SAFETY LIMITED
2872 Bristol Circle, Oakville, Ontario L6H 5T5
Tel: (905)829-3299 Fax: (905)829-2919
CANADA'S LEADER IN FIRE AND SAFETY.
The Rescue Chamber Cart, #PRC-180

Pictured at left, holds the entire system. The cart is made of rugged steel and painted with a safety orange powder coat. Pneumatic tires allow for ease of movement over rough terrain. The complete cart weighs 95lbs. Cart dimensions: 48" H x 35" W x 17" D.

The Rescue Chamber is folded and stored in the upper portion of the cart. The lower portion contains the 3-stage Grade-D filtration system. An on/off valve and an air quality test port is also provided. Ample space is available to store emergency items, such as a first aid kit, phone, or water. Automatic water drain lines are installed from the filters through the bottom of the cabinet.

When supplied with 160 cfm air flow at 100 psi, the PRC inflates, ready for use, in under 4 minutes. The 2 connecting hoses from the cart supply air to each independent chamber. They are attached with quick connect fittings to allow ease of service and to prevent kinking of the hoses during emergency set-up.

Once the right and left chambers fill to capacity, they automatically dump air into the center air lock. Entry and egress to the PRC is through this center air lock. Once inside the airlock, the external zipper is closed. Each interior chamber has its own entry zipper to enter and exit from the center air lock, thus maintaining positive pressure in each separate chamber. Emergency exit is available through a rear zipper located in each chamber.
RescueAir

THE FLEXIBLE SYSTEM TO SUPPLY BREATHTABLE AIR

ADVANTAGES
- Reliable and Easy to Use
- Cost Effective
- Self Sustained
- Maintenance Free
- Guaranteed Shelf Life
- ISO 9001 Certified

APPLICATION
- Underground Mines
- Reclamable Refuge Bays
- Strong Rooms
- Nuclear, Biological and Chemical Shelters
- Life Support Systems
- Emergency Services
RescueAir™-E

The Complete System

Features

Mobility
- User Friendly
- Cost Effective
- Durable Steel Construction
- 110V Power supply
  (30 hour 12V Back-up)

- CO₂/CO₂ Scrubbing
- Modular Design
- CO₂ Scrubbing
  (Up to 500 litre/hour)
- CO₂ Scrubbing
- Prepacked Vacuum Sealed
  Filter Cartridges
- No Physical Handling of Filter
  Material

Dimensions

- Height - 3 ft 6 in
- Width - 22 in
- Length - 4 ft
- Mass - fully operational
  1012 lbs (460 Kg)

Oxygen Supply

- Solid State O₂ System:
- 18 000 litre O₂
  (6 Individual Units)
- Gas Composition:
  O₂ > 99.5 %
  CO < 25 ppm
  CO₂ < 100 ppm

FOR FURTHER INFORMATION PLEASE CONTACT:

Malcolm Reading
Black Rock Trading Inc.
P.O. Box 91807
West Vancouver, B.C. Canada V7V 451
Tel: 1-604.932.2179
Fax: 1-604.922.7014
Cell: 604 306 1699
RESCUEAIR-E

Rescueair-E is a reliable and cost-effective stand-alone system for the ventilation of refuge stations.

1. APPLICATION

The system is designed to provide and maintain the supply of respirable air in the absence or interrupted supply of compressed air in sealed, permanent or reclaimable refuge stations.

2. PHYSICAL DESCRIPTION

- RESCUEAIR-E combines two integrated systems:

  Oxygen replenishment by means of solid state chemical oxygen generating units.

  The removal of metabolically produced carbon dioxide with a dual CO2 absorbant system.

- RESCUEAIR-E is operated with a user friendly electronic diary type control system, featuring pictograms, to indicate oxygen replenishment and CO2 absorbant changes.

FIGURE 1: RESCUEAIR-E
RESCUEAIR-E features various physical characteristics, i.e.:

- Durable powdercoated steel cabinet
- Dimensions
  - Height : 1440mm
  - Length : 1330mm
  - Width : 624mm
- Weight: 460kg (Operational)
- Mobility: Base mounted Castor wheels
- Power supply
  - 110 V AC Main supply
  - 24 Volt Battery back-up
- Controlled access to sub-systems

3. CAPABILITY

RESCUEAIR-E is capable of supporting 24 workers for up to 24 hours in a sealed refuge station, providing an adequate volume of respirable air, thus enhancing the life-sustaining potential of refuge stations.

RESCUEAIR-E consists of six individual solid state oxygen generating units which releases oxygen through the thermal decomposition of sodium chlorate. Each unit produces 2900 litres of pure oxygen at minimum purity of 99.5% within 45 minutes of activation. These units can be stored at temperatures ranging from -20°C to +60°C, is maintenance free, self sustaining and has a guaranteed shelf life of ten (10) years. Carbon dioxide is removed by circulating refuge station air through two separate blower driven scrubbing units.

Each scrubbing unit consists of three individual soda lime filled cannisters each containing 10 kg of soda lime. Air is circulated through the cannisters at a rate of 100cm³/hour by means of a 24V blower. A 30 hour battery back-up is guaranteed by two 12V (100Amp/hour), maintenance free, sealed lead-acid batteries and a built-in 3 Amp trickle charger. A complete set of three additional pre-packed, sealed filter cannisters is supplied with each scrubber which is stored in the base of the unit, eliminating physical handling of the absorbant material. Each scrubbing unit is capable of removing metabolically produced carbon dioxide from 12 workers for a period of 24 hours.

Figure 2 depicts the results of an underground test performed at Amot Ciliary, #8 shaft, section 2D in South Africa.
A user friendly electronic diary type control display system, consisting of pictograms, based on a pre-set time sequence, simplifies the operation of RESCUEAIR-E.

4. ADVANTAGES OF RESCUEAIR-E AS A LIFE SUPPORT SYSTEM

- Oxygen supply system
  - No pressure during storage
  - No maintenance
  - Ten year shelflife
  - Safe and easy to handle

- Carbon dioxide scrubbing
  - Dual system enhances safety
  - Pre-filled and sealed Soda Lime cannisters
  - No physical handling of absorbant material
  - Replacement cannisters stored in scrubber unit
5. LIMITATIONS

- A well sealed refuge station is a pre-requisite
- Limited contribution to positive pressure in refuge station

REPRESENTATIVE IN CANADA: Mr. Malcolm Reading
BLACK ROCK TRADING INC
Box 91807
Vancouver
Tel: 604-922 2179
Fax: 604-922 7014

MANUFACTURED BY: NASCHEM
DIVISION OF DENEL (PTY)LTD
Private Bag X1254
Potchefstroom
2520
REPUBLIC OF SOUTH AFRICA
Tel: 27-148-2977171 ext 2279
Fax: 27-148-2981171
Dräger escape chamber – a new concept for breathing protection in mines

Werner SCHÜTT and Dipl.-Ing. Dietmar DIERCKS

Breathing protection is required wherever and whenever the ambient atmosphere is no longer respirable. The Dräger escape Chamber affords such protection for six people for at least four hours. The chamber was developed specially for mines, for use in situations where the ambient atmosphere is no longer respirable (smoke, gases, etc.) over a lengthy period. The use of this escape chamber also means that the people at risk can find joint refuge, see one another and speak to one another.

The escape-chamber housing, which is both gastight and insulated, can seat six people and supply them with oxygen. The CO₂ is bonded, the ambient air is cooled and dried, and a pleasant illumination level is provided by the chamber lighting. A positive-pressure facility prevents the ingress of gas and smoke into the escape chamber. Should the mains supply fail, use can be made of the system-specific emergency power supply.

The ambient atmosphere is checked during the usage period with the aid of Dräger measuring instruments. The oxygen content and any traces of CO₂ are thus detected and recorded.

In order to prevent contamination of the escape-chamber atmosphere, the people entering through the door have to pass through an air curtain which removes any smoke residues and gases.

All the equipment in the escape chamber is designed for immediate use.

The chamber can be transported underground either using a fork-lift truck or with the aid of the transport slide which enables the entire system to be dragged through the gallery.

The compressed-air supply required for positive-pressure operation and for the air curtain is carried with the system.

The Dräger Escape Chamber is available in various sizes. It is designed in accordance with the user's requirements and the site conditions. The main determining factors are the number of people and the max. protection period required.
SURVIVAIR.
The difference between life and death.
Survivair: The life-saving new Oxygen Candle from Naschem.

When time is critical in reaching trapped or injured miners, Survivair will buy you valuable time. Survivair provides life-giving breathable air to those confined to refuge bays during an underground disaster.

Originally designed for use in submarines, the Survivair is totally self-sufficient and maintenance-free. Manufactured to the strictest quality specifications, the Survivair will function reliably whenever you need it.

Activating it is as simple as pulling a pin. This sets off a chemical process that releases 2900 litres of pure oxygen, or 15 000 litres of breathable air within 35 minutes.

Each Survivair system contains four oxygen candles, housed in a stainless steel container. When activated, each candle will provide enough breathable air to keep 10 people comfortable for up to 48 hours.

This could be just the time your rescue team needs to reach them.

The Survivair is your user-friendly, lightweight alternative to conventional oxygen cylinders. In fact, it is under no pressure during storage and, unlike pressurised cylinders, it cannot explode in a fire. No compressors, no fuss, just air.

Developed by Naschem, a division of the Denel group of companies, the Survivair has been approved as intrinsically safe for all mines by the Government Mining Engineer. Find out more about Survivair, the remarkable new Oxygen Candle, right away. It could mean the difference between life and death for your workers.

Black Rock Explosives Inc
P.O. Box 91807
West Vancouver, BC V7V 4S1
Tel: 604.922.2179
Fax: 604.922.7014
MINING PRODUCTS
Survivair, the life-saving new Oxygen Canister from Naschem, provides life-saving, breathable air to those confined to refuge bays during an underground disaster.

Testing and approved to be safe and reliable:
- Approved by the CME (Compressed Mixture Engineers).
- Survivair complies fully with national safety regulations on gases.
- Ignition resistant in compliance with American Military standards.
- Tested by the NIOSH, Institute for Exploration Technology and the FAA (Federal Aeronautics Agency) for 13 environmental conditions by Naschem's laboratories.

Life-saving, No Oxygen—Guaranteed breathable air.
- Survivair produces approximately 15,000 liters of breathable air within 23 minutes—this is over 200 times its own volume.
- One Survivair will keep 10 people alive for up to 38 hours.
- No specialized training required.
- No monthly refills.
- No maintenance.
- No reloading or refills needed.
- 10 year guarantee against manufacturer defects.
- One Survivair costs less than $1.50 a day.

Technical specifications:
- Dimensions: 9.5 x 9.5 x 9.5 inches.
- With lid: 14 inches.
- Gross weight: 15.4 kg.
- Active Chemicals:
  - Oxygen: 90% at 99.5% purity.
  - Inert: CO, < 1000 ppm.
  - Container: Steel.
  - Microitest: Total 1 ppm.
  - Rest: 1 ppm.

Find out about Survivair, the remarkable new life-saving Oxygen Canister. It could mean the difference between life and death.

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Silicone Penetration Seals
Stop Fire, Smoke, and Water

By Ted Altpeter
Market Supervisor
Dow Corning Canada Inc.

Fire losses in Canada and the U.S. are high as compared to losses in other industrialized nations. Fire death rates, for example, run almost double those of North European countries. Property losses are also high.

Causes of fire losses are many and complex. But studies show that smoke causes 70% of the deaths. Of the 85 persons who died in the MGM Grand hotel fire in Las Vegas, Nevada, 68 were on the 23rd floor. The fire was on the first floor.

Although not every major fire gives such stark testimony, statistics back up the point: Smoke barriers will reduce both fatalities and property loss. Water barriers will help reduce property loss.

Office buildings, hospitals, hotels, and other structures with many occupants have special fire-safety problems. So do industrial plants, with their many workers and enormous concentrations of property value.

In all these structures, walls and floors are penetrated by many steam lines, water pipes, electrical conduits and cables, communications and control wiring, and heating, ventilating, and air conditioning ducts or pipes. Comptor rooms may have hundreds of input-output cables. Each of these services requires a set of openings in walls and floors. If these openings are not adequately sealed, they become chimneys that spread flame, hot gases, and smoke to other parts of the structure.

Robert Taylor, a Republic Steel fire specialist who was an investigator in the MGM Grand hotel fire, says that a major killer in high-rise building fires is movement of smoke through unprotected pipe penetrations for bathroom fixtures.

What constitutes good protection? Seals are now defined in the building codes, and standards are enforced by building inspectors. But the first line of protection is the sense of craftsmanship of all members of the building team - from design consultants to workmen. Craftsmanship is involved both in the wise professional choice of penetration seals and in their installation on the job.

A workman, pressed for time, can undo the best planning if he closes a penetration with a low-cost, general-purpose organic caulking compound. In a fire, such caulks melt and burn - carrying fire from floor to floor or room-to-room.

Stuffing a penetration with mineral wool insulation is not much better. Though its melting point is higher than that of a caulk, hot gases pass through with little trouble, and such seals are easily washed away by fighters' hose streams.

Penetration seals of concrete or grout can be effective, although they are hard to apply well in some kinds of work. The worst problem comes when another penetration must be made to add a new conduit or cable. Drilling through six or eight inches of concrete is time-consuming and expensive. If the barrier is thinner, it may break up as the new penetration is made.

Also, concrete is unyielding. If an imbedded pipe or conduit must move to accommodate deflection of floors, thermal expansion or contraction, something has to give. If it's the grout, there's an unsealed penetration that no one knows about. If it's the pipe or conduit, there are more immediate problems.

In the early 1970s, construction engineers in nuclear plants examined new alternatives for seals that would block fire, smoke, and water. They found an answer that met all requirements: a fire-blocking silicone foam developed by Dow Corning. Within a few years, the success of the product in the nuclear plants carried it into conventional power plants, industrial plants, and into high-rise buildings.

Even more recently, the job-proved silicone foam has been supplemented with a fire-resistant sealant. The two products are now included in the fire stop system. Together, they can be used to meet most needs for sealing openings in walls and floors which would otherwise offer an inviting path for the spread of fire and smoke.

Dominion and provincial fire marshals' offices, fire insurers, and others concerned with fire safety are concentrating more attention on penetration seals. Increasingly, building professionals, building owners, and tradespeople are adopting the silicone firestops to decrease fire risk and meet regulatory requirements.

For instance, penetration seals of silicone foam, seal telephone cable where they pass through floors of the Bow Valley Square building complex in Calgary. Without a
seal, cable runs would spread fire and hot gases to every floor of the high-rise office buildings.

Originally, a seal of mineral wool insulation with a "mortar" grout was planned. But telephone installers found that this grout seal was destroyed every time a new cable was run. In contrast, the silicone foam allowed easy placement of new cables simply by cutting a new hole through it. Any repair necessary was quickly handled with additional silicone.

By switching from an organic caulking compound formulated for fire resistance to a silicone fire stop sealant, a Seattle contractor has reduced mat cost, and has shaved his sealant labor costs by one-third. Howard S. Wright Construction, the general contractor, used Dow Corning Fire Stop Sealant in the 26-storey Rainier Bank Plaza in Bellevue, Washington.

Officials of Bellevue, a Seattle suburb, require that all floors of the 440,000 sq. ft. building have a two-hour fire rating. All penetrations must be restored to the two-hour rating. And all penetration seals must be UL listed.

To meet these requirements, the contractor first chose an organic caulking compound. But progress was slow. "It was unmanageable," said Kevin G. Johnson, one of the workers responsible for sealing floor penetrations. "The caulk did take a lot of work," agreed Al Crozier, project superintendent. "It was slow going and the material was expensive."

After struggling with the caulking compound for nine floors, Wright switched to Dow Corning Fire Stop Sealant. Crozier estimates that the use of this material cut application time by one-third over the previous method. That time-saving was meaningful. Each floor had at least a dozen penetrations.

At the Smooth Rock Falls Mill of Abitibi-Price Inc. in Ontario, the firm's insurer pointed out the need to seal cable and raceway feed-throughs in the walls of the motor control centres in the power house, chlorine bleach plant, and the stud mill. Some of these walls were three feet thick.

After checking previous installations; Jim Lamarche of the Smooth Rock Falls Engineering Department chose Dow Corning silicone foam for these penetration seals. It is UL listed, and is one of only a few products that comply with Standard CAN4-S115-M85 tests as a seal against fire, smoke, and water.

In some installations, the tight seal provided by silicone fire stop systems gives other benefits. At the Consolidated Bathurst Ltd., pulp mill in Bathurst, New Brunswick, it protects computer and electrical control rooms of a paper mill from dirt, fumes, and water as well as fire. The benefit to the paper mill: lower maintenance cost and less downtime in computers and electrochemical controls. For related reasons, foam seals are used to protect a computer room in a railway traffic centre, and in a sewage treatment plant.

The same foam is used as a sound-absorber and fire barrier around a jet engine test room. The benefit to the testing firm: safer working conditions for engineers and technicians who monitor the tests in an adjacent instrument room.

The Dow Corning Fire Stop System was designed to be both effective and easy to use. Penetration seals for commercial buildings must allow for the urgencies of schedules and the pressure of cost. Above all, the system is made to meet "real world" fire-safety problems: to establish and maintain fire walls that will stop fire as long as the wall itself, will not be washed out by fire-hose streams, and will stop fumes and smoke.

The one-part material, Dow Corning Fire Stop Sealant, is simply gunned into the small wall and floor penetrations. It's formulated for smooth application and easy handling. It can be applied to any clean, dry, frost-free surface at temperatures anywhere from -38°C to -1°C, and cures in a few days to form a very flexible rubber. It is listed by UL for many different one, two and three-hour penetration seal designs.

The two-part silicone foam, Dow Corning Fire Stop Foam, foams soon after the two liquid components are mixed. Mixing is to be done by hand or in automated mixing and dispensing equipment, and the liquid material is then poured or injected into the cavity to be sealed.

Dams or forms confine the material in the cavity as it foams. Its consistency is such that it easily fills complex penetrations such as multiple cable-tray passthroughs. Foam rise is complete in about five minutes, creating a tight, compressive seal around cables, conduits, pipes, and other penetrating lines.

Special techniques are used to meet certain needs - fire stops above masonry walls topped with steel decking, for example. Often, gaps that could spread fire and smoke are created by the fluted profile of the decking. If the openings are small, they can be closed with Dow Corning Fire Stop Sealant. Larger openings can be stopped with seals performed from Dow Corning Fire Stop Foam and pushed into the opening. To ensure retention of these molded seals, they can be bonded in place by using Dow Corning Fire Stop Sealant as an adhesive. Because the foam and the sealant are flexible, they allow movement of the decking with loads or temperature changes without destroying the seal.

Another common situation is the sealing of penetrations through fire-rated drywall. Silicone penetration seals have successfully passed ASTM E814 Through-Penetration Fire Stop tests for fire-rated gypsum walls.

The seals, made with the Dow Corning Fire Stop System, met both the 30-psi hose-stream test and fire requirements for one-hour and two-hour fire-rated walls and ceilings. The testing included gypsum-board
elevator-shaft walls. All testing was done by Warnock Hersey International Inc., an independent testing laboratory located at Antioch, California. The laboratory tested the foam and sealant around galvanized pipe and electrical cables in 10 different assembly designs.

The use of effective penetration seals with gypsum-board drywall is a particularly important fire-safety development for such projects as apartment buildings, condominiums, office buildings, and hotels.

Both Dow Corning Fire Stop Sealant and Fire Stop Foam are silicone materials. Silicones are semi-inorganic materials, chemical relatives of sand and quartz rock that have been modified with them to be transformed from liquids to rubbers. This chemical nature gives them great stability so great that they were used in the re-entry shields of the first space craft, and are still used to protect launch pads and equipment from rocket exhausts. A penetration seal made from either the sealant or the foam will stay rubbery in spite of aging or constant vibration. It won’t crumble or dry out.

Subjected to flame, the surface of the rubber forms a durable char that acts as an insulating barrier to keep both heat and air away from the unexposed sealant. And that char protects the still-rubbery fire stop material from the flame, enabling it to maintain a gas-tight, water-tight seal.

The system is particularly useful in retrofit work. Either hand-mixed foam or ready-to-use sealant is easily handled in small quantities. Laying in a barrier of one-part sealant, for example, probably will take a worker less time that improvising a makeshift seal from mineral wool insulation, and it will be far more effective.

Compared to packing these penetrations with grout or concrete, the silicone system offers flexibility to allow for building movement and the movement of pipes as they heat or cool. More important, the silicone system allows much easier addition of new pipes or cables. Workers from a variety of trades quickly learn to use fire stop materials in heating, air conditioning, ventilation, electrical, or plumbing applications.

It offers a versatile solution to a very serious problem: the spread of fire and smoke through the pass-throughs that are installed by all of these trades.
DESCRIPTION

DOW CORNING Fire Stop Intumescent Wrap Strip 2002 is a protective material designed to be used with DOW CORNING Fire Stop Sealant or DOW CORNING Fire Stop Foam. It provides through-penetration fire protection by stopping the spread of flame, water, smoke and noxious fumes through voids created when plastic pipe burns. UL classified (UL1479) Fire Test Stop Systems 180, 181, 184, 185, 186.

USES

When wrapped around items such as plastic pipe in through-penetrations and exposed to temperatures of 350°F (177°C), DOW CORNING Fire Stop Intumescent Wrap Strip 2002 expands up to ten miles of its volume, filling the void left by the burning plastic pipe and creating a rigid barrier against flame, water, smoke and gases. The material protects occupants and reduces property damage by encapsulating the burning plastic pipe and stopping the spread of fire to other parts of the structure. During testing, the expanded intumescent material remained in place in temperatures up to 1850°F (1010°C) - the current limit of 2 hour UL 1479 and ASTM E-814 testing.

DOW CORNING

Fire Stop Intumescent Wrap Strip 2002

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Intumescent fire stop material</td>
</tr>
<tr>
<td>Form</td>
<td>Wrap strip</td>
</tr>
<tr>
<td>Special Properties</td>
<td>Expansion upon exposure to heat; greater flexibility than competitive wraps</td>
</tr>
<tr>
<td>Primary Use</td>
<td>To fill the void created when plastic pipe in through penetration burns</td>
</tr>
</tbody>
</table>

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Gray</td>
</tr>
<tr>
<td>Backing Material</td>
<td>Aluminium foil</td>
</tr>
<tr>
<td>Expansion Begins, ƒ (°C)</td>
<td>250 (121)</td>
</tr>
<tr>
<td>Significant Expansion, ƒ (°C)</td>
<td>350 (177)</td>
</tr>
<tr>
<td>Full Expansion, ƒ (°C)</td>
<td>500 (260)</td>
</tr>
<tr>
<td>Free Expansion, times</td>
<td>5 to 10</td>
</tr>
<tr>
<td>Comptability with DOW CORNING Fire Stop Sealant</td>
<td>Excellent</td>
</tr>
<tr>
<td>DOW CORNING Fire Stop Foam</td>
<td>Excellent</td>
</tr>
<tr>
<td>Bulk Density, pounds per roll, approximate</td>
<td>8</td>
</tr>
<tr>
<td>Storage and Application Temperatures, ƒ(°C)</td>
<td>50 to 100 (-45 to 38)</td>
</tr>
</tbody>
</table>

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.
HOW TO USE
DOW CORNING Fire stop intumescent Wrap Strip 2002 is designed to be wrapped around plastic pipes and secured by wire ties or foil tape. The material has no noxious odor and is easier to install than existing intumescent materials because of its flexibility.

SHIPPING LIMITATIONS
None.

STORAGE AND SHELF LIFE
When stored between -50 and 100F (-45 and 38C), DOW CORNING Fire Stop Intumescent Wrap Strip 2002 has no known shelf life limitations.

PACKAGING
DOW CORNING Fire Stop Intumescent Wrap Strip 2002 is available in 1/4 x 2" x 12' rolls. The 12' rolls reduce waste by eliminating costly tab ends. The rolls are packaged in lightweight carrier/dispenser boxes.

MSDS INFORMATION
ATTENTION: PRODUCT SAFETY INFORMATION REQUIRED FOR SAFE USE IS NOT INCLUDED. BEFORE HANDLING, READ PRODUCT AND MATERIAL SAFETY DATA SHEETS AND CONTAINER LABELS FOR SAFE USE, PHYSICAL AND HEALTH HAZARD INFORMATION. THE MATERIAL SAFETY DATA SHEET IS AVAILABLE FROM YOUR DOW CORNING REPRESENTATIVE, OR DISTRIBUTOR, OR BY WRITING TO DOW CORNING CUSTOMER SERVICE, OR BY CALLING 1-517-496-6000

WARRANTY INFORMATION- PLEASE READ CAREFULLY
Dow Corning believes that the information in this publication is an accurate description of the typical characteristics and/or uses of the product or products, but it is your responsibility to thoroughly test the product in your specific application to determine its performance, efficacy and safety.

Unless Dow Corning provides you with a specific written warranty of fitness for a particular use, Dow Corning's sole warranty is that the product of products will meet Dow Corning's ten current sales specifications. DOW CORNING SPECIFICALLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTY, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR USE. Your exclusive remedy and Dow Corning's sole liability for breach of warranty is limited to refund of the purchase price or replacement of any product shown to be other than as warranted, and Dow Corning expressly disclaims any liability for incidental or consequential damages.
1. PRODUCT NAME

DOW CORNING Fire Stop Sealant: a one-part silicone elastomeric sealant.

2. MANUFACTURER

DOW CORNING CORPORATION
BOX 0984
MIDLAND, MICHIGAN 48640
PHONE: (517) 496-4000

3. PRODUCT DESCRIPTION

DOW CORNING Fire Stop Sealant is a ready-to-use silicone penetration sealant that stops the passage of fire, smoke and water through fire-rated wall and floor penetrations. The sealant cures in the presence of atmospheric moisture to produce a durable and flexible seal.

Because of the nonslump characteristics of DOW CORNING Fire Stop Sealant, little or no damming is required for most types of small, simple penetrations. The sealant's compression and extension properties surpass cycling at ≈40 percent of original joint width without affecting adhesion, making this product suitable for fire-rated expansion joints.

DOW CORNING Fire Stop Sealant forms air-and watertight bonds with most common building materials in any combination. These include cement, masonry, steel and aluminum. In many cases, no prime coat is needed.

Basic Uses:

DOW CORNING Fire Stop Sealant is designed for sealing simple penetrations, such as those for basic wiring and plumbing, in fire-rated walls and floors. The sealant's excellent adhesion and extension compression capabilities permit its use as a seal for fire-rated expansion joints.

Because it forms an air-and watertight seal, DOW CORNING Fire Stop Sealant can be used as a penetration seal in various applications, including:

- Dustproofing computer control rooms and clean rooms.
- Waterproofing rooms containing electrical electronic and other water sensitive equipment.
- Ensuring proper air flow in specialized ventilation systems.

At this time no nationally recognized tests exist for evaluating materials for sailling slot or fire wall/roof deck (ceiling) interface applications. The fire test data provides information that may be useful to solve fire and smoke seal problems in these areas.

Limitations:

DOW CORNING Fire Stop Sealant should not be applied:

- To polycarbonates.
- To building materials that bleed oils, plasticizers or solvents (impregnated wood, oil-based caulks, green or partially vulcanized rubber).
- In totally confined spaces where sealant is not exposed to atmospheric moisture.
- To surfaces which will be painted. The paint film will not stretch with the extension of the sealant and may crack and peel.
- To areas which are continuously immersed in water.

DOW CORNING Fire Stop Sealant is a one-part, ready-to-use material with the consistency of a soft caulk. The consistency remains uniform at temperatures ranging from -35 to 160°F (-37 to 71°C), allowing the sealant to be applied easily at any outdoor working temperature.

Packaging:

DOW CORNING Fire Stop Sealant is packaged in 10.3-fl oz (305-ml) disposable cartridges which fit standard caulking guns. Unused material may be stored in these cartridges if a plug is allowed to form in the cut nozzle opening. Inverting and inserting the tip initially cut from the nozzle is useful to reseal the cartridge. DOW CORNING Fire Stop Sealant is supplied as cement gray.

Applicable Standards:

DOW CORNING Fire Stop Sealant is classified by Underwriters Laboratories, Inc. as a "Fill, Void or Cavity Material" for through-penetration fire stop systems. Several different 1,2, and 3 hour ratings were achieved in independent tests per ASTM E-814/UL 1479 conducted at UL. Specifics regarding test designs and penetrating items can be found in UL's Building Materials Directory.

4. TECHNICAL DATA

DOW CORNING Fire Stop Sealant is virtually unaffected by the temperature changes, air and dirt exposure, and movement it will experience for many years. This long life is attributable to the inherent chemical stability of silicone elastomers. A seal made of DOW CORNING Fire Stop Sealant, if applied properly and subjected to normal use, will not peel, crack or crumble with age.

The unique combination of elongation and extension compression recovery characteristics leads to the use of DOW CORNING Fire Stop Sealant as a fire-rated expansion joint seal. The sealant accommodates both normal movement and the extreme movement caused by the intense heat of a building fire.

The typical properties of DOW CORNING Fire Stop Sealant are shown in Table 1.
TABLE 1: TYPICAL PROPERTIES OF DOW CORNING
FIRE STOP SEALANT
These values are not intended for use in preparing
specifications.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-S-8802D</td>
<td>Flow, Sag or Slump</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>Working Time, minutes</td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td>Full Cure and Adhesion, days</td>
<td>14-21</td>
</tr>
<tr>
<td>ASTM D 2240</td>
<td>Durometer Hardness, Shore A, points</td>
<td>15</td>
</tr>
<tr>
<td>ASTM D 412</td>
<td>Ultimate Tensile Strength, maximum elongation, psi</td>
<td>95 (0.07 kgt/mm²)</td>
</tr>
<tr>
<td>ASTM D 412</td>
<td>Elongation, percent max</td>
<td>1300</td>
</tr>
<tr>
<td>MIL-S-8802D</td>
<td>Peel Strength, lbs/in</td>
<td>25 (4.46 kg/cm)</td>
</tr>
<tr>
<td></td>
<td>Joint Movement Capabilities, percent extension</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>compression</td>
<td>40</td>
</tr>
</tbody>
</table>
5. INSTALLATION

Preparatory Work:

Clean all concrete, masonry and stone penetrations of all contaminants and impurities. Concrete form release agents, water repellents, laitance, surface dirt and rust, all old sealants and other surfaces treatments are examples of materials that must be removed from the surfaces to be sealed. Dust and loose particles should be blown out with oil-free compressed air. No moisture or frost should be present.

Metal surfaces should be cleaned by wiping them with oil-free absorbent cloth saturated with solvent such as xylol or toluol. Do not use alcohols.

Priming:

Most masonry surfaces and steel sleeves do not require a prime coat before sealant application. If using a nonstandard substrate, testing adhesion by applying a bead of sealant to the involved surface is required. Adhesion can be improved by the use of DOW CORNING 1200 prime coat.

Masking:

Areas surrounding the penetration may be masked to ensure a neat finished appearance. Masking tape should not touch areas to which sealant is to adhere. The tape should be removed immediately after tooling is completed.

Application:

Damming the penetration with material to support DOW CORNING Fire Stop Sealant is rarely required, because the sealant is nonslump. However, if the opening is so wide that support is necessary, any available material such as newspaper, duct tape, cardboard, Styrofoam plastic foam or backer rod, preferably open celled, may be used.

After the applicator nozzle is cut for the size of bead desired, the sealant is applied by pushing it ahead of the nozzle and against the sides of the penetration opening. When using material from the 2-gallon pail to fill larger gaps, use a trowel, putty knife or spatula to scoop out the material and work it into the hole. Make sure sealant contracts all surfaces to ensure adhesion. For a 2-hour fire rating, a 1 1/2 inch thickness is recommended when the sealant is installed alone. However, if 3 inches of fire-resistant mineral fiber are used as damming material, a 1/2-inch thickness of sealant will also achieve the 2-hour fire rating.

The completed seal should be tooled immediately to give it a concave profile and smooth appearance. Excess sealant on nonporeous surfaces can be wiped up with a solvent-saturated cloth before it cures. Excess sealant on porous surfaces should be allowed to cure, then removed by wire brushing or other mechanical means.

The working time of DOW CORNING Fire Stop Sealant is 10 to 30 minutes. The completed seal should be left undisturbed for 48 hours.

Precautions:

Uncured sealant may irritate skin and eyes upon contact. Avoid prolonged or repeated skin contact and avoid any contact with eyes.

DOW CORNING 1200 RTV prime coat is flammable. Keep it away from heat and open flame and use only with adequate ventilation. Use the same precautions with any solvents used for cleaning, being sure to follow the manufacturer's label directions.

Storage and Shelf Life:

When stored at or below 90 F (32 C), DOW CORNING Fire Stop Sealant has a shelf life of 6 months from the date of shipment.

6. AVAILABILITY AND COST

Availability:

DOW CORNING Fire Stop Sealant is marketed throughout the United States and Canada through authorized distributors and Dow Corning representatives.

Cost:

Prices vary depending upon volume purchased.

7. WARRANTY

Dow Corning Corporation warrants that each quantity of DOW CORNING Fire Stop Sealant delivered shall be the same kind designated or specified by it, and no other warranty (except by title) shall be implied.

8. MAINTENANCE

No maintenance of the seal is required. However, if penetrating items must be changed, the sealant can be cut and the seal restored easily. DOW CORNING Fire Stop Sealant will adhere to itself.

9. TECHNICAL SERVICES

Complete technical information and product literature are available from authorized Dow Corning distributors. Laboratory facilities, technical services and a list of distributors are available from Dow Corning.

10. FILING SYSTEMS

SPEC-DATA II.

CSI Spec-Data Index:

Section 07900 Joint Sealers.

Section 10520 Fire Protection
REDUCE NOISE AND OIL MIST IN ALL COMPRESSED AIR SYSTEMS
Noise from pneumatic valves is far more dangerous than most people imagine.

The human brain is incapable of registering the actual strength of the extremely rapid chain of events the ear is exposed to.

The strength and harmfulness of impulse noise, e.g., compressed air noise or hammering noise, is frequently underestimated.

A half-inch valve that regulates a pneumatic cylinder making three strokes per minute generates a noise level as high as a continuous noise source of 92 dB(A). Working on a daily basis in such an acoustic environment is directly injurious.

Fortunately, noise of this type is, for the most part, avoidable. With the right technique, compressed air noise can virtually be eliminated.

OPUS silencers effectively muffle the noise of exhaust air from one or several valves.

For additional information on noise related to the use of compressed air in automated and semi-automated production systems, the handbook "Combating Noise with OPUS" is available upon request.

---

**CHOOSE THE OPUS SILENCERS YOU NEED TO SOLVE YOUR COMPRESSED AIR NOISE PROBLEMS**

**Cylinder ID** | **Valve Size** | **Max Piston Speed** (fps) | **OPUS Silencer** | **Noise Reduction (dB)**
--- | --- | --- | --- | ---
1 1/4 | 1/8 | 1.97 | SDV 18 | 25
1 1/4 | 1/8 | 3.28 | SDR 18 | 25
1 1/2 | 1/4 | 2.43 | SDV 14 | 25
1 1/2 | 1/4 | 3.28 | SDR 14 | 25
2 | 1/4 | 1.97 | SDV 14 | 25
2 | 1/4 | 3.28 | SDR 14 | 25
2 1/2 | 3/8 | 3.28 | CD/CDO | 34
3 1/4 | 3/8 | 3.28 | CD/CDO | 34
4 | 1/2 | 3.28 | CD/CDO | 34
5 | 1/2 | 3.05 | CD/CDO | 34
6 | 3/4 | 3.28 | ED 1023 | 31
8 | 3/4 | 2.30 | ED 1023 | 31
>8 | 1 | 1.64 | ED 1023 | 31
>8 | 1 | 1.64 | ED 2033 | 29

Piston speed = mean speed for a single stroke.

\[
\text{Piston speed} = \frac{\text{Stroke length (ft)}}{\text{Time for a single stroke (sec)}}
\]

**Example:** Cylinder 5" with piston speed 0.82 ft/s requires silencer CD/CDO.
<table>
<thead>
<tr>
<th></th>
<th>PRODUCT CHART SILENCERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Hose Silencer SDR</strong></td>
</tr>
<tr>
<td></td>
<td>SDR-straight hose silencer. Available in two sizes with 1/8&quot; and 1/4&quot; connection. For mounting directly in the valve's exhaust ports. Provides noise reduction of approx. 25 dB(A).</td>
</tr>
<tr>
<td>2</td>
<td><strong>Hose Silencer SDV</strong></td>
</tr>
<tr>
<td></td>
<td>SDV-angled hose silencer. Available in two sizes with 1/8&quot; and 1/4&quot; connection. The silencer has a specially designed angled connection with a snap-on nut. Allows the silencer to be conveniently pressed into position in the valve's exhaust ports. Provides noise reduction of approx. 25 dB(A).</td>
</tr>
<tr>
<td>3</td>
<td><strong>Central Silencer CD</strong></td>
</tr>
<tr>
<td></td>
<td>CD-central silencer. Designed for muffling noise generated by exhaust-air from a single large valve or a central silencer for several smaller valves. Dimensioned for valves with connection threads of up to 1/2&quot;. Provides noise reduction of 30-34 dB(A).</td>
</tr>
<tr>
<td>4</td>
<td><strong>Central Silencer CDO with Oil Separation</strong></td>
</tr>
<tr>
<td></td>
<td>CDO-central silencer. The same performance as the CD but with intensive oil separation. Reduces the oil mist content of the air by approx. 99%. UK collection vessel for oil, complete with bracket holder, supplied as an accessory.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Expansion Silencer ED1023</strong></td>
</tr>
<tr>
<td></td>
<td>ED1023, expansion silencer with oil separation. Used in systems with short cycles requiring low back pressure. Dimensioned for valves with connection threads of up to 1/2&quot;. Provides noise reduction of 30-35 dB(A).</td>
</tr>
<tr>
<td>6</td>
<td><strong>Expansion Silencer ED2033</strong></td>
</tr>
<tr>
<td></td>
<td>ED2033, expansion silencer with oil separation. Used as a central silencer for entire groups of machines or in systems requiring quick pressure drop. Dimensioned for valves with connection threads of up to 2&quot;. Provides noise reduction of 28-33 dB(A).</td>
</tr>
<tr>
<td>7</td>
<td><strong>Custom Made Silencers</strong></td>
</tr>
<tr>
<td></td>
<td>SILVENT also produces special OPUS silencers on request. Constant flow systems and applications requiring a system pressure in excess of 200 kPa (30 psig) necessitate the use of special silencers. Contact us for suggestions.</td>
</tr>
<tr>
<td>8</td>
<td><strong>Manifolds and Couplings</strong></td>
</tr>
<tr>
<td></td>
<td>The OPUS range also includes a variety of manifolds and coupling components to facilitate problem free installation.</td>
</tr>
</tbody>
</table>
OPUS hose silencers are designed to be mounted directly in the exhaust ports of the valve. They are available in two sizes, 1/8" and 1/4", both with either straight or angled connections.

The patented OPUS hose silencer provides noise reduction of 20-25 dB(A).

These hose silencers afford considerable advantages in comparison with competing products constructed of sintered metal or plastic. Besides providing more effective noise suppression, hose silencers can not clog. A plugged silencer in a compressed air system often results in an interruption of service whose cause can be extremely difficult to locate. Moreover, with sinter silencers, there is clearly a risk of explosion. The design of OPUS hose silencers eliminates both the risk of accident and disruption of service.

**CONSTRUCTION**

The flexible absorber in the OPUS hose silencer stretches with each blast of air, thereby allowing dirt and ice to pass unhindered. The OPUS hose silencer cannot possibly clog.

**NOISE REDUCTION**

![Graphs showing noise reduction comparison]

**SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Silencer</th>
<th>SDV 18</th>
<th>SDR 18</th>
<th>SDV 14</th>
<th>SDR 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. op. pressure</td>
<td>kPa</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>psi</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Op. temperature</td>
<td>°C</td>
<td>70°</td>
<td>70°</td>
<td>70°</td>
</tr>
<tr>
<td></td>
<td>°F</td>
<td>150°</td>
<td>150°</td>
<td>150°</td>
</tr>
<tr>
<td>Flow</td>
<td>Nm³/h</td>
<td>10.9</td>
<td>20.4</td>
<td>26.1</td>
</tr>
<tr>
<td></td>
<td>Sdm²</td>
<td>6.42</td>
<td>12.02</td>
<td>15.37</td>
</tr>
<tr>
<td>Weight</td>
<td>g</td>
<td>16</td>
<td>15</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>lbs</td>
<td>0.035</td>
<td>0.033</td>
<td>0.075</td>
</tr>
<tr>
<td>Material</td>
<td>PVC, PP</td>
<td>PVC, PP</td>
<td>PVC, PP</td>
<td>PVC, PP</td>
</tr>
</tbody>
</table>

**ORDERING INFORMATION**

<table>
<thead>
<tr>
<th>Thread</th>
<th>L (mm)</th>
<th>H (mm)</th>
<th>N (mm)</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>260</td>
<td>10.23</td>
<td>13</td>
<td>0.51</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>330</td>
<td>12.99</td>
<td>17</td>
<td>0.67</td>
</tr>
<tr>
<td>Angled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>260</td>
<td>10.23</td>
<td>14</td>
<td>0.55</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>330</td>
<td>12.99</td>
<td>17</td>
<td>0.67</td>
</tr>
</tbody>
</table>

The picture above shows a pneumatic press where hose silencers have effectively eliminated impulse noise.
The exhaust ports from two pneumatic boxes connected to a single central silencer. The silencer has effectively solved the noise problem.

The OPUS central silencer is designed to silence exhaust air from a single large valve or as a common silencer for a number of smaller valves.

This silencer has been dimensioned to manage the flow from 1/2" valves operating at short intervals. In machines containing a larger number of valves, the timing of the cycles is often irregular. In such systems, several valves can be connected to a central silencer. See recommendations for coupling on page 10.

The patented OPUS central silencer provides a noise reduction of 30-35 dB(A).

The OPUS central silencer has a radically different construction than competing silencers. The larger silencers on the market are often designed to lead air to the middle, to a central tube shaped filter, a so-called coalescence filter.

The disadvantage of this construction is that, sooner or later, the filter clogs, resulting in interruption of service. The most commonly occurring problems in pneumatic systems are, however, caused by diffusion silencers, or so called sinter silencers. Every day, clogged sinter silencers lead to thousands of unnecessary and expensive disruptions and breakdowns in industries throughout the world. Furthermore, clogged sinter silencers involve an indisputable risk of explosion.

The design of the OPUS silencer eliminates the risk of disruption due to clogging (see page 7) as well as providing oil separation that cleans exhaust air.

Our central silencers are available in two models: CD and CDO. The essential difference between the two models is the degree of oil separation. The CD silencer separates oil in the filter only, providing more than adequate separation for most industrial environments. The CDO silencer is designed with a built in oil trap as well, for intensive oil separation. See the following page.
The OPUS central silencer CDO has the same capacity as the CD for noise suppression, in addition to intensive oil separation. This silencer is equipped with a built-in oil trap, where oil is separated from exhaust air and drained.

The OPUS central silencer CDO reduces the amount of oil mist in exhaust air by approx. 99%.

Most pneumatic systems contain apparatus for mist lubrication, which mixes oil mist into the compressed air. When the entrained oil has served its purpose, it passes through the valve's exhaust ports into the workplace.

Aside from the practical disadvantages that grease and dirty oil involve, there are medical considerations; health hazards associated with both inhalation of and direct skin contact with oil.

Diffusion silencers of the sinter type actually exaggerate the problem of oil mist in the working environment. Oil droplets passing through the sintered material are diffused, thereby increasing the amount of oil mist in the air.

The OPUS CDO reduces the amount of oil mist in exhaust air to well under existing limits; levels are so low that they are barely perceivable using ordinary measuring equipment.

<table>
<thead>
<tr>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silencer</strong></td>
</tr>
<tr>
<td>Max. op. pressure</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Op. temperature</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Flow</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Materials</td>
</tr>
</tbody>
</table>

**ORDERING INFORMATION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Remarks</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central silencer</td>
<td>Complete with filter, connection pipe, hose clamp and 0.5 m (19.7&quot;) connection hose Φ20/16 (SL16)</td>
<td>CDO</td>
</tr>
<tr>
<td>Oil vessel</td>
<td>Complete with mounting bracket</td>
<td>UK</td>
</tr>
</tbody>
</table>
BUILT-IN PROTECTION AGAINST CLOGGING

The cutaway diagram on the left shows how the OPUS central silencer is constructed.

Noise is muffled as the compressed air passes through the sound absorbing filters. The large surface area makes clogging highly unlikely. Should routine filter change be overloaded and the outer filter become blocked after an extended period of use, it is forced out of the filter holder when back pressure becomes too great, allowing the air to pass.

There is no interruption of service.

It is recommended that filters be changed on a regular basis in connection with routine maintenance of the pneumatic system. Filter replacement is both easy and inexpensive.

Every silencer in the OPUS range provides built-in protection against clogging.

EASY INSTALLATION AND FILTER REPLACEMENT

FILTER REPLACEMENT

Unscrew the filter holder and replace filter FA. The filter should be placed with the smooth side out. If filter FC needs replacement, the connection pipe must be disassembled and the diffuser removed.

Please note! The guide on the diffuser should fit in the groove in the housing. OPUS ED 1022 and ED 2033, the largest silencers in the OPUS range, are fitted with the same size filters as the CD. Filter replacement as for the CD.

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Diameter (D)</th>
<th>Height (H)</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter FA</td>
<td>Ø 109 (4.29&quot;)</td>
<td>20 (0.79&quot;)</td>
<td>FA</td>
</tr>
<tr>
<td>Filter FC</td>
<td>Ø 73 (2.87&quot;)</td>
<td>35 (1.38&quot;)</td>
<td>FC</td>
</tr>
</tbody>
</table>
The OPUS expansion silencer ED 1023 is designed for noise suppression and oil separation in systems with large air flows.

The ED 1023 is dimensioned to handle the flow from cylinders with large stroke volumes. This silencer is capable of managing exhaust air from several 1" valves operating at short intervals.

Typical areas of application are machines with short cycles and requirements for low back pressure. Such applications require large expansion volumes to attain sufficiently quick pressure drop in the system. The ED 1023 is also suitable for use as a common silencer for entire groups of machines.

The ED 1023 provides noise reduction of 30-35 dB(A).^2

Here, an OPUS ED 1023 is connected to a folding machine with 2 x 7 rubber bellows.

The silencer has three 1" inlets and two drainage outlets for oil separation. Oil separation is approximately 99%.

As is the case with all OPUS silencers, the ED 1023 affords built-in protection against dogging.

### NOISE REDUCTION/OIL SEPARATION

<table>
<thead>
<tr>
<th>NOISE REDUCTION</th>
<th>OIL SEPARATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; valves</td>
<td>Oil separator</td>
</tr>
<tr>
<td>(50 Hz, 70° F)</td>
<td>Oil inlet 15</td>
</tr>
<tr>
<td></td>
<td>cm² (s)</td>
</tr>
<tr>
<td>dB(A) 100</td>
<td>10</td>
</tr>
<tr>
<td>90</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>5</td>
</tr>
<tr>
<td>70</td>
<td>5</td>
</tr>
</tbody>
</table>

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Silencer</th>
<th>ED 1023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. op. pressure</td>
<td>200 psi</td>
</tr>
<tr>
<td>Op. temperature</td>
<td>70° C</td>
</tr>
<tr>
<td>Flow</td>
<td>490 Nm/h</td>
</tr>
<tr>
<td>Weight</td>
<td>3630 g</td>
</tr>
<tr>
<td>Material</td>
<td>Steel, Polypropylene, Fiberglass, Nitril rubber</td>
</tr>
</tbody>
</table>

### ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion silencer</td>
<td>ED 1023</td>
</tr>
</tbody>
</table>
COUPLING ASSEMBLIES FOR CENTRAL SILENCERS

The OPUS range includes a large number of fittings with which exhaust air from a number of valve ports can be brought to a common noise suppressor - a central silencer.

STRAIGHT COUPLING
Available in many connection sizes.

Y-PIECE
The simplest method for joining exhaust ports is by means of a Y-piece. The OPUS range includes a wide selection of sizes.

DUMMY PLUG
For closing off connections that are not used.

REDUCER
Reduces increase combination possibilities.

OPUS CENTRAL SILENCER
Normally, 6-10 1/4" valves can be connected to a single central silencer without risk of disruption. In applications involving large amounts of air and requiring low back pressure, each valve should be connected to its own central silencer. For extremely large air flows, an OPUS expansion silencer is recommended.

ANGLE COUPLING
With swivelled connection. For maximum speed of assembly, the threaded port is a separate unit which is first screwed into the port before the angled section is snapped into place.

HOSE CLAMP
The range also includes an assortment of hose clamps and hose clips.

COUPLING MANIFOLD
The OPUS range contains a large number of standard types.

Hose
The range includes hoses with a larger internal dimension than the hose on the delivery side; both a simple PVC hose of oil resistant quality and a reinforced hose that is extra flexible and adaptable.

---

ASSEMBLY EXAMPLES WITH Y-PIECE

<table>
<thead>
<tr>
<th>Valve diam.</th>
<th>1/4&quot;</th>
<th>3/8&quot;</th>
<th>1/2&quot;</th>
<th>3/4&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coupling</td>
<td>RN 1412</td>
<td>RN 3812</td>
<td>RN 1216</td>
</tr>
<tr>
<td>Hose clamp</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 16</td>
</tr>
<tr>
<td>Hose</td>
<td>SL 12</td>
<td>SL 12</td>
<td>SL 12</td>
<td>SL 16</td>
</tr>
<tr>
<td>Hose clip</td>
<td>KK 12</td>
<td>KK 12</td>
<td>KK 12</td>
<td>KK 16</td>
</tr>
<tr>
<td>Hose clamp</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 18</td>
</tr>
<tr>
<td>Y-piece</td>
<td>Y 12</td>
<td>Y 12</td>
<td>Y 16&quot;</td>
<td>Y 16&quot;</td>
</tr>
<tr>
<td>Hose U-30</td>
<td>SL 12</td>
<td>SL 12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

ASSEMBLY EXAMPLES WITH COUPLING MANIFOLD

<table>
<thead>
<tr>
<th>Valve diam.</th>
<th>1/8&quot;</th>
<th>1/4&quot;</th>
<th>3/8&quot;</th>
<th>1/2&quot;</th>
<th>3/4&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coupling</td>
<td>RN 1810</td>
<td>RN 1412</td>
<td>RN 3812</td>
<td>RN 1216</td>
</tr>
<tr>
<td>Hose clamp</td>
<td>SK 04</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 16</td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td>SL 10</td>
<td>SL 12</td>
<td>SL 12</td>
<td>SL 16</td>
<td></td>
</tr>
<tr>
<td>Hose clip</td>
<td>KK 10</td>
<td>KK 12</td>
<td>KK 12</td>
<td>KK 16</td>
<td></td>
</tr>
<tr>
<td>Hose clamp</td>
<td>SK 04</td>
<td>SK 10</td>
<td>SK 10</td>
<td>SK 16</td>
<td></td>
</tr>
<tr>
<td>Dummy plug</td>
<td>P 18</td>
<td>P 14</td>
<td>P 14</td>
<td>P 14</td>
<td></td>
</tr>
<tr>
<td>Coupling</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Coupl. manifold</td>
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<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Hose clamp</td>
<td>SK 16</td>
<td>SK 16</td>
<td>SK 16</td>
<td>SK 16</td>
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</tr>
<tr>
<td>Hose</td>
<td>KK 16</td>
<td>KK 16</td>
<td>KK 16</td>
<td>KK 16</td>
<td></td>
</tr>
<tr>
<td>Hose clip</td>
<td>SL 16</td>
<td>SL 16</td>
<td>SL 16</td>
<td>SL 16</td>
<td></td>
</tr>
</tbody>
</table>

OPUS central silencer CD or CDO

* Connecting hose to Y-piece Y16 is easier if the hose is warmed.
**COUPLING COMPONENTS**

**Y-PIECE**
For hose

<table>
<thead>
<tr>
<th>d1 mm</th>
<th>d2 &quot;</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1/4&quot;</td>
<td>Y06</td>
</tr>
<tr>
<td>10</td>
<td>3/8&quot;</td>
<td>Y10</td>
</tr>
<tr>
<td>12</td>
<td>1/2&quot;</td>
<td>Y12</td>
</tr>
<tr>
<td>16</td>
<td>5/8&quot;</td>
<td>Y16</td>
</tr>
</tbody>
</table>

Tip: When connecting SL 16 hose to Y-piece Y12, first press an approx. 200 mm (0.79') long piece of SL 12 hose onto the Y-piece.

**COUPLING MANIFOLD**
1/8" and 1/4" threaded connection

<table>
<thead>
<tr>
<th>No. of inlets x thread</th>
<th>L mm</th>
<th>L&quot;</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 1/8&quot;</td>
<td>125</td>
<td>4.92</td>
<td>KR1841</td>
</tr>
<tr>
<td>8 x 1/4&quot;</td>
<td>225</td>
<td>8.85</td>
<td>KR1881</td>
</tr>
<tr>
<td>4 x 1/8&quot;</td>
<td>140</td>
<td>5.51</td>
<td>KR1441</td>
</tr>
<tr>
<td>6 x 1/4&quot;</td>
<td>200</td>
<td>7.87</td>
<td>KR1461</td>
</tr>
<tr>
<td>8 x 1/4&quot;</td>
<td>260</td>
<td>10.23</td>
<td>KR1481</td>
</tr>
</tbody>
</table>

**COUPLING MANIFOLD**
For hose

<table>
<thead>
<tr>
<th>No. of inlets</th>
<th>ID mm</th>
<th>L mm</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>10</td>
<td>3/8&quot;</td>
<td>125 4.92</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>3/8&quot;</td>
<td>225 8.85</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>1/2&quot;</td>
<td>140 5.51</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>1/2&quot;</td>
<td>200 7.87</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>1/2&quot;</td>
<td>260 10.23</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>5/8&quot;</td>
<td>155 6.10</td>
</tr>
<tr>
<td>4+1</td>
<td>16</td>
<td>5/8&quot;</td>
<td>155 6.10</td>
</tr>
</tbody>
</table>

**DUMMY PLUG**
Plastic, for coupling manifolds with thread.

<table>
<thead>
<tr>
<th>Dim G</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8&quot;</td>
<td>P18</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>P14</td>
</tr>
</tbody>
</table>

**DUMMY PLUG**
Plastic, for coupling manifolds for hose.

<table>
<thead>
<tr>
<th>Dim d mm</th>
<th>Dim d  &quot;</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>5/8&quot;</td>
<td>P16</td>
</tr>
</tbody>
</table>

**CX-HOSE**
Extra flexible and shape retentive polyester reinforced PVC hose. Max. pressure 1 MPa (143 psi)

<table>
<thead>
<tr>
<th>d/D mm</th>
<th>Description</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3/8&quot;</td>
<td>SL06</td>
</tr>
<tr>
<td>12</td>
<td>1/2&quot;</td>
<td>SL10</td>
</tr>
<tr>
<td>16</td>
<td>5/8&quot;</td>
<td>SL16</td>
</tr>
</tbody>
</table>

**HOSE CLAMP**
Plastic

<table>
<thead>
<tr>
<th>Min. dia.</th>
<th>Max. dia.</th>
<th>For hose</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.7</td>
<td>10.0</td>
<td>SL06</td>
<td>SK02</td>
</tr>
<tr>
<td>10.8</td>
<td>12.3</td>
<td>SL10</td>
<td>SK04</td>
</tr>
<tr>
<td>12.0</td>
<td>13.7</td>
<td>CX10</td>
<td>SK06</td>
</tr>
<tr>
<td>15.0</td>
<td>16.8</td>
<td>SL12/CX12</td>
<td>SK10</td>
</tr>
<tr>
<td>19.9</td>
<td>21.7</td>
<td>SL16</td>
<td>SK16</td>
</tr>
<tr>
<td>21.4</td>
<td>23.0</td>
<td>SL16</td>
<td>SK18</td>
</tr>
<tr>
<td>22.7</td>
<td>24.7</td>
<td></td>
<td>SK20</td>
</tr>
</tbody>
</table>

*SK18 for connection to Y-piece Y-16-

**ANGLE**
Max. pressure 10 bar (143 psi)

<table>
<thead>
<tr>
<th>Thread</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>RV38</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>RV12</td>
</tr>
</tbody>
</table>

**PVC-HOSE**

<table>
<thead>
<tr>
<th>d/D mm</th>
<th>Description</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/8</td>
<td>Hose 6 mm (1/4&quot;)</td>
<td>SL06</td>
</tr>
<tr>
<td>10/12</td>
<td>Hose 10 mm (3/8&quot;)</td>
<td>SL10</td>
</tr>
<tr>
<td>12/15</td>
<td>Hose 12 mm (1/2&quot;)</td>
<td>SL12</td>
</tr>
<tr>
<td>16/20</td>
<td>Hose 16 mm (5/8&quot;)</td>
<td>SL16</td>
</tr>
</tbody>
</table>

**ALTERNATIVE CONNECTION PIPES**
Connection pipe AR 12 for hose with int. diam. 12 mm (1/2"), Steel. Order no. AR12.
When a CD central silencer was installed at Scania in Södertälje, Sweden, their machine was suddenly so quiet that the company's personnel was convinced that there was something wrong with the machine. Safety Inspector Anders Rundgren confirmed that noise peaks were reduced from 105 dB(A) to 84 dB(A) after the installation.

The picture above shows 15 hose silencers SDR mounted on a 3" exhaust pipe from a pressure casting press. The risk of hearing loss has been entirely eliminated.

The Swedish camera-makers Hasselblad has installed a number of OPUS silencers in their production facilities to eliminate oil mist and impulse noise. The picture shows a CNC machine equipped with a CDO for oil separation.

Matra, French subcontractor to Renault, has installed 140 CDs in their spot welding machines. The equivalent noise level has been reduced from 92 dB(A) to less than 85 dB(A).

SILVENT
JH BLANDFORD & ASSOC. LTD.
2241 MANSFIELD DR.
BURLINGTON, ONTARIO
L7P 3J5
TEL: 905-319-9486
TEL: 888-745-6368
FAX: 905-319-1495

SILVENT AB
Göteborgsvägen 99
S-502 60 BORÅS
SWEDEN
Telefon +46 33-10 07 20
Fax +46 33-10 07 80
INCO - MATERIAL SAFETY DATA SHEET

FIRE CLAY (CRUDE LUMP)

1. PRODUCT INFORMATION

PRODUCT IDENTIFIER: FIRE CLAY (CRUDE LUMP)
INCO WHMIS LABELS AVAILABLE: NONE
INCO REFERENCE NO: 1987-0896
PRODUCT IDENTIFICATION NO: N/AP
WHMIS CONTROLLED PRODUCT: YES

MANUFACTURER:
BOGNAR AND COMPANY INCORPORATED
31 MOFFETT STREET P.O. BOX 13566
PITTSBURGH PA
15243
EMERGENCY PHONE NO: 412-344-9900

PRODUCT USE: FIRE CLAY

VENDOR: BOGNAR AND COMPANY, INCORPORATED
31 MOFFETT STREET P.O. BOX
PITTSBURGH PA
15243
PHONE NO: 412-344-9900

2. PREPARATION INFORMATION

INCO CONTACT: OCCUPATIONAL HEALTH 705-682-8301
SUPPLIER MSDS PREPARATION DATE: 93-02-11
LOCATIONS USED:
COPPER CLIFF
SECTION: MISCELLANEOUS
WHMIS HAZARD CLASSIFICATION:
D.2

3. PRODUCT COMPOSITION AND TOXICOLOGICAL DATA

COMPONENTS & FORMULAS % CAS NO EXPOSURE LIMIT
RESPIRABLE FREE SILICA
LD50(ORL,SP) LC50(INH,SP)
0.1 MG/M3

EXPOSURE LIMITS USED THROUGHOUT THIS MSDS ARE TAKEN FROM THE ONTARIO
REGULATIONS FOR DESIGNATED SUBSTANCES, OR THE CONTROL OF EXPOSURE TO
BIOLOGICAL OR CHEMICAL AGENTS. OTHER SOURCES WILL BE SPECIFIED AS
REQUIRED. (1) ACGIH THRESHOLD LIMIT VALUES, (2) OSHA PERMISSIBLE
EXPOSURE LIMITS, (3) MANUFACTURER’S RECOMMENDED LIMIT.

4. PHYSICAL DATA

SPECIFIC GRAVITY (H2O =1): 2.60 AT C F
SOLUBILITY IN WATER: N.A. AT C F
APPEARANCE AND ODOR:
GRAY COLOUR GRANULES WITH EARTHY DAMP ODOR.
PHYSICAL STATE:
SOLID
5. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NOT AVAILABLE  
TEST METHOD:

EXTINGUISHING MEDIA:
MAY BE USED AS 
EXTINGUISHING MEDIA.

SPECIAL FIRE FIGHTING PROCEDURES:
INORGANIC MATERIAL
NON FLAMMABLE.

FIRE AND EXPLOSION HAZARDS:
N.A.

6. REACTIVITY DATA

STABILITY: STABLE 
HAZARDOUS POLYMERIZATION WILL NOT OCCUR 

INCOMPATIBILITY - AVOID CONTACT WITH:
NONE.

CONDITIONS TO AVOID:
NONE.

7. FIRST AID MEASURES

SKIN CONTACT:
WASH WITH SOAP AND WATER

EYE CONTACT:
FLUSH WITH WATER FOR 15 MINUTES

8. HEALTH HAZARD DATA - TOXICOLOGICAL

CONDITIONS AGgravated BY EXPOSURE: BRONCHIAL AND/OR RESPIRATORY PROBLEMS. 
CARCINOGENICITY: NTP NO; IARC MONOGRAPHS NO; OSHA REGULATED NO.

9. HEALTH HAZARD DATA - EXPOSURE

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>EFFECTS OF ACUTE EXPOSURE</th>
<th>EFFECTS OF CHRONIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKIN</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>EYE</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>INH</td>
<td>MAY BE HARMFUL IF INHALED OVER PROLONGED PERIOD, AND MAY CAUSE DELAYED LUNG INJURY.</td>
<td>N.A.</td>
</tr>
<tr>
<td>ING</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
10. PREVENTIVE MEASURES - SPILL, LEAK AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
WET SWEEP OR SCOOP UP AND REUSE
SCOOP OR VACUUM SPILLAGE. USE APPROPRIATETECHNIQUE
TO MINIMIZE DUST GENERATION. PLACE RESIDUES IN CLO-SED
CONTAINER FOR RE-USE OR DISPOSAL.

WASTE DISPOSAL METHOD:
FOLLOW FEDERAL, PROVINCIAL AND LOCAL
REGULATIONS.

11. PREVENTIVE MEASURES - SPECIAL PROTECTION INFORMATION

ENGINEERING CONTROLS:
LOCAL EXHAUST
AS REQUIRED TO MEET TLV'S.

EYE:
SAFETY GLASSES

HAND (GLOVE TYPE):
NOT REQUIRED

RESPIRATOR TYPE:
NIOSH OR MSHA APPROVED
RESPIRATOR AS NECESSARY.

OTHER PROTECTIVE EQUIPMENT:
NONE.

12. PREVENTIVE MEASURES - HANDLING, STORAGE AND SHIPPING PROCEDURES

PRECAUTIONARY MEASURES:
WASH THOROUGHLY AFTER HANDLING
DO NOT BREATHE DUST, VAPOUR, GAS OR MIST

OTHER STORAGE CONDITIONS:
AVOID CREATION OF LARGE DUST CLOUDS IN CONFINED AREAS
WHERE IGNITION SOURCES ARE PRESENT.

OTHER HANDLING CONDITIONS:
AVOID ACCUMULATION OF DUST AND EXCESSIVE GENERATION OF
DUST. PRODUCT IS SLIPPERY WHEN WET. USE GOOD PERSONAL
HYGIENE.

13. ADDITIONAL INFORMATION

DESIGNATED SUBSTANCES:
1 SILICA

INFORMATION:
MANUFACTURER'S MSDS AVAILABLE FROM ENVIRONMENTAL CONTROL 682-8301.

------------------------INCO AUTHORIZED USE ONLY------------------------
INCO - MATERIAL SAFETY DATA SHEET

FIRE CLAY (GROUND 14 MESH)

HM901802

1. PRODUCT INFORMATION

PRODUCT IDENTIFIER: FIRE CLAY (GROUND 14 MESH)
INCO WHMIS LABELS AVAILABLE: NONE
INCO REFERENCE NO: 1987-0897
PRODUCT IDENTIFICATION NO: N/AV
WHMIS CONTROLLED PRODUCT: YES

MANUFACTURER:
BOGNAR AND COMPANY INCORPORATED
31 MOFFETT STREET P.O. BOX 13566
PITTSBURGH PA
15243
EMERGENCY PHONE NO: 412-344-9900

PRODUCT USE: FIRE CLAY

VENDOR: BOGNAR AND COMPANY, INCORPORATED
31 MOFFETT STREET P.O. BOX 13566
PITTSBURGH PA
15243
PHONE NO: 412-344-9900

2. PREPARATION INFORMATION

INCO CONTACT: OCCUPATIONAL HEALTH 705-682-8301
SUPPLIER MSDS PREPARATION DATE: 93-02-11
LOCATIONS USED:
COPPER CLIFF
SECTION: MISCELLANEOUS
WHMIS HAZARD CLASSIFICATION:
D.2

3. PRODUCT COMPOSITION AND TOXICOLOGICAL DATA

COMPONENTS & FORMULAS % CAS NO EXPOSURE LIMIT
RESPIRABLE FREE SILICA
LD50(ORL,SP) LC50(INH,SP)

EXPOSURE LIMITS USED THROUGHOUT THIS MSDS ARE TAKEN FROM THE ONTARIO REGULATIONS FOR Designated substances, OR THE CONTROL OF EXPOSURE TO BIOLOGICAL OR CHEMICAL AGENTS. OTHER SOURCES WILL BE SPECIFIED AS REQUIRED. (1) ACGIH THRESHOLD LIMIT VALUES, (2) OSHA PERMISSIBLE EXPOSURE LIMITS, (3) MANUFACTURER’S RECOMMENDED LIMIT.

4. PHYSICAL DATA

SPECIFIC GRAVITY (H2O =1): 2.60 AT C F
SOLUBILITY IN WATER: N.A. AT C F
APPEARANCE AND ODOUR:
GRAY COLOUR GRANULES WITH EARTHY ODOUR.
PHYSICAL STATE:
LIQUID
5. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NOT AVAILABLE. TEST METHOD:

EXTINGUISHING MEDIA:
MAY BE USED AS EXTINGUISHING MEDIA.

SPECIAL FIRE FIGHTING PROCEDURES:
INORGANIC MATERIAL
NON FLAMABLE.

FIRE AND EXPLOSION HAZARDS:
N.A.

6. REACTIVITY DATA

STABILITY: STABLE
HAZARDOUS POLYMERIZATION WILL NOT OCCUR

INCOMPATIBILITY - AVOID CONTACT WITH:
NONE.

CONDITIONS TO AVOID:
NONE.

7. FIRST AID MEASURES

SKIN CONTACT:
WASH WITH SOAP AND WATER

EYE CONTACT:
FLUSH WITH WATER FOR 15 MINUTES

8. HEALTH HAZARD DATA - TOXICOLOGICAL

CONDITIONS AGGRAVATED BY EXPOSURE: BRONCHIAL AND/OR RESPIRATORY PROBLEMS.
CARCINOGENICITY: NTP NO; IARC MONOGRAPHS NO; OSHA REGULATED NO.

9. HEALTH HAZARD DATA - EXPOSURE

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>EFFECTS OF ACUTE EXPOSURE</th>
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<td></td>
</tr>
<tr>
<td>EYE</td>
<td>N.A.</td>
<td></td>
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<td>MAY BE HARMFUL IF INHALED OVER PROLONGED PERIOD, AND MAY CAUSE DELAYED LUNG INJURY.</td>
<td></td>
</tr>
<tr>
<td>ING</td>
<td>N.A.</td>
<td></td>
</tr>
</tbody>
</table>
10. PREVENTIVE MEASURES - SPILL, LEAK AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
WET SWEEP OR SCOOP UP AND REUSE
SCOOP OR VACUUM SPILLAGE. USE APPROPRIATE TECHNIQUE
TO MINIMIZE DUST GENERATION. PLACE RESIDUES IN CLO-SED
CONTAINER FOR RE-USE OR DISPOSAL.

WASTE DISPOSAL METHOD:
FOLLOW FEDERAL, PROVINCIAL AND LOCAL
REGULATIONS.

11. PREVENTIVE MEASURES - SPECIAL PROTECTION INFORMATION

ENGINEERING CONTROLS:
LOCAL EXHAUST
AS REQUIRED TO MEET TLV'S.

EYE:
SAFETY GLASSES

HAND (GLOVE TYPE):
NOT REQUIRED

RESPIRATOR TYPE:
NIOSH OR MSHA APPROVED
RESPIRATOR AS NECESSARY.

OTHER PROTECTIVE EQUIPMENT:
NONE.

12. PREVENTIVE MEASURES - HANDLING, STORAGE AND SHIPPING PROCEDURES

PRECAUTIONARY MEASURES:
WASH THOROUGHLY AFTER HANDLING
DO NOT BREATHE DUST, VAPOUR, GAS OR MIST

OTHER STORAGE CONDITIONS:
AVOID CREATION OF LARGE DUST CLOUDS IN CONFINED AREA
WHEREignITION SOURCES ARE PRESENT.

OTHER HANDLING CONDITIONS:
AVOID ACCUMULATION OF DUST AND EXCESSIVE GENERATION OF
DUST. PRODUCT IS SLIPPERY WHEN WET. USE GOOD PERSONAL
HYGIENE.

13. ADDITIONAL INFORMATION

DESIGNATED SUBSTANCES:
1 SILICA

INFORMATION:
MANUFACTURER'S MSDS AVAILABLE FROM ENVIRONMENTAL CONTROL 682-8301.

------------------------------INCO AUTHORIZED USE ONLY------------------------------
1. PRODUCT INFORMATION

PRODUCT IDENTIFIER: FIRE CLAY, FIRECLAY AS
SYNONYMS: HYDROUS ALUMINA SILICATE
INCO WHMIS LABELS AVAILABLE: INCO WORKPLACE
INCO REFERENCE NO: 1987-0866
PRODUCT IDENTIFICATION NO: N/AV
WHMIS CONTROLLED PRODUCT: NO

MANUFACTURER:
CEDAR HEIGHTS CLAY (DIVISION OF RESCO)
BOX 295
OAK HILL OHIO
45656
EMERGENCY PHONE NO: 614-682-7794

PRODUCT USE: FIRE CLAY
CHEMICAL NAME: HYDROUS ALUMINUM SILICATE

VENDOR: AS ABOVE

2. PREPARATION INFORMATION

INCO CONTACT: OCCUPATIONAL HEALTH 705-682-8301
SUPPLIER MSDS PREPARATION DATE: 93-02-03
LOCATIONS USED:
FORT COLBORNE
SECTION: REFRACTORY MATERIALS
WHMIS HAZARD CLASSIFICATION:
D2: MATERIALS CAUSING OTHER TOXIC EFFECTS

REVISED MSDS AVAILABLE FROM OCCUPATIONAL HEALTH AT 682-8301.

INCO STOCK CODES:
84 96304

3. PRODUCT COMPOSITION AND TOXICOLOGICAL DATA

COMPONENTS & FORMULAS % CAS NO EXPOSURE LIMIT
CRystalline Silica (Quartz) 10-30 14808-60-7 0.1 MG/M3 (RESP)
SiO2 LC50(THB,SP)

EXPOSURE LIMITS USED THROUGHOUT THIS MSDS ARE TAKEN FROM THE ONTARIO
REGULATIONS FOR DESIGNATED SUBSTANCES, OR THE CONTROL OF EXPOSURE TO
BIOLOGICAL OR CHEMICAL AGENTS. OTHER SOURCES WILL BE SPECIFIED AS
REQUIRED. (1) ACGIH THRESHOLD LIMIT VALUES, (2) OSHA PERMISSIBLE
EXPOSURE LIMITS, (3) MANUFACTURER’S RECOMMENDED LIMIT.

4. PHYSICAL DATA

BOILING POINT: N/A C F
FREEZING POINT: C 3000 F
SPECIFIC GRAVITY (H2O =1): 2.60 AT C F
VAPOUR PRESSURE (MM MERCURY): N/A AT C F
FIRE CLAY, FIRECLAY AS

SOLUBILITY IN WATER: NEGLIGIBLE AT C F
PERCENT VOLATILES BY VOLUME: N/A
APPEARANCE AND ODOUR:
MEDIUM GREY COLOUR WITH EARTHY ODOUR.
PHYSICAL STATE:
SOLID

5. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NON-FLAMMABLE TEST METHOD:
EXTINGUISHING MEDIA:
MAY BE USED AS AN EXTINGUISHING MEDIA.

SPECIAL FIRE FIGHTING PROCEDURES:
NONE.

HAZARDOUS COMBUSTION PRODUCTS (EXPOSURE LIMIT):
SULPHUR DIOXIDE (TWAEV 2 PPM; 5), CARBON MONOXIDE (TWAEV 35 PPM; 400), CARBON DIOXIDE (TWAEV 5000 PPM; 30000).

FIRE AND EXPLOSION HAZARDS:
NON-EXPLOSIVE.

6. REACTIVITY DATA

STABILITY: STABLE
HAZARDOUS POLYMERIZATION WILL NOT OCCUR

INCOMPATIBILITY - AVOID CONTACT WITH:
NO KNOWN INCOMPATIBLE MATERIALS

HAZARDOUS DECOMPOSITION PRODUCTS - THERMAL AND OTHERS (EXPOSURE LIMIT):
SULPHUR DIOXIDE, CARBON MONOXIDE & CARBON DIOXIDE GASES ARE LIBERATED WHEN HEATED IN EXCESS OF 260.0 C (500 F).

CONDITIONS TO AVOID:
HEAT
AVOID FIRING PRODUCT IN RESTRICTED AIR SPACES. FIRE ONLY IN WELL-VENTILATED AREAS.

7. FIRST AID MEASURES

SKIN CONTACT:
WASH WITH SOAP AND WATER
FLUSH SKIN THOROUGHLY WITH WATER IF IRRITATION DEVELOPS.

EYE CONTACT:
FLUSH WITH WATER FOR 15 MINUTES
GET MEDICAL ATTENTION
FLUSH EYES WITH WATER IF IRRITATION DEVELOPS. SEEK MEDICAL ATTENTION IF CONDITION PERSISTS.

INHALATION:
REMOVE TO FRESH AIR
8. HEALTH HAZARD DATA - TOXICOLOGICAL

'CAUTION'

THIS PRODUCT CONTAINS FREE SILICA. INHALATION OF THIS DUST IN THE RESPIRABLE SIZE RANGE PRESENTS A POTENTIAL HEALTH HAZARD, EXCESSIVE INHALATION WILL INCREASE YOUR RISK OF SERIOUS RESPIRATORY DISEASE. (SILICOsis). PRIMARY ORGAN AFFECTED (LUNGS).

DO NOT BREATH DUST. WEAR A NIOSH OR MSHA APPROVED RESPIRATOR DURING HANDLING OF THIS PRODUCT. FOR FURTHER INFORMATION, PLEASE REFER TO MATERIAL SAFETY DATA SHEET MANUAL PROVIDED BY YOUR EMPLOYER AND REGULATIONS RESPECTING SILICA.

9. HEALTH HAZARD DATA - EXPOSURE

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>EFFECTS OF ACUTE EXPOSURE</th>
<th>EFFECTS OF CHRONIC EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKIN</td>
<td>MAY AGGRAVATE EXISTING SKIN CONDITIONS.</td>
<td></td>
</tr>
<tr>
<td>EYE</td>
<td>CAN ABRAScE AND IRRITATE EYES.</td>
<td></td>
</tr>
<tr>
<td>INH</td>
<td>MAY CAUSE SHORTNESS OF BREATH, IRRITATE RESPIRATORY TRACT, AGGRAVATE EXISTING LUNG CONDITIONS.</td>
<td>MAY PROMOTE LUNG DISEASE.</td>
</tr>
<tr>
<td>ING</td>
<td>SHOULD NOT BE A PROBLEM.</td>
<td></td>
</tr>
</tbody>
</table>

10. PREVENTIVE MEASURES - SPILL, LEAK AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
- WET SWEEP OR SCOOP UP AND REUSE
- DRY CLEAN UP MAINTAINING DUST LEVELS.

WASTE DISPOSAL METHOD:
- LANDFILL
- ANY APPROVED WASTE DISPOSAL METHOD INCLUDING BURIAL.

11. PREVENTIVE MEASURES - SPECIAL PROTECTION INFORMATION

ENGINEERING CONTROLS:
- LOCAL EXHAUST
- KEEP DUST LEVELS BELOW RECOMMENDED LIMITS.

EYE:
- CHEMICAL SAFETY GOGGLES

RESPIRATOR TYPE:
- FILTER - DUST, FUME, MIST
- IF DUST LEVELS EXCEED RECOMMENDED LEVELS, USE NIOSH APPROVED RESPIRATORS FOR SILICA DUST.

OTHER PROTECTIVE EQUIPMENT:
- MINIMIZE DUST GENERATION AND EXPOSURE. DUST LEVELS SHOULD BE MONITORED AND LEVELS MAINTAINED BELOW THE RECOMMENDED
12. PREVENTIVE MEASURES - HANDLING, STORAGE AND SHIPPING PROCEDURES

PRECAUTIONARY MEASURES:
WASH THOROUGHLY AFTER HANDLING
DO NOT GET IN EYE, ON SKIN OR CLOTHING
DO NOT BREATHE DUST, VAPOUR, GAS OR MIST

OTHER STORAGE CONDITIONS:
GOOD HOUSEKEEPING PRACTICES SHOULD BE MAINTAINED TO KEEP DUST LEVELS AT A MINIMUM.

OTHER HANDLING CONDITIONS:
AVOID GENERATING OR BREATHING DUST. USE GOOD PERSONAL HYGIENE. FIRE THIS PRODUCT ONLY IN WELL-VENTILATED AREAS, PREFERABLY IN A VENTED KILN.

13. ADDITIONAL INFORMATION

DESIGNATED SUBSTANCES:
1 CRYSTALLINE SILICA (QUARTZ) 10-30%

INFORMATION:

* MANUFACTURER’S MSDS AVAILABLE FROM ENVIRONMENTAL CONTROL 682-8301

-----------------------------INCO AUTHORIZED USE ONLY-----------------------------
MASHA recognizes that individual companies must develop health and safety policies and programs which apply to their workplaces and comply with appropriate legislation. The information contained in this reference material is distributed as a guide only to assist in developing those policies and programs.

While MASHA cannot guarantee the absolute accuracy or sufficiency of this information, we will make every effort to correct, revise and update information as necessary, and we will be pleased to respond to your individual requests for information at any time.