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# PROTECTIVE MEASURES AND SITUATION READINESS FOR FIREFIGHTERS

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PROTECTIVE MEASURES AND SITUATION READINESS
FOR FIREFIGHTERS

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# PROTECTIVE MEASURES AND SITUATION READINESS FOR FIREFIGHTERS

## 1.0 INTRODUCTION

### 1.1 Purpose

The purpose of this publication is to discuss protective measures for firefighters and basic readiness for various types of fire and other emergencies. This information will assist the regional Fire and Safety Officers (RFSO) in the planning of volunteer fire brigade training programs. A main objective when establishing volunteer fire brigade training programs is to inform the students of the dangers inherent in exposure to fires. Volunteer fire brigade members should be made aware that exposure dangers can be significantly reduced through safety measures, proper use and storage of equipment, application of tested and approved procedures, and plain common sense.

This publication applies to the Indian and Inuit Affairs Program of the Department.

This publication is intended for use by the RFSO, their staff and Indian band councils concerned with protecting volunteer fire fighters from exposure fires.

### 1.2 Definitions

The atmosphere is all the air surrounding the earth which is necessary to support life.

Convection is the movement of heated gases.

A flame is the visible burning of materials in the presence of a normal (oxygen-rich) atmosphere.

Fire gases are gases which remain when products of combustion are cooled to normal temperatures.

A fire hall is a building used to store fire-fighting equipment, with areas set aside for training of volunteer fire brigade members.

A lining is a material or material assemblage attached to the inside of the outer shell of a coat for thermal protection and padding.

Mutual aid refers to the involvement of the volunteer fire brigade with other fire departments within a geographical location in order to act as one unit in times of emergency.

An outer shell is the outside material of the fire protection garment.

Protective clothing refers to garments worn by firefighters in the course of performing firefighting operations in buildings (structural firefighting). These garments include an assembled coat (outer shell, vapour barrier, and lining), trouser, a helmet, boots and mitts.

Resuscitation is the revival of a person apparently dead or in a faint.

A self-breathing apparatus is a device designed to provide the wearer with a supply of respirable atmosphere carried in or generated by the apparatus.

Trim is tape material permanently attached to outer shell material for visibility enhancement.

Vapour barrier is that material used to prevent or substantially inhibit the transfer of water, corrosive liquids, and steam or other hot vapors from passing through a garment to the wearer's body.

## 2.0 VOLUNTEER FIRE DEPARTMENT OPERATION

### 2.1 Tactical Operations

Tactical operations are the various means employed by fire suppression forces to cope with fire incidents. Although in some instances a situation may dictate only one tactical operation, each fire brigade member should be trained to carry out all these operations.

#### 2.1.1 Size-up

One important tactical operation that does not involve any physical activity is size-up. This is a continual mental evaluation of the situation and all related factors that may determine the success or failure of the fire suppression operation. This mental evaluation should begin as soon as the fire brigade is alerted, and continue throughout the incident. Size-up should not be limited to the fire chief but should be practiced by each volunteer firefighter involved with the incident.

#### 2.1.2 Rescue Operations

Rescue is the first and most important consideration at any fire incident, and may precede any attempts at extinguishment. Rescue operations may be simple, requiring only one or two volunteer fire fighters, or may require resources beyond the capabilities of the entire fire brigade. Rescue operations may be compounded by the time of the incident, the occupancy, the height, and the construction of the structure. <u>Rescue is the only acceptable reason for exposing volunteer firefighters to otherwise unnecessary risks</u>.

#### 2.1.3 Exposure Protection

The failure to adequately protect exposed structures often leads to large fire loss that extend beyond the building of origin. The problem of exposure protection may be compounded by closely spaced buildings, combustible construction, the type of occupancy, the lack of fire department access, and the lack of volunteer fire department resources. (Refer to BTP-FS-3 "Protection of Buildings from Exposure Fires"). Exposure protection is a vital and necessary tactical operation, and should be anticipated. Exposure protection should commence as soon as possible to prevent the extension of fire to exposed structures.

2.1.4 Confinement

Confining a fire to its area of origin is often a complex operation because it first requires locating the fire. Heavy smoke conditions will cause a delay. All avenues of possible fire travel must be explored. The concept of surrounding the fire (over, under, and on all sides), is necessary for successful confinement. Additional factors that influence the success or failure of confinement operations are the type of fuel involved, the location of the fire, construction features of the building, the presence of built-in fire suppression systems, and the availability of fire brigade resources.

2.1.5 Extinguishment

The problems associated with confinement, such as the type of fuel, the location of the fire, and the degree of involvement, are generally applicable to extinguishment operations. Extinguishment may involve one or two hose lines. In some instances the use of foam may be required. Often the success of extinguishing operations will depend upon the availability of volunteer fire brigade resources to apply water in sufficient quantities where needed.

2.1.6 Ventilation

In some cases it may be necessary to commence ventilation before rescue in order to protect occupants from combustion products and heat until rescue operations can be completed. Also, it may be necessary to provide ventilation for visibility and tenability during rescue operations. Ventilation is also mandatory during confinement and extinguishment to make it easier to locate the fire and to provide better working conditions for fire suppression personnel.

### 2.1.7 Salvage

Salvage operations are activities conducted by fire suppression personnel to minimize damage to the structure and contents due to heat, smoke, flame and water. Salvage is an integral part of tactical operations and should commence as soon as possible to prevent additional damage to both structure and contents.

### 2.1.8 Overhaul

Overhaul operations include completely extinguishing a fire, rendering the structure safe, and aiding the investigator in determining how the fire started.

Extensive overhaul may require the use of special pieces of equipment beyond what is normally provided by the volunteer fire brigade. It is important that extensive overhaul not be commenced prior to a thorough investigation to determine the cause of the fire. Once the investigation is complete, overhaul should continue to ensure that the premises are left as safe as possible and that all fires are extinguished.

## 2.2 Suppression Strategy

The success of any fire suppression operation is dependent upon how efficiently and effectively the fire brigade's resources are managed. It is the responsibility of the chief (or officer in charge) to manage these resources and deploy equipment to achieve maximum benefit.

The management of fire brigade resources normally employs the concepts of fire suppression strategy and tactics.

Suppression strategy is the method employed by the fire chief to coordinate the use of equipment and the management of additional resources (mutual aid) if required, to successfully control the incident.

## 2.3 Risk Potential in Buildings

### 2.3.1 General Remarks

The fire brigade should have a general knowledge of potential fire problems in their area. They must be aware of the layout and occupancy of buildings, industrial plants, and other hazards in the area. On arrival, the fire brigade officer is called upon to make instant, often irrevocable decisions on strategy which may affect the lives of his personnel and the general public. He thus commits personnel and apparatus based on a number of choices. Apart from obvious and visible indicators of the fire situation, the brigade officer needs an understanding of the way the fire can be expected to behave. In determining risk, certain questions should be considered.

### 2.3.2 Risk Factors

These questions take a semi-analytical approach to assessing the risk factor in fires, and they can be applied to any building fire from an old wood-frame nursing home to a modern industrial plant.

This approach can be used for planning resources, establishing response times, and preparing action plans. It can also be used to develop training exercises using group reaction techniques that help prepare the fire chief and deputy chief (captain) to think in terms of a systematic assessment for fire suppression decision-making.

2.3.2.1 Life Risk

a. Are the occupants likely to be active, physically capable, and able to help themselves, or are they likely to be infirm, aged, bedridden, handicapped, or otherwise unable to take any action towards self-rescue?

b. Are the occupants likely to be awake or asleep and, therefore, more prone to being trapped?

c. Are there several persons concentrated together, possibly presenting a multiple rescue problem (with a possible panic condition)?

2.3.2.2 Building Contents

a. Are the building contents highly flammable, therefore likely to give off considerable heat? Are they liable to explode, or to produce dense smoke rapidly, etc., or are they generally incombustible?

b. Are the contents in quantity or limited? Isolated or all in one area?

c. Are the contents themselves liable to promote rapid flame spread and flashover (independent of interior surface finishes)?

2.3.2.3 Construction

a. Is the construction fire-resistant and likely to maintain structural integrity, or is it unprotected and liable to fail early in the operation?

b. Are the interior finishes liable to cause rapid flame spread and extension of fire?

c. Is the building compartmented with fire walls and doors that can be taken into account in determining a course of fire suppression activity?

d. Are there openings in floors, walls, ducts, shafts, etc.?

e. Is the building old, or has it been remodeled with possible resultant weakness?

f. Are there structures which present a situation in which a developed fire is virtually impossible to control by standard fire hose streams (for example, because of heat release, or--in the case of a church--height)?

2.3.2.4 Built-in Protection

a. Are there sprinklers which might restrict growth and spread of fire?

b. Are there fire doors, compartments, etc.?

c. Are there other fire protection arrangements (for example, halon systems) which would cancel the fire effect?

2.3.2.5 Time

a. Are there occupants who are alert and would discover a fire soon after it started, or, are occupants asleep or absent?

b. Is there a smoke or fire detection system?

c. Is the fire some distance from the fire hall?

d. Are there any other factors that would delay discovery, alarm, or response?

2.3.2.6 Suppression Resources

a. Is water or an other extinguishing agent available?

b. Will there be a problem regarding access?

c. What demands for manpower will be created?

d. Is special equipment required?

e. Will there be a rescue problem? Will there be a need for support services, for example, band police or ambulance?

2.4 Transportation Incidents

2.4.1 Road Incidents

Incidents involving road transportation may range from a simple car engine fire to an exploding tank truck. Such incidents often involve simultaneous fire and rescue operations in which speed is an essential element. Extreme caution is required in handling any truck fire until the exact nature of its contents is known. Many firemen have been injured or killed when dealing with what appeared to be a simple fire situation, but was found too late to involve extremely hazardous materials.

2.4.2 Rail Incidents

A wide range of cargoes is carried by rail. In any fire involving rail cars, extreme caution is required. Until the nature of the cargo can be determined, fire-fighters should assume a highly defensive posture. Cargo is identified by means of labels or placards on the product or car, and by the manifests or waybills carried in the locomotive or caboose. Contact with the railway concerned might assist where positive identification cannot be made on the scene or when other advice or assistance is required. Often, mixed cargoes are involved which may seriously compound the risk.

### 2.4.3 Air Incidents

Aircraft crashes can occur on or off airfields and invariably present a fire and rescue problem. In order to carry out rescue, volunteer fire brigade action has to be rapid and effective. Local fire brigades should be included in aircraft rescue and fire-fighting training activities conducted at the airport (where applicable) to increase their knowledge in handling off-airport accidents and when assisting in a mutual aid capacity at serious accidents. This requires Transport Canada approval and concurrence. After rescue work, the fire-fighters should concentrate on final extinguishment.

## 3.0 PRODUCTS OF COMBUSTION AND THEIR EFFECTS ON LIFE SAFETY

### 3.1 Fire Gases - General Remarks

The fire-fighter must know what to expect to find in a building full of hot smoke and hot poisonous and flammable gases.

The products of combustion can be divided into four categories: fire gases, flame, heat, and smoke.

These products have a variety of effects on humans, the most important being burns and the toxic effects which result from the inhalation of heated air and gases.

Most combustible materials contain carbon which burns to form carbon dioxide when the air supply is ample, but dangerous carbon monoxide when the air supply is poor. The air supply in the combustion zone is usually poor. When materials burn, other gases are formed. Gas formed by a fire depends on many variables, the principle ones being the chemical composition of the burning material, the amount of oxygen available, and the temperature.

Several variables determine whether the gaseous products of combustion will have a toxic effect on the individual, including concentration of the gases in the air, the time of exposure, and the physical condition of the individual. It has been found that the toxic effects on persons inhaling fire gases are greater during a fire because the rate of respiration is increased by exertion, heat, and an excess of carbon dioxide. Under such conditions, gas concentrations which are ordinarily harmless may become dangerous.

Investigations into the hazardous properties of fire gases have shown the following gases to be the main causes of fire deaths; carbon monoxide, carbon dioxide, hydrogen sulfide, nitrous oxide, sulfur dioxide, ammonia, hydrogen cyanide, hydrogen chloride, nitrogen dioxide, acrolein and phosgene.

## 3.2 Description and Effects by Type

### 3.2.1 Carbon Monoxide

Carbon monoxide (the chief danger in most fire gases) is not the most toxic of fire gases, but is always one of the most abundant and is produced because of the deficiency of oxygen.

Carbon monoxide is a very active poison (poisons by axphyxiation). It is odourless, cannot be detected by sight, is flammable (ignition temperature 651°C, 1204°F) and explosive (range is 12.5% - 74% mixture with air). Even a small fraction of 1% of this gas in air produces a stupefying effect. Carbon monoxide forms a staple compound with the haemoglobin (the red colouring matter) of the blood, and this reduces the amount of oxygen carried by the blood to all parts of the body. This mode of action makes carbon monoxide dangerous at relatively low contentration:

a. Exposure to 0.15% for 1 hour or 0.05% for 3 hours is dangerous to life.

b. Exposure to 0.4% or greater is fatal in less than 1 hour.

c. Exposure to 1.3% will cause unconsciousness in two or three breaths, and will cause death in a few minutes.

Many variables such as exertion, heat, and the presence of carbon dioxide and other toxic gases affect the amount of carbon monoxide which can be tolerated without causing unconsciousness, permanent damage, or death.

Table 1 shows the carbon monoxide-carboxyhemoglobin relationship.

TABLE 1

Carbon Monoxide and Carboxyhemoglobin

| Carbon Monoxide Concentration | | Maximum Exposure | Approximate Carboxyhemoglobin Levels Reached and Symptoms |
|---|---|---|---|
| PPM | Per Cent | Hours | Per Cent |
| 50 | 0.005 | 8 | 10 (no effect) |
| 200 | 0.02 | 2 | 20 (slight effect) |
| 1,000 | 0.1 | 1 | 40 (severe effect) |
| 10,000 | 1.0 | 1 min. | 20 (fatal) |

It is nearly impossible to revive a person who has been poisoned by this gas.

### 3.2.2 Carbon Dioxide

Carbon dioxide is usually evolved in large quantities from fires. High levels of this colourless, odourless, heavier-than-air gas overstimulate the rate of breathing. This condition, combined with decreased oxygen and the presence of irritating substances in a fire environment, may cause the lungs to swell from an excess of fluid. The speed and depth of breathing are said to be increased 50% by 2%

carbon dioxide or 100% by 3% carbon dioxide in air. It is not poisonous, but it is a suffocant because it displaces the oxygen in the area. Since a high concentration of carbon dioxide increases the breathing rate, it also increases the rate of intake of other toxic gases that may be present and, therefore, it increases the hazard.

It should be noted that carbon dioxide is used as an extinguishing agent for Class B and C fires.

3.2.3 Hydrogen Sulfide

The incomplete combustion of organic materials that contain sulfur yields hydrogen sulfide. For example, this gas is formed when wool, rubber, hides, meat and hair are burned.
Hydrogen sulfide is identified by its "rotten egg" smell. However, its smell is unreliable as an exposure warning. At concentrations above 0.02%, the average human sense of smell deteriorates so rapidly that after a few inhalations the presence of the gas is undetectable. Exposure to 0.04 to 0.07% for more than one-half hour is dangerous and can cause such symptoms as dizziness and intestinal disturbances, as well as dryness and pain in the respiratory system. Above 0.07% in air, hydrogen sulfide is actually poisonous, affecting the nervous system and causing an extremely rapid breathing rate followed by respiratory paralysis. So, it is vitally important to take protective action the moment hydrogen sulfide is detected.

3.2.4 Nitrous Oxide

Nitrous oxide is produced whenever nitro-cellulose products are burning. These include celluloid, plastic and pyroxelin products such as movie films, X-ray films, combs, brushes, toilet seats and lacquer. It is colourless, but can be detected by a pleasant odour and sweet taste. It does not burn itself, but it supports combustion of many well-burning substances. If inhaled in large quantities, it produces temporary unconsciousness and insensibility to pain.

Proper self-protection must be provided as it is possible to inhale sufficient amounts to be fatal without a great deal of discomfort. Nitrous oxide fumes as a result of combustion are seldom found by themselves, but rather in combination with nitric oxide and nitrogen tetroxide. The mixture of these gases is deep orange and extremely poisonous.

3.2.5 Sulfur Dioxide

Complete oxidation of sulfur-containing materials yields sulfur dioxide, a colourless and suffocating gas which gives adequate warning of its presence, as evidenced by an extremely irritating effect on the eyes and respiratory tract. It can be detected by its strong sulphurous taste and odour and is not flammable or explosive. Concentrations of 0.05% are considered dangerous, even for short exposures. Sulfur dioxide is a combustion product of wool, rubber, and some woods. However, the quantities are said to be too small to be toxic. Mixtures of 1 part per 10,000 parts of air are usually not fatal unless exposure is for more than 30 minutes.

3.2.6 Ammonia

Ammonia is formed during the burning of combustible material containing nitrogen (wool, silk, acrylic, and plastic and phenolic and melamine resins combined with fillers). As a common refrigerant in refrigeration systems, ammonia is a potential toxic hazard because of the possibility of accidental release during a fire. Because ammonia is extremely irritating to the eyes, nose, throat and lungs, people usually will not voluntarily remain in an ammonia-containing atmosphere long enough to suffer serious effects. Exposure between 0.25% and 0.65% ammonia in air for one-half hour is sufficient to cause death or serious injury.

### 3.2.7 Hydrogen Cyanide

Hydrogen cyanide is highly toxic but is not likely to be produced in dangerous quantities by a fire. Relatively large quantities may be produced by incomplete combustion of certain nitrogen-containing materials such as wool, silk, urethane, polyamides and acrylics. Some nitrogen fixation--the combining of atmospheric nitrogen with carbon from burning materials--also occurs in wood and paper fires. Exposure to 0.3% is fatal. The characteristic bitter almond odour sometimes warns of the presence of hydrogen cyanide.

### 3.2.8 Hydrogen Chloride

Hydrogen chloride is a product of combustion of chlorine-containing plastic materials. Polyvinylchloride is the most notable because of the large quantities used for electrical conductor insulation, conduit, and piping. Although inhalation of concentrations of about 100 parts per million in air for a few minutes is fatal, hydrogen chloride's pungent and irritating odour make it unlikely that a person would inhale it voluntarily.

### 3.2.9 Nitrogen Dioxide

Nitrogen dioxide (peroxide) is extremely toxic. A concentration of only 0.0025% for a few minutes makes air unsafe to breathe. It is formed with other oxides of nitrogen during decomposition and combustion of cellulose nitrate, and in fire involving ammonium nitrate and other inorganic nitrates or when nitric acid comes in contact with metals or combustible material. In a fire it can usually be identified by its reddish-brown colour.

Nitrogen dioxide tends to anesthetize the throat so that its presence may not be recognized. The toxic effect is delayed unless the exposure is very great. In moderate exposures, effects appear as much as eight hours later when breathing becomes distressed by the accumulation of fluid in the lungs. Recovery is difficult, and sometimes pneumonia can result. Brief exposures to 200 to 700 parts per million may be rapidly fatal.

3.2.10 Acrolein

Acrolein (acrylic aldehyde) is a highly irritating and toxic gas produced during combustion of petroleum products, fats, oils and many other common materials. Although acrolein is only a minor constituent of fire gases, humans find concentrations of 1 part per million are lethal in a short time.

3.2.11 Phosgene

Phogene is highly toxic, but is not usually present in the products of combustion of ordinary combustible materials. Whenever a chlorinated compound comes in contact with flame, phosgene is one of the products of combustion. Thus, it may be found in fires involving polyvinylchloride plastic or where chlorinated solvents are exposed to flame. Phosgene has been reported as the cause of death when carbon tetrachloride was used as an extinguishing agent.

3.3 Flame

The burning of materials is generally accompanied by a flame--considered a distinct product of combustion. Burns can be caused by direct contact with flames, or heat radiated from flames. Flame is rarely separated from the burning materials by an appreciable distance. However, in certain types of smoldering fires without evidence of flame, smoke and gas can develop. Air currents can carry these elements far in advance of the fire.

## 3.4 Heat

Heat is the combustion product mostly responsible for the spread of fire in buildings. The physiological dangers of heat range from minor injury to death. Exposure to heated air may cause dehydration, heat exhaustion, and blockage of the respiratory tract due to fluids and burns. Heat also causes an increased heart rate, and when the intensity of heat exceeds the threshold of human tolerance, it is fatal.

A temperature of 149°C can be endured only for a short period and only when there is no moisture present. When water is used in fire-fighting, steam is produced and the atmosphere in the fire area is moisture-laden.

It has been suggested that fire-fighters not enter atmosphere exceeding 49°C (120°F) to 54°C (130°F) without special protective clothing and masks. No one can expect to inhale more than one or two breaths of moisture-saturated air at these temperatures without suffering serious consequences.

Burns caused by heat and fire are commonly classified as first-, second- and third-degree burns. First-degree burns involve only the outer layer of the skin and are characterized by abnormal redness, pain and sometimes a small accumulation of fluid. Second-degree burns penetrate more deeply into the skin. The burned area is moist and pink. There are blisters and usually a considerable amount of subcutaneous fluid accumulation. Third-degree burns are the most severe and penetrate down to the subcutaneous fat. Third-degree burns are usually dry, pearly white or charred, and are not painful because the nerve endings have become inactivated. Burns result in 20 seconds at 55°C and in 1 second at 70°C. The time for the body temperature to be increased will depend on the exposure temperature which in most fires increase rapidly in the first few minutes.

Death may result from exposure to excessive heat for a sufficient period of time (hypothermia) without visible signs of burning, as in a flash fire. This condition will occur if the body absorbs heat faster than it can be dissipated by vapourization of surface moisture and outward radiation, thereby elevating the general body temperature sufficiently above normal to cause damage, particularly to the nerve centers of the brain.

Shock is often diagnosed in delayed deaths (survival longer than three hours) and may occur after exposure to heat alone, or irritants, or oxygen deficiency plus high carbon monoxide.

A person exposed to excessive heat may die if the heat is conducted to the lungs rapidly enough to cause a serious decline in blood pressure and failure of circulation due mainly to capillary blood vessel collapse. This condition is also caused by large amounts of irritants such as acid anhydrides, acids (acetic, sulfuric, etc.) and aldehydes, such as acrolein.

## 3.5 Smoke

Smoke is made up of very fine solid particles and condensed vapour. Fire gases from common combustibles (such as wood) contain water vapour, carbon dioxide and carbon monoxide. Under the usual conditions of insufficient oxygen for complete combustion, methane, methanol, formaldehyde and formic and acetic acids are also present. These gases are usually evolved from the combustible with sufficient velocity to carry with them droplets of flammable tars which appear as smoke. Particles of carbon develop from the decomposition of these tars and are also present in the fire gases from the burning of petroleum products, particularly from the heavier oils and distillates.

Certain fire gases (for example, oxides of nitrogen) and, in some instances, condensed steam and other atomized liquids, contribute to the visibility of fire gases. There are certain combustion conditions under which materials can burn without producing visible products of combustion, however, smoke generally accompanies fire, and like flame it is visible evidence of fire.

While the heat and toxic qualities of fire gases can be injurious or fatal, the solid and liquid particles in suspension in the gases (for example, smoke particles) also have harmful effects. The particles may be of such colour, size and quantity that they can obscure the passage of light, thus blocking vision to exits and exit signs. The development of quantities of smoke particles sufficient to make exitways unusable can be very rapid. Smoke is the principle life hazard which frequently provides the early warning of fire and thus contributes to panic conditions by the very nature of its blending and irritating effects.

Smoke particles can be irritating when inhaled, and long exposure may cause damage to the respiratory system. Particles lodged in the eyes induce tears which may impair vision. Those lodged in the nostrils and throat can cause sneezing and coughing at times when the persons so affected need all their normal faculties. Smoke particles in air streams may cool to the point where water vapour, acids and aldehydes will condense on them. If inhaled, such moisture-ladened particles might carry in the respiratory system highly poisonous or irritating liquids of undetermined composition. Also these particles may cause eye injury.

## 3.6 Insufficient Oxygen

When oxygen drops from its usual level of about 21% in the air to 15%, muscular skill is diminished, and when it drops lower (14%-10%) a person is still conscious but has faulty judgement (which is not self-evident) and becomes quickly fatigued. In the 10%-6% range, one collapses but can be revived by fresh air or oxygen. During periods of exertion, increased oxygen demands may result in oxygen deficiency symptoms at much higher percentages.

## 4.0 PROTECTIVE CLOTHING FOR STRUCTURAL FIRE-FIGHTING

### 4.1 General Remarks

This section is a guide for fire officers and others responsible for purchasing protective clothing for structural fire-fighting by volunteer fire brigade personnel. Such clothing serves to protect against extremes of temperature, steam, hot water, hot particles and other hazards encountered during fires and related lifesaving.

Protective clothing must be flame-retardant, durable, lightweight, water-resistant, nonirritating to the skin, and cleanable.

Protective clothing shall be designed to give minimum interference to physical movement, the use of fire-fighting tools, and protective breathing apparatus.

Materials used in garment construction shall not shrink more than 10% under heat exposures of 260°C (500°F) in a forced air oven for a period of five minutes.

These three points should be taken into consideration in the garment design:

a. Air circulation within the coat is desirable for cooling; belts, therefore, should not be worn.

b. Striking and being struck by objects, particulary in the upper extremities, are the most frequent causes of injury at a fire and of these, injuries to the upper extremeties are the most numerous. Incorporation of impact protection by padding in the coat is highly desirable, providing the weight is not greatly increased.

c. Elbow protection for wear resistance and heat protection when crawling is also desirable.

4.2 Sizing

4.2.1 Coat

In selecting a coat, the protection afforded the legs and buttocks area by boots and protective trousers should be considered. While coats should be made to allow room for air circulation, it is standard practice to purchase coats slightly larger than needed to allow room for winter clothing. The coat length shall be such as not to interfere with the knee movements, and sleeve lengths should be specified if an individual has unusually long or short arms. Sleeve length is correlated to chest measurement (taken well up under the arms, and across the shoulder blades with normal clothes worn). Back length is determined by measuring from the collar base to the coat bottom.

4.2.2 Trousers

Waist measurements and leg length of trousers must be specified.

The waist measurement is obtained by measuring in a horizontal plane at the top edge of the pelvic bones and over the top of a normally worn belt and trousers. Overlapping allowance for the trouser fly shall be made in addition to the waist measurement. Add 25 mm or 50 mm to the actual waist measurements to ensure ease of donning.

The leg length is the inseam length from the crotch to the bottom of the trouser leg. Trousers are usually shorter than normal pant length owing to boot bulkiness and high instep construction. Trousers should never be cuffed, rolled or allowed to drag on the ground when worn.

## 4.3 Stitching

### 4.3.1 Seams

Each load-bearing seam, including pockets, their dividers and the storm flap, shall have breaking strength of at least 36.3 kg, or 80% of the outer shell material strength.

### 4.3.2 Thread

Thread fibre shall be compatible with the material on which it is used and shall not carbonize at a temperature below 260°C.

## 4.4 Protective Coat

### 4.4.1 Outer Shell

#### 4.4.1.1 Material

The outer shell material (including trim) shall meet the following conditions: tearing strength 9.53 kg minimum, colour-fastness, 3% maximum shrinkage in laundering, 28% maximum water absorption, and flame resistance.

The manufacturer must provide statements on resistance to corrosive substances, on the wearability of the garment, and on the stability of the fabric at high temperatures (260°C) not to char, separate, or melt.

There shall be at least 120 000 $mm^2$ retro-reflective flourescent trim on each coat, to comply with the trim configuration developed by the volunteer brigade chief. A suggested configuration is:

a. a circumference band on each sleeve near the cuff,
b. a circumference band around the bottom of the coat within 152 mm of the coat hem,
c. two 381-mm vertical strips on the back, and
d. a 762-mm vertical strip down the centre and
e. 2 432-mm vertical strips on each side of the front.

All trimming tape shall be at least 50.8 mm wide and be of a light colour, thus making the fireman easy to see at the fire scene.

4.4.1.2 Pockets

Pockets should be large enough to carry essential tools and items and be placed to allow for easy access while wearing breathing apparatus.

Pockets should be reinforced in the two top corners and in the flap corners with a series of stitches forming a bar. Each outside pocket should have a flap at least 76 mm deep, while the lowest 127 mm of each pocket attached to the exterior of the outer shell shall be reinforced with a double thickness of material. The pocket should have two holes at the bottom for drainage of water.

4.4.1.3 Labels

Each outer shell shall have sewn to the inside a permanent label stating the fibre content, the size of the garment, the care instructions, and a warning that the garment is not a proximity or entry suit and should not be kept in direct contact with flames.

4.4.2 Collar

The collar (cotton corduroy material) must be snug fitting but comfortable, and must completely cover the neck and throat when in the raised position.

There shall be a throat strap at least 76 mm wide on the underside of the collar on the left side which closes by means of hook and pile fastener tape or by a snap fastener, and is held in the stowed position by a securing device.

Metal fasteners must not come in contact with the skin when the collar is in a closed position.

The collar shall provide water penetration protection at least equal to the vapour barrier.

4.4.3 Sleeves

Sleeves should be attached to the coat so that there is no restriction and the wrist remains covered when the arms are raised above the head. An optional reinforcement for the lower part of the sleeve may be considered.

Each sleeve should have a suitable and durable wristlet which meets the flammability requirements for the other shell material, and which is constructed as to keep out water when the arm is in the raised position. It shall fit snugly and retain its shape for the expected life of the coat.

4.4.4 Closures

The front of the coat should close so as to protect against steam and water but allow freedom of leg movement. Conventional coat designs feature a storm flap to provide this protection.

4.4.5 Hanger Loops

A fabric hanger loop should be provided inside the neck and shall not tear or separate from the coat when the coat is hung up by the hanger loop, loaded evenly with a weight of 36 kg and allowed to hang for one minute.

4.4.6 Vapour Barrier

The vapour barrier should have a minimum allowable water penetration under test (Textile Test Methods) and shall be insulated from the body of the protective garment.

4.4.7 Linings

Garment linings should be fabricated of material with a minimum warp of 15 oz./sq. yd. (426 $g/m^2$) and should have 10 oz./sq. yd. (283 $g/m^2$) of fill.

The lining should extend to within 76 mm of the bottom hem of the coat.

Sizing must be compatible with that of the outer shell and not restrict body motion, even when the arms are raised directly overhead.

Each lining shall have a label stating the fibre content, size, and care instructions.

Linings should be securely attached to the outer shell material by stitching in the neck area. Fastener tape or snap fasteners shall secure the rest of the liner to the front face and wristlet areas of the outer shell.

4.4.8 Thickness

The minimum thickness of the assembled protective coat should be 4.7 mm when tested using a compressometer with a 76 mm diameter presser foot at 0.3 kPa, allowing 5 seconds to lapse between the application of the load and the thickness reading. The manufacturer shall supply information on the thickness of the coat prior to sale.

4.4.9 <u>Weight</u>

The assembled garment shall include the required outer shell, vapour barrier and lining.

The total weight of an assembled coat size 40 with a 1 016 mm (40 in.) back length should not exceed (7 lbs.) 3.2 kg.

4.5 <u>Protective Trousers</u>

Trousers shall have buttons or other holders for suspenders with two buttons on each side of the fly on the front and two buttons on each side of the center back.

Trousers should have a fly front designed to remain fastened during all forms of vigorous physical movement.

One hip pocket at least 127 mm (5 in.) wide by 152 mm (6 in.) deep shall be provided on the exterior of the trousers. Pocket material and stiching shall conform to the requirements of the material to which it is attached. A flap with a means of fastening shall be provided.

The total weight of an assembled pair of trousers size 36 with 812 mm (32 in.) inseam length shall not exceed 5 lbs. (2.3 kg).

Material for protective trousers will be compatible with the manufacturer's material specifications for the protective coat selected.

4.6 <u>Helmet and Accessories</u>

Firefighters' helmets are made of polycarbonate or similar material with a polyethylene or similar material adjustable crown suspension. This tough durable material can be compared to metal, yet is lightweight. It is impervious to scratches and abrasion, has a high dielectric quality, together with maximum impact protection and resistance to penetration. The assembled helmet with suspension, chin strap and "D" ring should weigh approximately 560 g.

Helmets should comply to CSA Specifications Type I, Class D covering firefighters' head protection. The helmet should come complete with an adjustable crown suspension, chin strap and winter liner. Many helmet manufacturers produce a clear cellulose acetate face-shield 203 mm long, 15 mm thick, and aluminum bound for rigidity and shape retention, which provides eye and face protection against heat, dust, sparks, flying particles, and splashing liquids. This added protection should be acquired when purchasing helmets. Helmets are available in high luster finish in colours of black, white, red, yellow and high visibility lime-yellow. Red will always retain a "new" look.

## 4.7 Rubber Boots

Rubber boots should be knee high, with a safety toe, heavily corrugated punctureproof soles, pull-on loops and warm felt lining. Bright lime-yellow safety strips should be around the boot just below the knee to aid visibility. Some boot manaufacturers use black soles with lime-yellow trim to ensure increased wear and visibility.

## 4.8 Gloves

Many types of protective gloves are manufactured. They use lightweight aramid fibre with extraordinary strength, toughness, and outstanding cut and abrasion resistance. They are inherently flame-resistant, do not support combustion, and withstand limited contact exposure up to 537°C (1 000°F). The leather palms are usually specially treated leather not to shrink when wet and do not harden when exposed to high temperature. Gloves should have extended wristlets to provide the wearer with extra thermal, cut and puncture protection. Other types of gloves have foam insulation for warmth, and are jersey lined with vinyl coatings that stay soft when cold, and use the curved finger wing-thumb pattern. Gloves come in various colours and colour combinations such as black, white, yellow, green and lime-yellow.

It is not uncommon for the volunteer fire brigade to be equipped with several types of gloves and use the type most suited to the occasion.

### 4.9 Fasteners

All outer surfaces on metal parts should be rust-resistant and nonferrous to avoid sparking.

Fasteners may be hooks and dees, rivets, snaps or tape and the type or combination of types used on the garment should be indicated by the manufacturer.

## 5.0 RESPIRATORY PROTECTIVE EQUIPMENT FOR FIREFIGHTERS

### 5.1 The Respiratory System

The human respiratory system is a sensitive, delicate group of organs which supplies oxygen to the blood stream. The nose and throat are lined with a sensitive membrane that can be easily irritated and inflamed. The windpipe or trachea extends from the mouth, down the throat, through the chest cavity, and to the lungs. The chest cavity contains the bronchi and brochioles which make up the lung structure. These bronchial tubes carry each breath to and from the lungs. As the network of bronchioles becomes smaller, they become more delicate. There are over five million air sacs in the human lung. It should be a fundamental rule in firefighting that no one be permitted to enter a building which is charged with smoke and gas unless he is equipped with self-contained breathing equipment.

5.2 Types of Breathing Apparatuses

There are three approved types of breathing apparatuses for fire department use:

a. self-contained open-circuit "demand" and "pressure-demand" types connecting one or more cylinders of respirable air,

b. the closed-circuit type using a chemical as the source of respirable oxygen, and

c. the closed circuit compressed oxygen type.

Note: Because b. & c. are not commonly used, they will not be discussed here.

A demand-type breathing apparatus consists of a facepiece connected by a tube to a regulator or pressure reducing valve which is connected to a pressure tank of air or oxygen. It also has a pressure gauge and the necessary harness. The tank is intended to provide 30 minutes protection to the average wearer. The period may be shorter for persons of above average breathing capacity or when worn during heavy exertion. Recharging is relatively inexpensive, and many fire brigades carry additional cylinders on the fire truck.

Note: The latest information is that the demand type breathing apparatus has limitations. "Canada Labour Views" reports that the seals on the apparatus are not sufficient to prevent toxic gases, such as hydrogen sulphide, from contaminating the air breathed by the wearer, particularly when the apparatus is worn in a cofined space. Constant pressure masks are much safer because the pressure inhibits inflow of contaminated air.

Pressure-demand equipment is the most widely used of the three types, provides a protection factor of 10,000 to 1, and is designed to give absolute assurance of breathing protection in the deadliest of atmospheres by exerting a slight positive pressure on the breathing circuit at all times, thus preventing the possibility of contaminants entering the breathing system. Pressure-demand equipment assures that the added security of positive pressure is maintained under all breathing conditions. On inhalation, the positive pressure in the facepiece is slightly reduced, causing the demand valve to open and allowing air to flow into the respirator system. On exhalation the pressure increases, causing the facepiece exhalation valve to open and the regulator demand valve to close.

## 5.3 Components

### 5.3.1 General Description

Figure 1 shows a commercially produced self-contained breathing apparatus.

A pressure-demand unit consists of five major components:

a. a facepiece and low pressure hose,
b. a regulator,
c. an audible alarm and high pressure hose,
d. a cylinder and valve assembly, and
e. a backpack,

There is also a carrying case which is optional.

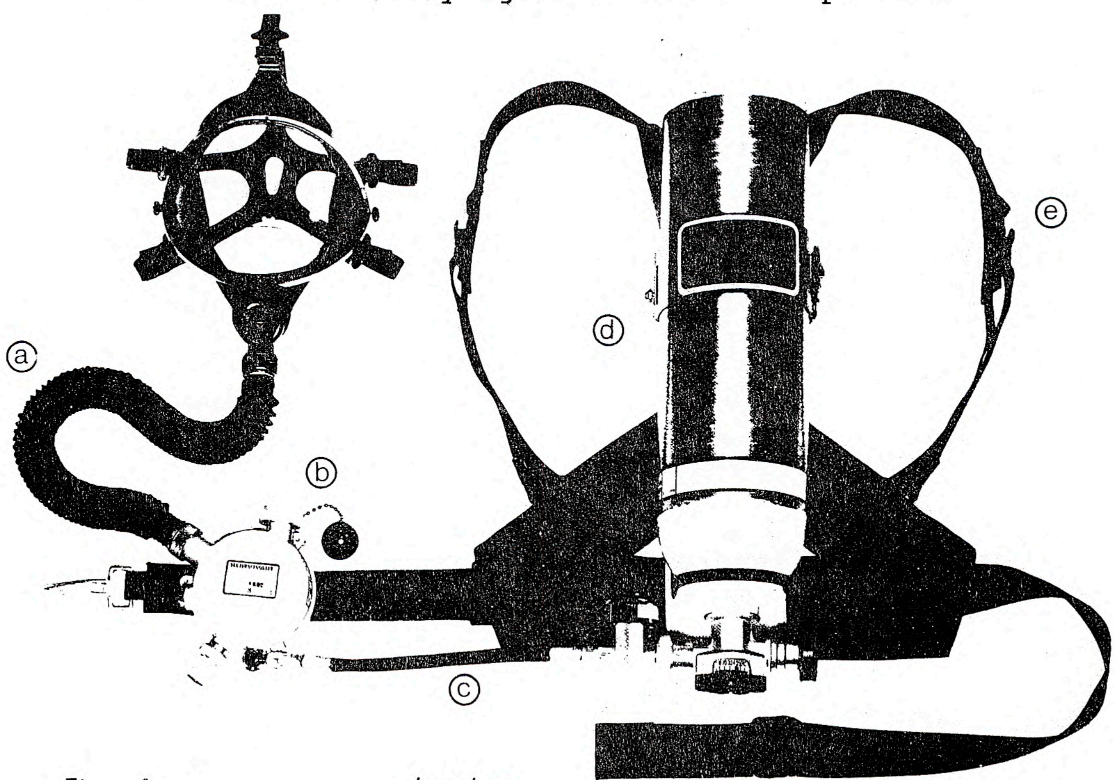



Figure 1

5.3.2 Facepiece and Low Pressure Hose Assembly

The facepiece is normally made of a molded neoprene or silicone rubber skirt with feathered sealing edges that ensure comfort and seal. Some facepieces have a clear deflector that directs the air up and over the lens to reduce fogging during use. A positive-pressure exhalation valve maintains pressure at a constant value.

The facepiece, flexible through a wide temperature range, is held in place by a head harness with five or six adjustable straps that attach to quick release buckles on the skirt.

The low-pressure hose is approximately 488 mm long in the free position and extends to 976 mm. It is made of ethylene propylene diene elastomer (or a similar product) and is not affected by temperature.

5.3.3 Regulator

The pressure-demand regulator is the heart of the unit. A two-stage regulator is illustrated in Figure 2. The components of the regulator are: a mainline shut-off valve, a bypass valve, a pressure gauge, a filter, a lever to change from don to use position, and an injector nozzle which jets the air up the convoluted hose to the facepiece, providing massive air flows to meet peak requirements.

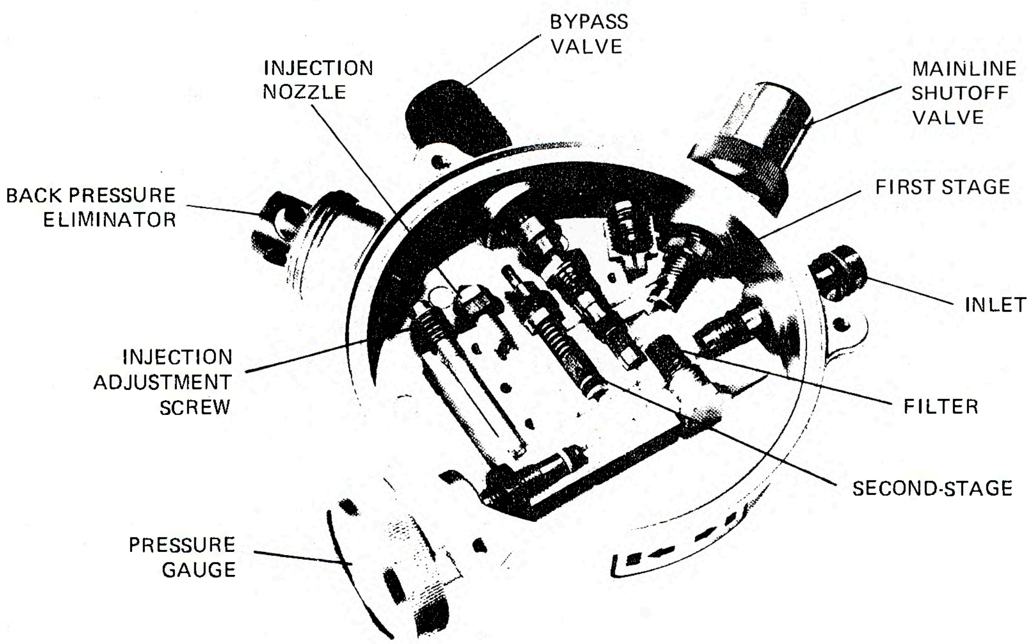



Figure 2

The mainline valve is used to shut off the functioning of the regulator and control the air flow with the bypass valve, which the user may adjust to the air flow he desires. However, the mainline valve has a locking device to assure that the valve is not accidentally closed. To prevent confusion, the mainline valve handle is usually square-shaped, clear anodized aluminum, while the bypass valve handle is round and red anodized aluminum.

The gauge assembly displays the pressure inside the regulator and high-pressure hose at all times. Pressure inside the tube makes it deflect, causing the pointer to rotate in an arc the length of which is proportional to the pressure.

A filter prevents foreign matter larger than 50 microns from entering the regulator.

The regulator case and body is usually made of anodized aluminum and is sealed with a coating to increase corrosion resistance. Stainless steel is normally used for the backplate and diaphragms are made of silicone rubber (or similar composition) to ensure flexibility and ease of operation at various temperatures. The regulator and hose fitting connections are usually swivel (banjo) design for comfort during use.

### 5.3.4 Audible Alarm and High Pressure Hose (Figure 3)

The audible alarm is designed to ring continually after the air cylinder pressure has decreased to 6 894 kPa (1 000 psi). The alarm body is usually manufactured from an aluminum alloy (to reduce weight) and sealed for maximum corrosion resistance.

Alarms are usually connected at the regulator end with a banjo swivel and a hand-tight fitting O-ring seal at the cylinder end.

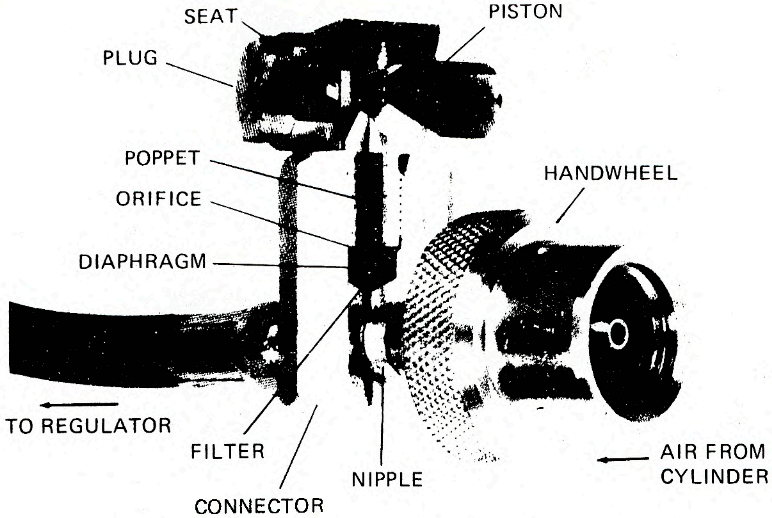



Figure 3

5.3.5 <u>Cylinder and Valve Assembly (Figure 4)</u>

The cylinder valve provides a continuous reading pressure gauge and should have a locking device to protect against accidential closing during use.

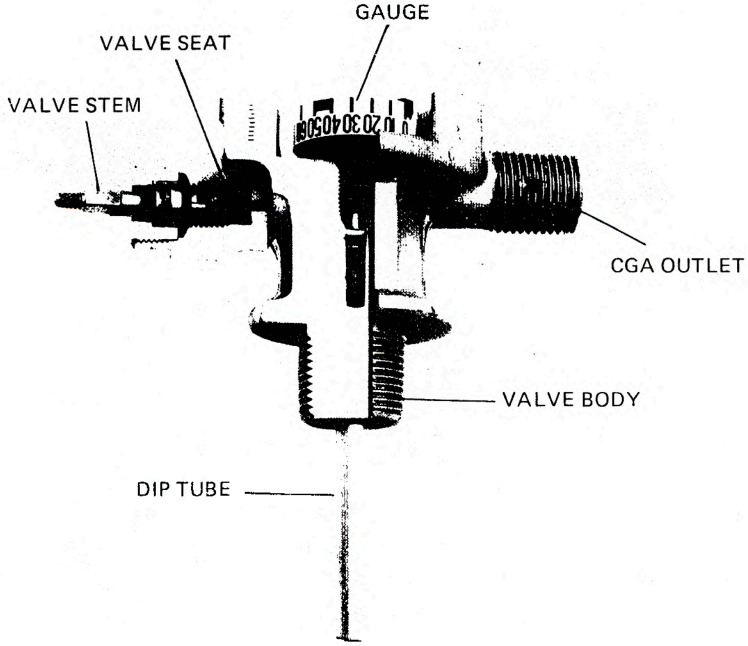



Figure 4

The cylinder valve handle is normally positioned horizontally for ease in turning the valve on and off when the breathing apparatus is being worn.

The valve body is made of aluminum alloy and uses standard threads.

5.3.6 Backpack

Backpacks are designed to distribute the weight over the hips, thus allowing the back, shoulders and arms to be free to perform work without restrictions. Some backpacks have a support plate hinged at the shoulder blades to allow more freedom of movement and a waist strap with slide buckle and shoulder straps with thumb-tab adjustment buckles for rapid donning of the apparatus. The frame is made of aluminum. Backpack straps are made of nylon webbing and vary in width from 2.54 cm to 5.08 cm while strap hardware is made of stainless steel.

5.3.7 Carrying Case

An optional carrying case is made to facilitate storing and carrying the breathing apparatus and should be purchased with the unit.

5.4 Use of Equipment

Protective breathing equipment should be used only after thorough training with the specific type of equipment available for use and practice in working under restricted breathing and visibility conditions. Firefighters wearing masks should not work alone and should be under supervision of the chief or trainer. Masks should not be donned by persons who have been subjected to heavy exertion and smoke. The use of masks does not protect the individual against excessive heat, gases, and poisons that attack the body through the skin.

Breathing apparatus equipment is equipped with an audible warning signal (see 5.3.4) to warn the user when the air or oxygen supply is low. When the alarm sounds, wearers should leave the contaminated area immediately. A wearer should leave the mask on until a safe atmosphere is reached or help is available.

A number of volunteer fire brigades have scuba designed for their own purposes. Fire department air or oxygen masks should not be used for underwater work.

Instruction in the use and care of protective breathing apparatus is part of basic fire fighting training. Confidence in the equipment, as well as knowledge of its practical limitations, should increase with use.

## 5.5 Donning of Equipment

Most breathing apparatus equipment is donned in a similar manner. The wearer removes the backpack from the carrying case and places it on his back while he is bending forward. Once the shoulder straps are in place, he straightens up and secures the waist harness and pulls all straps to a snug position. He then puts on the facepiece.

Since facepieces for most breathing equipment are applied in a similar manner, a step-by-step procedure of applying a six-strap model will be described. Head harness straps should be snug, not excessively tight. Although other types of facepieces may have fewer head harness straps or may have various sizes and shapes of lens before the eyes, most facepieces are similar in design.

a. Loosen the head harness strap so that the tab end of each strap is against the facepiece buckle. With both hands, fold these straps in a bundle across the top of the facepiece. Hold the facepiece and straps by grasping the upper sides with both hands (Figure 5a).

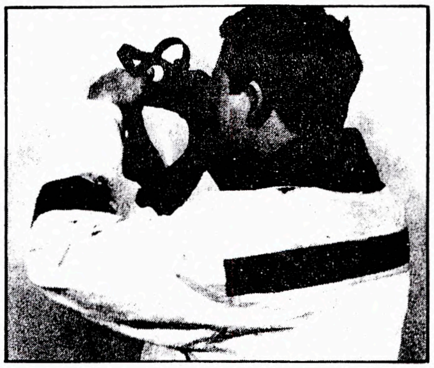


Figure 5a

b. Place the chin well into the small pocket at the bottom of the facepiece and fit the facepiece to the temples and forehead (Figure 5b).

Figure 5b

c. Release the facepiece with both hands, but hold secure to the harness and pull the harness over the top of the head (Figure 5c).

Figure 5c

d. Tighten the chin straps first by pulling out and back on the tabs provided. This operation secures the facepiece in position and places the head harness on the back of the head so that the bottom strap is across the back of the neck and below the ears (Figure 5d).

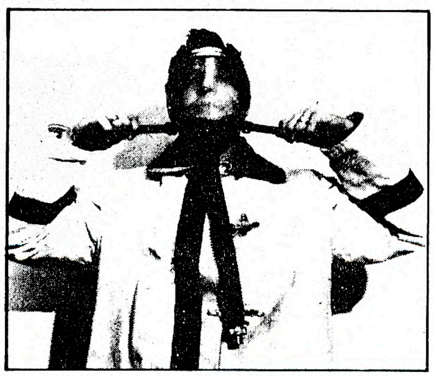


Figure 5d

e. Tighten temple straps next and further secure the facepiece snugly to the head (Figure 5e).

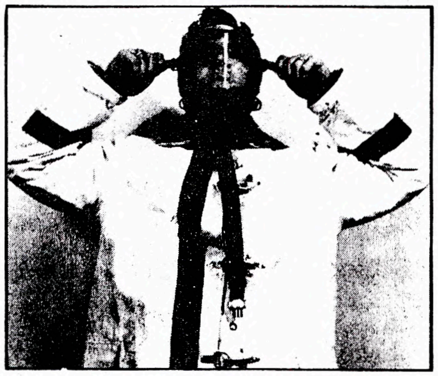


Figure 5e

f. Tighten the top straps last (Figure 5f).

Figure 5f

Notice that the head harness is placed at the back of the head, not on top. If the top straps are tightened first, the head harness may be pulled out of position. The facepiece is now ready to be tested for leakage: hold one hand over the end of the breathing tube or squeeze the breathing tube and then trying to inhale. If the facepiece fits snugly, it should collapse against the face.

## 6.0 FIRE VENTILATION AS APPLIED TO FIREFIGHTING

### 6.1 General Remarks

Ventilation, applied to fire fighting, is the planned and systematic release and removal of heated air, smoke, and gases from a structure and the replacement of these products of combustion with a supply of cooler air. One cannot rely solely upon knowledge gained from practical experience in actual fire situations, since no two fires are identical.

### 6.2 Objectives and Advantages

The major objectives of a fire brigade are to reach the scene of the fire as quickly as possible, rescue trapped victims, locate the fire, and apply suitable extinguishing agents with a minimum of fire, water, smoke and heat damage. Ventilation during firefighting definitely aids these objectives. To accomplish some of the objectives, it often becomes necessary to safely get inside a structure. This is one reason why all volunteer fire brigades should be equipped with adequate respiratory protection. Although fire ventilation provides better breathing conditions within a structure, it does not remove all hazards and dangerous gases. When proper ventilation is aiding fire control, there are several advantages:

a. Proper ventilation simplifies and expedites the rescue of victims by removing smoke and gases which endanger occupants who are trapped or unconscious, and by making conditions safer for fire-fighters.

b. The removal of smoke, gases and heat from a building permits fire-fighters to more rapidly locate the fire and proceed with its extinguishment. Proper ventilation of a building further enables fire fighters to determine the path or travel of the fire and to take proper steps for its control.

c. Situations which create a back draft--the explosion and rapid burning of gases--are confinement and intense buildup of heated gases in an atmosphere being depleted of oxygen. Proper ventilation is a procedure whereby these heated gases can be released with a minimum of additional damage to the structure.

d. Proper ventilation of a building during a fire reduces the possibility of mushrooming, where heat and gases spread out laterally at the top of the structure. It tends to draw the fire to a point by providing an escape for the rising heated gases.

e. Proper ventilation reduces the obstacles which hinder fire-fighters while they perform fire extinguishment, salvage, rescue, and overhaul procedures, by enhancing vision and removing the discomfort of excessive heat.

f. Rapid extinguishment of a fire reduces not only the actual fire damage but also water damage. Proper ventilation assists in making this damage reduction possible. One method of ventilation is applying water to the heated area in the form of water fog or spray. The gases and smoke may be dissipated, absorbed, or expelled by the rapid expansion of the water when it is converted into steam. In addition to removing gases, smoke and heat, this method also reduces the amount of water that may be required to extinguish the fire.

g. Smoke may be removed from burning buildings by controlling heat currents, by collecting carbon in the condensed steam, by dissipating smoke through the expansion of water as it is turned into steam, or by mechanical processes. Mechanical processes include blowers, exhaust fans, and smoke ejectors. Regardless of the method used, ventilation reduces smoke damage because fuel vapours and carbon particles are removed.

h. When smoke, gases, and heat are removed from a burning building, the fire can be more quickly confined to an area. This accomplishment will permit effective salvage operations to be initiated even while fire is being controlled. Very little merchandise is saved when covers are placed over water-soaked smoke-filled materials; therefore, it is imperative that salvage operations be started as soon as possible.

i. When an opening is made in the upper portion of a building during ventilation, a chimney effect is created which draws air currents from throughout the building in the direction of the opening. For example, if this opening is made directly over the fire, it will tend to localize the fire. If it is made elsewere, it may contribute to the spread of the fire.

## 6.3 Ventilating a Closed Building

### 6.3.1 Prevailing Conditions

A fire may occur at any time of the day or night. If it happens during the day it will probably be discovered at the start and be controlled. If it occurs at night, two conditions will likely prevail:

a. the fire will not be discovered in its early phase, and
b. the building will be closed weather-tight.

If a fire starts in a closed room it will burn freely as long as the oxygen is sufficient. As the hot gases of combustion are produced, they rise and mix with the cold air, while the cooler air in the room moves downward and supplies the fire with available oxygen. Two distinct things are happening:

a. the air in the room is being heated, and
b. the supply of oxygen is being exhausted.

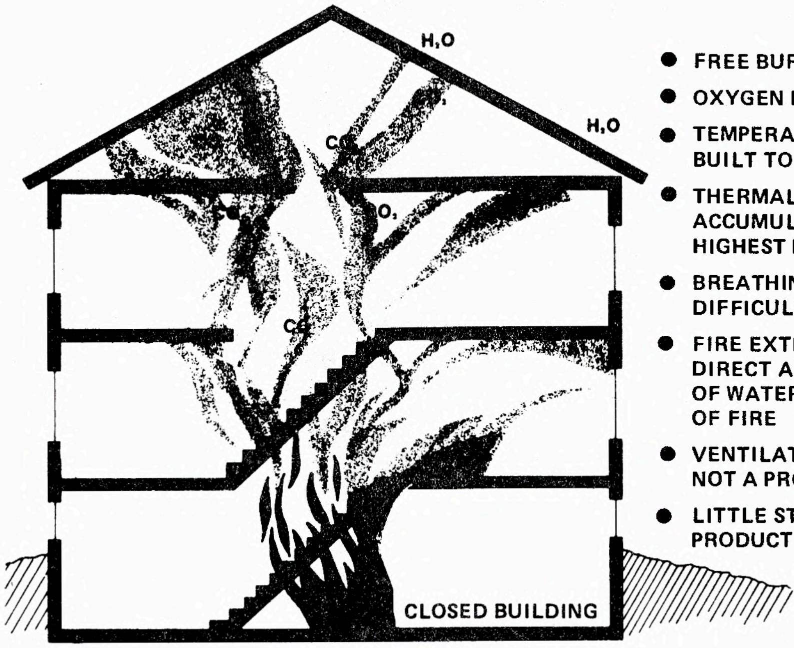
As the oxygen supply is exhausted, the fire takes on a smouldering condition.

Now the products of combustion have changed from water vapour and carbon monoxide to water vapour, carbon dioxide, carbon monoixe, and smoke. As a result the fire continues to smoulder, creating an extremely hazardous situation--an atmosphere devoid of life- and fire-sustaining oxygen--and filled with life-destroying and combustible carbon monoxide.

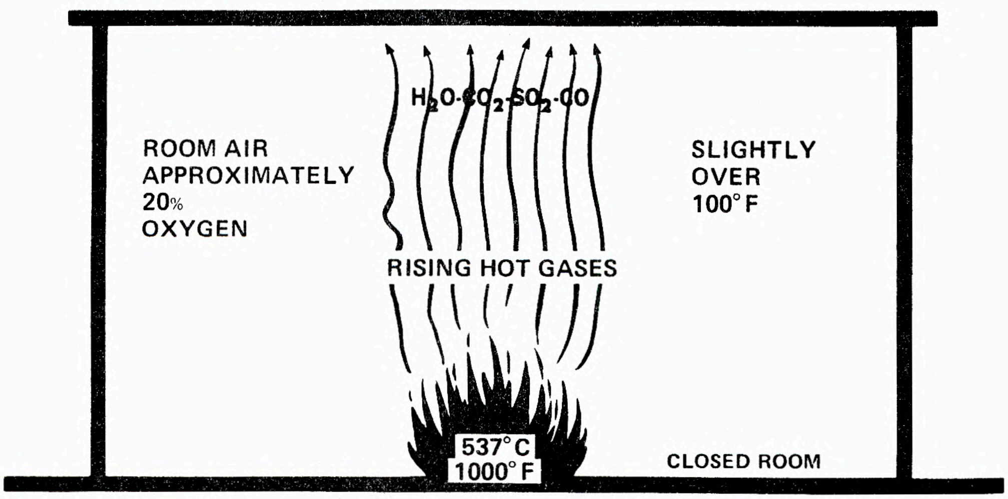
6.3.2 Three Phases of a Fire in a Closed Building or Room

First Phase - incipient or beginning

In the first phase, the oxygen content in the air has not been significantly reduced and the fire is producing water vapour, carbon dioxide, carbon monoxide, perhaps a small quantity of sulphur dioxide and other gases (Figure 6) Some heat is being generated and the amount will increase with the progress of the fire. The fire may be producing a flame temperature well above 537°C (1 000°F), yet the temperature in the room at this stage may be only slightly increased.




- FREE BURNING FIRE – ± 93°C (200°F)
- OXYGEN PLENTIFUL – +21%
- TEMPERATURE HAS NOT BUILT TO HIGH PEAK ± 537°C (1000°F)
- THERMAL UPDRAFT RISES, ACCUMULATES AT HIGHEST POINT
- BREATHING NOT DIFFICULT
- FIRE EXTINGUISHMENT: DIRECT APPLICATION OF WATER AT BASE OF FIRE
- VENTILATION: NOT A PROBLEM
- LITTLE STEAM PRODUCTION



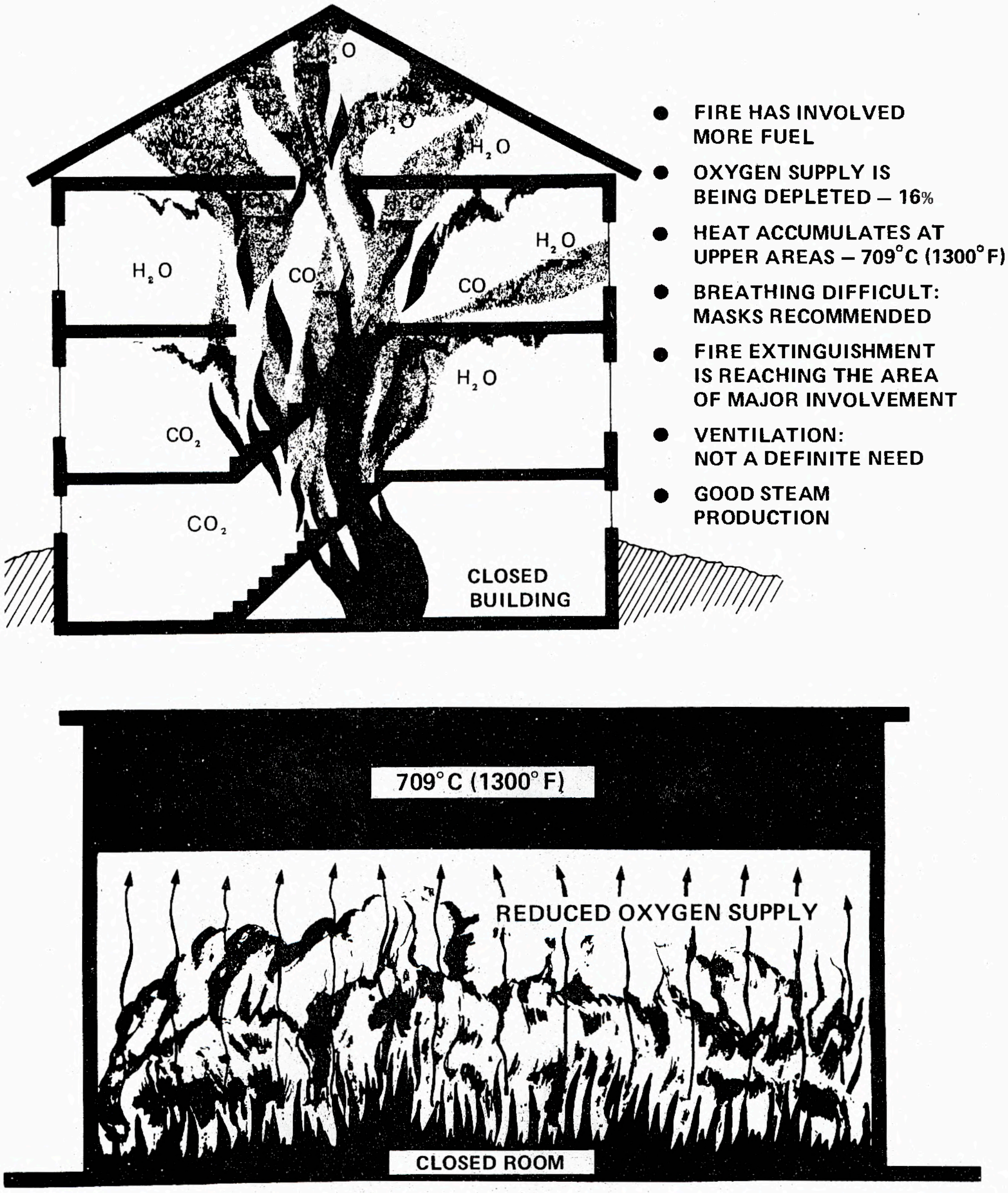

# Incipient Phase

Figure 6

Second Phase - free burning

The second phase of burning encompasses all of the free-burning activities of the fire. During this phase, oxygen-rich air is drawn into the flame as convection carries the heat to the uppermost regions of the confinement area (Figure 7) The heated gases spread out laterally from the top downward, forcing the cooler air to seek lower levels and eventually igniting all the combustible material in the upper levels of the room or building. At this point, the temperature in the upper regions can exceed 709°C (1 300°F). As the fire progresses through the latter stages of this phase, it continues to consume the free oxygen until it reaches the point that there is insufficient oxygen to react with the liberated fuel. The fire is then reduced to the smoldering phase and needs only a supply of oxygen to burn rapidly or explode.

Figure 7

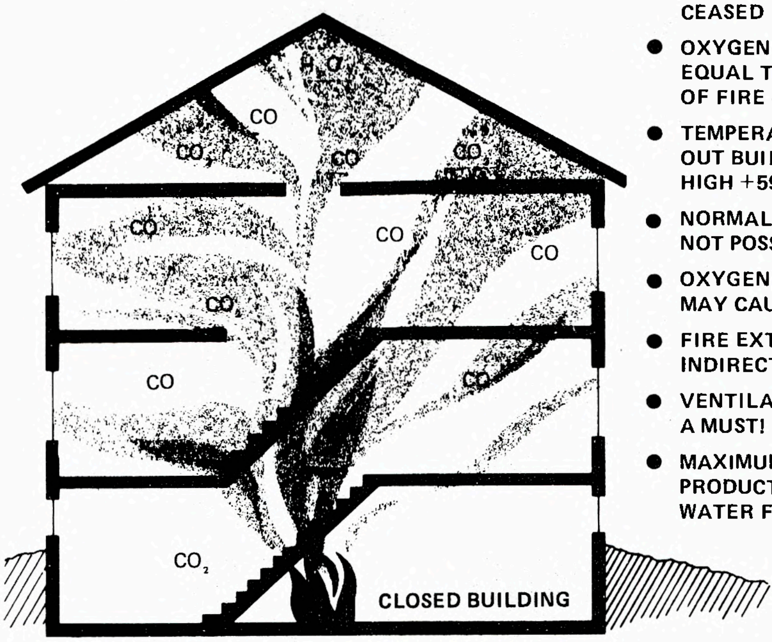



**Free Burning Phase**

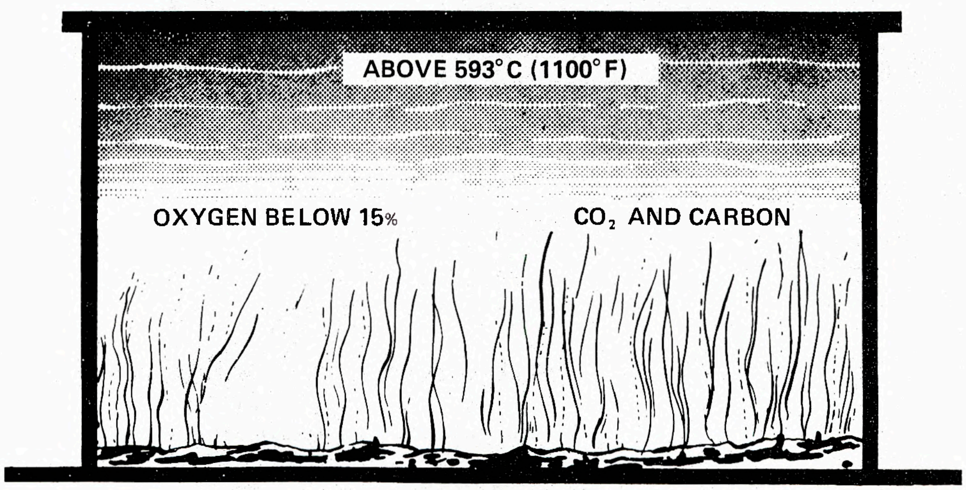
Figure 7

Third Phase - smoldering

In the third and final phase, flame may cease to exist if the area of confinement is sufficiently airtight. In this instance, burning is reduced to glowing embers, as shown in Figure 8. The room becomes completely filled with dense smoke and gases to the extent that it is forced from all cracks under pressure. The fire will continue to smolder and the room will completely fill with dense smoke and gases of combustion at a temperature of well over 593°C (1 100°F). The human body cannot survive in such an atmosphere without special protection.




- FREE BURNING HAS CEASED
- OXYGEN SUPPLY NOT EQUAL TO DEMANDS OF FIRE – 13 - 15%
- TEMPERATURE THROUGHOUT BUILDING IS VERY HIGH +593°C (1100°F)
- NORMAL BREATHING IS NOT POSSIBLE
- OXYGEN DEFICIENCY MAY CAUSE BACKDRAFT
- FIRE EXTINGUISHMENT: INDIRECT METHOD
- VENTILATION: A MUST!
- MAXIMUM STEAM PRODUCTION FROM WATER FOG




**Smoldering Phase**

Figure 8

A firefighter should use personal protection when entering a closed building when a fire emergency exists. (Refer to 3.0).

6.4 Requirements of Ventilation

A series of decisions must be made before a fire chief directs a ventilation operation.

First Decision

Is there a need for ventilation at this time?

The answer to this question must be based upon the heat, smoke, and gas conditions within the structure, and the danger to life.

Second Decision

Where is ventilation needed?

The answer involves construction features of the building, exposures, wind direction, extent of the fire, location of the fire, top or vertical openings, and cross or horizontal openings.

Third Decision

What type of ventilation should be used?

The answer to this question may be derived from a fire officer's knowledge of the following three methods of ventilation:

a. providing an opening for the passage of air between interior and exterior atmospheres,

b. using the application of water fog and the expansion of water into steam to displace contaminated atmospheres, and

c. using forced air ventilation.

When a fire chief (officer) determines the need for ventilation he should also consider the precautions that may be necessary for the control of the fire and the safety of his volunteer brigade members. There is a need for protective breathing equipment for respiratory protection, especially during the ventilation process. The possibilities of fire spreading throughout a building and the dangers of exposure fires are always present.

## 6.5 Procedures

### 6.5.1 General Remarks

One proven method by which smoke and heat may be removed from a burning building is opening the structure at a strategic place to permit the smoke and heat to escape. This method may be used for top or vertical ventilation as well as for cross or horizontal ventilation.

### 6.5.2 Top Level Ventilation

After the fire chief (officer) has considered the building involved and the location and extent of the fire, moved volunteer fire brigade members and tools to the roof, observed safety precautions, and has selected the place to ventilate, he has still not completed the operation. Prior to and during the actual opening of the roof, the officer-in-charge should:

a. co-ordinate the action of those on the roof with those on the ground,

b. observe the wind direction with relation to exposure,

c. note any obstructions or weight on the roof,

d. secure a lifeline to the roof as a secondary means of escape,

e. utilize natural roof openings whenever possible,

f. cut a large hole if one is required, rather than several small ones,

g. exercise care in making the openings so that main structural supports are not cut,

h. direct the work with the wind at the back or side to protect the operators while they are cutting the roof opening,

i. guard the opening to prevent personnel from falling into the building, and

j. extend a blunt object through the opening to break out the ceiling.

The senior volunteer fire brigade member on the roof should be in constant communication with the fire chief at the scene. Portable radios are most adaptable to this type of communication. His responsibilities on the roof include:

a. insuring that only necessary openings are made,

b. coordinating his crew's efforts with those of the fire-fighters who are inside the building,

c. insuring the safety of all personnel who are assisting him in opening the building by:

    (1) providing a secondary means of escape,

    (2) preventing personnel from walking on spongy or springy roofs,

    (3) securing a lifeline to any fire-fighter who is to enter a weakened roof area;

(4) protecting personnel from sliding and falling,

(5) exercising caution in working around electric wires and guy wires,

(6) insuring that the person making the opening is standing to the windward side of the cut and is wearing the proper protective equipment,

(7) not allowing other persons within range of the swing of the axe,

(8) cautioning axe users to be aware of overhead obstructions within the range of their swing,

(9) cautioning all cutting equipment operators to make sure the angle of the cut is not toward their person, and

(10) being on the lookout for indications of weakening structures and other hazards.

6.5.3 <u>Cross or Horizontal Ventilation</u>

6.5.3.1 <u>General Conditions</u>

There are many instances where vertical ventilation would be impractical or impossible.

Some of the factors that influence the need for horizontal ventilation are as follows:

a. structural characteristics of the building,

b. location and extent of the fire,

c. weather conditions,

d. internal and external exposures, and

e. the application of water fog as an aid to ventilation.

6.5.3.2 Precautions Against Upsetting Established Cross Ventilation

Opening a door or window on the wrong side of a building may reverse air currents and drive heat and smoke back upon fire-fighters. Opening doors and windows between the advancing fire-fighting crew and the established ventilation exit point will block the intake of fresh air. Fire-fighters following established cross ventilation currents are illustrated in Figure 9. The smoke and heat intensifying as the established current is interrupted by the blocking of fresh air is illustrated in Figure 9.

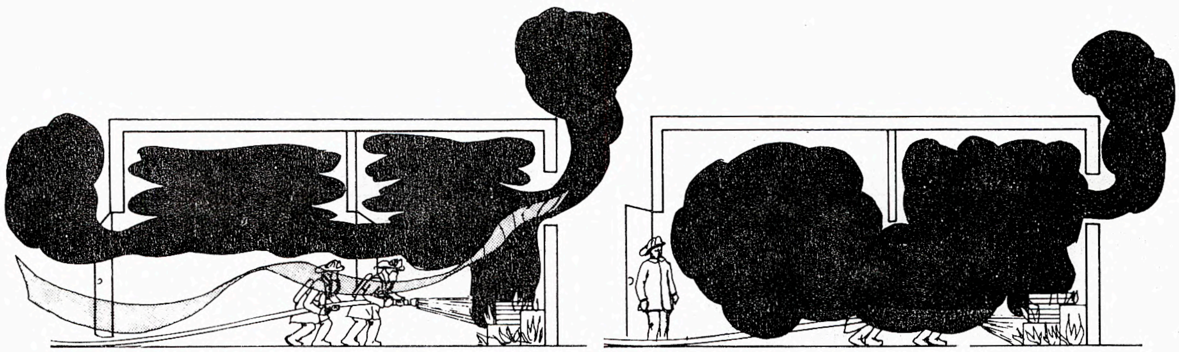


Figure 9a Figure 9b

6.5.3.3 Forced Ventilation

a. Method

Ventilation has thus far been considered from the standpoint of the natural flow of air currents, the currents created by fire, and the effect of fog streams. Force ventilation is accomplished by mechanical blowers or fans. The fact that forced ventilation is effective and can be depended upon for smoke removal when other methods are not adequate proves its value and importance.

b. Advantages

The value of mechanical ventilation may be further realized when, in order to protect human life it becomes necessary to rid premises or areas of an undesirable atmosphere. Even though fire may not be a factor, contaminated atmospheres must be rapidly and thoroughly ejected. Even when it is not the only means of clearing a contaminated atmosphere, it is always a welcome addition to normal ventilation. Some of the reasons for employing mechanical or forced ventilation are:

(1) it ensures more positive control,

(2) it supplements natural ventilation,

(3) it speeds the removal of contaminants, facilitating more rapid rescue under safer conditions,

(4) it may be used where other methods fail,

(5) it reduces smoke damage, and

(6) it minimizes damage to property.

c. Disadvantages

If mechanical or forced ventilation is misapplied or uncontrolled, it can cause a great deal of harm. Some disadvantages are:

(1) it can move fire along with the smoke and extend it to lateral areas,

(2) it can introduce air in such great volumes that it can be the cause of a fire spreading,

(3) it is dependent upon power, the interruption of which renders it ineffective,

(4) it employs additional manpower for its operation, and

(5) it requires special equipment.

c. Forced Ventilation Equipment

It is difficult to classify forced ventilation equipment by any particular type. The principle applied is that of moving large quantities of air and smoke. These portable blowers are all powered by electric motors or gasoline-driven engines. Various types of electric forced air blowers are identified by different names, such as ejectors, extractors, exhausters and blowers. Forced air blowers should always be equipped with explosion-proof motors and power cable connections when used in a flammable atmosphere. Forced air blowers should be shut down when they are moved. Before they are started, be sure that there are no persons near the blades and that no clothing, curtains, or draperies are in a position to be drawn into the fan. Blowers should always be moved by the handles which are provided for this purpose.

## 7.0 FIRE SERVICE RESCUE OPERATIONS

### 7.1 General Remarks

The job of the volunteer fire brigade is to protect life and property against fire, storm (acts of god), explosion, or any other occurrence likely to disrupt normal day-to-day living conditions.

Rescue, one of the functions of the fire fighter, is concerned with the careful removal of people (and animals) from any of these hazardous situations to a point of safety.

### 7.2 Training

In order to carry out the rescue operation speedily, safely and efficiently, it is necessary that the fire-fighters involved be properly trained. This training should include:

a. a complete course in first aid, under the direction of Canada Red Cross or St. John's Ambulance;

b. the operation, care and maintenance of resuscitators and inhalators;

c. the operation, care and maintenance of protective breathing apparatus;

d. stretcher use;

e. lowering victims from heights;

f. raising victims from below ground level; and

g. personal protection of the rescuer.

It is difficult to draw the line between rescue work and first aid, and, in normal practices both services are rendered by the same group.

7.3 Self-protection

Since fire-fighters must go into hazardous situations to effect a rescue, they must take the necessary precautions to protect themselves against the hazards or they too will need to be rescued, thus compounding the problem.

7.4 Locating the Victim

Rescue operations cannot be carried out until the victim or victims are located. Seconds may mean life. Therefore, locating the victim in the shortest time possible, and being able to help him when found is extremely important.

The speed and safe working activities of the rescue force will depend on their knowledge of the building, the habits and daily activities of the occupants, and the means of escape.

## 7.5 Situations Making Rescue Operations Necessary

### 7.5.1 Burning Buildings

To determine possibilities for rescue work consider what sorts of situations are created in a burning building:

People exist in buildings in many different circumstances. Some are:

a. hospitals or care facilities, in which patients are unable to care for themselves and are wholly or partly dependent on the attendants;

b. public places, in which to be safe, it is a requirement that people enter in an orderly manner and depart in the same manner;

c. apartment buildings, in which many families have homes but for economic reasons are above ground level and use common exits;

d. office (administration) buildings, in which people usually work only during the daytime. (If occupied during the night, the occupants--workers, security, and cleaning staff--are awake and alert);

e. industrial buildings, in which a complication of hazardous situations may be expected due to processing methods, storage, design, and many other technical features set up by the very nature of the user;

f. school buildings, which people occupy only during the daytime, although the gymnasium, industrial art shops and other course areas may be in use during evening hours; and

g. private residences, in which a family dwells. Due to the freedom afforded the occupants and the limit in size, it would seem that a home would offer the least hazardous situation, but the family's lack of preparation when a fire occurs make residences the largest contributor to fire deaths and injuries on Indian reserves (communities).

In each of the previously mentioned building types, rescuers may expect to find the occupants in fairly predictable conditions. Being able to anticipate existing conditions facilitates the careful removal of victims to a safe area. Victims are usually found in a burning building in two conditions:

a. asleep, in which case the victim may be overcome by smoke, gas, or may even be burned; or

b. awake, in which case the victim may become lost in his search for an exit, or overcome after leaving the sleeping area.

In institutions such as hospitals or care facilities, many occupants are unable to move. Therefore, rescue involves removing the victim without further aggravating his/her weakened condition.

7.5.2 Demolished Buildings

The most common cause of demolished buildings is an explosion, and the exploding medium may be a combustible gas, an overheated gas, compressed air or gas, steam in the case of heating and power equipment, or combustible dust.

In situations caused by demolished buildings, rescue workers should expect usually to find the victims "pinned" under wreckage. The chances are that in addition to being pinned the victim will be injured and possibly unconscious.

7.5.3 Gaseous Areas

The human body must have oxygen to live, which is obtained by breathing air. When the air becomes deficient in oxygen or is contaminated by concentrations of toxic vapours, gases, smoke, dusts, mists or fog (see 3.0) the victim is asphyxiated.

Gaseous situations are produced when industrial and fuel gases leak from their containers or conductors, by the vapourization of petroleum and petroleum products in storage tanks, and may be produced from open gas and kerosene stoves. Cracks in the fire pot of a furnace or holes in the smoke pipe will emit deadly gas that will prove hazardous to the occupants. Normally the entire family will be asphyxiated.

7.5.4 Electrical Contact

Any material having the property to conduct electricity will serve to carry electrical currents and these currents will follow the path of least resistence. The human body, though not a good conductor, will carry electrical energy when it is made part of the path of least resistance. Situations where electrical contact may accidently occur are:

a. touching a light socket while in a bath tub,

b. coming in contact with fallen electrical distribution lines, and

c. contact with metal pipes or objects that are touching fallen electrical lines.

A hazardous situation is set up because once a human body is allowed to become a conductor, any other human body touching it will become a part of the same conduction path. Therefore, the rescuer must use extreme caution or there will be two victims rather than one.

7.5.5 Earth Cave-ins

Earth cave-ins are encountered in ditching, excavating, tunnelling, and mining. If a cave-in occurs while persons are working, a serious situation occurs, usually burying or trapping the workers.

The rescuer must use extreme caution when effecting the rescue operation not to cause further cave-in, thus endangering the trapped victims and the rescue force. All earth excavations should be shored up during rescue operation, either by using timber or other suitable means to protect the rescuers and prevent further cave-ins.

7.5.6 Water Accidents

All that is necessary to cause a water accident is that the face be submerged and the victim be unable to remove it. The result is suffocation. Such situations occur when:

a. nonswimmers get out of their depth,

b. good swimmers become fatigued or develop cramps,

c. boats or canoes capsize,

d. winter snow equipment goes through thin ice, and

e. small children fall into pools or through thin ice.

Water rescue must be done by those near the victim if it is to be successful. Seldom does the volunteer fire brigade have the opportunity to participate. Their job is to recover the body after it has gone to the bottom, and if possible to resuscitate the victim.

7.5.7 Storms and Floods

Extreme weather conditions set up situations that are no different from those previously mentioned. Wind storms demolish buildings and by doing so rupture gas systems and damage electrical systems, thereby causing fire. The significant fact is that storms and floods create not just one type of rescue demand, but rather a combination of several.

## 7.6 Conditions in Which Victims May be Found

Victims may be found in many conditions, and as such the conditions may dictate or determine the rescue procedures to be used.

### 7.6.1 Trapped Victim

A victim is considered trapped when he cannot escape from the situation in which he finds himself. A victim may be perfectly normal, injured, shocked or bewildered. To remove a trapped victim, otherwise uninjured, it is only necessary to lead, lower or raise him to safety. If he is injured and unable to walk, he must be carried (see Red Cross Manual - Transportation).

### 7.6.2 Pinned Victim

This situation occurs when a person is held fast by materials and cannot move to safety. This may happen in building collapse, explosions, falling timber, earth cave-ins, traffic accidents and other such incidents. The victim may be normal, injured, in shock, or unconscious.

To make the rescue, precaution must be taken to free the victim without further injury. Never pull the victim by the body, but remove the obstacle holding the victim or get sufficient space to remove the pinned part of the body if the holding material is massive and heavy.

### 7.6.3 Burned Victim

In second degree burns, the skin is so damaged that with improper handling it may be destroyed. In third degree burns, this destruction may include the flesh as well. The rescuer must first examine the burned victim and administer first aid treatment, if possible. This victim will probably be suffering from shock, and this should be dealt with accordingly (Refer to Red Cross Manual).

7.6.4 Unconscious Victim

A victim is liable to become unconscious through an injury, loss of blood, electric shock, asphyxiation or suffocation from gas or smoke, or fainting from strain or excitement of the situation. The victim may be injured, yet unable to make it known, therefore the rescuer must make a careful examination and protect any injury.

7.6.5 Shocked Victim

Shock may be brought about by severe pain, extensive injury, exposure to extreme heat or cold, witnessing others in distress, sudden fright, anger or joy, being overcome by gas, or contact with electrical current. The nervous system that controls one's vital functions becomes deranged, while the victim becomes partially or totally unconscious and, if not given proper treatment may die. Shock may develop at the time of injury, or show up later. It may be light, or severe enough to prove fatal.

Some of the symptoms of shock are: partial or total unconsciousness, cold, clammy sweat, particularly on the hands and forehead; victim feels cold and may have a chill; a weak but rapid pulse; the victim appears stupid, and his actions are listless; victim is restless and complains of clouded vision, dizziness and thirst; slowness of expression and understanding; nausea and vomiting; shallow, irregular breathing. Should one or more of the above symptoms occur, first aid treatment should be applied at once. The victim should be kept lying down, and a stretcher used to transport him.

For full instructions in treating "shock", refer to the Canadian Red Cross First Aid Manual.

7.6.6 Sleeping Victim

A sleeping victim is unconscious for the time being, but may be awakened to full responsibility unless otherwise affected while sleeping. People may be found asleep in burning buildings or in other situations where the disturbance is not severe enough to waken them. Such victims need only be awakened and led to safety. Caution must be used so that the victim does not become panicky or bewildered.

7.6.7 Bedridden Victim

A bedridden victim is one who, because of illness or injury, cannot help him/herself. Extreme caution must be taken by the rescuer to protect each individual's physical condition. Operations may be aggravated and surgical treatment rendered ineffective by the careless handling by an untrained rescuer.

Such rescue work demands special "carries" and in severe cases the transportation of the victim without removing him/her from the mattress.

7.6.8 Panic Victim

A panic victim is one whose normal mental state has been so seriously disturbed by existing conditions, real or imaginary, that he is more likely to act abnormal.

Such conditions occur where there are gatherings of people, and their safety is menaced, or where a victim is trapped or pinned and recoginizes the dangerous predicament. Panic must be prevented, or quelled once it occurs. A commanding voice able to impact information to a group of excited people may be able to prevent panic.

The principle of diverting the victim's attention from the distress should be used to control panic. Rescue consists of comfort of the mind as well as the body.

7.6.9 Intoxicated Victim

An intoxicated victim is one whose normal physical and mental abilities have been disrupted due to excessive amounts of alcohol. These persons may fall into a state of unconsciousness, thus rendering them incapable of helping themselves during an emergency. Some intoxicated victims may become conscious but may become belligerent during a rescue attempt and refuse to be helped. Two rescuers could probably help the victim if he refuses help or shows signs of resistance.

7.7 Rescue Procedure

Like every other phase of the fire service, rescue work should be done rapidly, but safely, and requires a definite procedure.

7.7.1 Answering the Call

The answering of a rescue call may be well defined if the call definitely designates a rescue job. If it is a fire call, the rescue procedure must of necessity go hand in hand with the fire fighting operation. In some cases, even though the saving of life comes first, the rescuers themselves may need the protection of clothing and hose streams to carry out the rescue work.

It may be even necessary for the first volunteer fire brigade members arriving on the scene to organize into a rescue force. Therefore, all fire brigade members should be thoroughly trained in rescue work.

7.7.2 Locating the Victim

The first question after arrival at the site of the emergency is: "Where is the victim?"

Seconds may mean life, and locating the victim in the least possible time and being able to help him is of utmost importance. This is another phase of firefighting in which regular fire prevention inspections play an important part. Firefighters should know the habits and daily activities of the occupants and the layout of the building, (means of escape, location or gas line valves, electrical panel location, etc). The speed and safety of the rescuers may depend on this knowledge.

In locating victims, the rescuer should learn the act of listening and signalling. If the victim is injured and conscious, he will probably be pounding, moaning, shouting or even sobbing or crying. These sounds can be used to locate the victim.

Persons who have escaped or have been rescued can give a lot of valuable information to the searchers. No clue should be overlooked, as time is vitally important.

### 7.7.3 Personal Protection

Rescuers should protect themselves against the very elements that may have made the rescue necessary, such as gas, fire, explosion, cave-in, etc. Rescuers should work in pairs at all times because:

a. two people can handle a victim much more easily than one; and

b. there is always the possibility of accident to the rescuer, and if he is alone he cannot help himself.

A lifeline may be worn if the firefighter has no hose line, so that with a set of pre-arranged signals he can communicate with his fellow firefighters outside. Also, in heavy smoke or in darkness he can always find his way out and if he, for any reason, gets into difficulty, he can be located by the lifeline.

Respiratory protection is a must if the rescuer is to do a good job, because with the self-contained types of protective breathing apparatus the rescuer may work in oxygen-deficient, gaseous atmospheres up to 30 minutes, thus allowing a reasonable amount of time to search for the victim. Protective equipment helps to keep the rescuer safe and lessens the chance of injury, leaving a greater number of volunteer firefighters on duty. (Refer to 5.0).

7.7.4 Administering First Aid

The fire fighter must have a thorough knowledge of first aid to the injured and be able to make a speedy examination of the victim to determine what injuries there are and how they are to be treated. He should have a good knowledge of stretcher work and the different types of carries used to transport victims.

7.7.5 Stretcher Transportation

The ideal method of transporting a severely injured victim is by the use of a stretcher. Once placed on the stretcher, the victim may be carried to safety in a natural position and with the least possible chance of further injury.

Stretchers should be part of the rescue equipment, and stretcher drills should be carried out regularly as part of the rescue training. In emergencies, stretchers can be improvised from a door, a corrugated metal sheet, a wide board, a short ladder, a tarpaulin, or a rug with two pike poles.

The commercially manufactured stretchers are the ordinary army type or the fire department stretcher type which is made of galvanized metal and is either callapsible or in one section.

The victim should be carried in a horizontal position where possible. Stretchers are normally carried with the victim's head in the direction of travel. This does not hold good when going down steep slopes, stairways, etc. In the two-man carry, the bearers break step, that is, the bearer in front steps off with the left foot.

7.7.6 Lowering Practices

7.7.6.1 General Remarks

When natural exits are blocked, a victim must be rescued by some other means of escape, normally a ladder from the outside. The means employed will depend on whether the victim is unconscious, injured, or uninjured.

7.7.6.2 Ladder Rescue

If the victim is conscious and not injured, it is no problem to guide him down the ladder. Great care must be taken as in all possibility the victim is not used to descending a ladder and will be frightened, tense, possibly a bit bewildered, and subject to a fainting spell. The rescuer should proceed down the ladder below the victim, keeping his arms around him and his knees close together to assure support should the victim faint or slip. The rescuer should ensure that he has his arms on each side of the victim.

Should the victim be unconscious and a life line is not available, he is placed facing into the building on the ladder, in spread-eagle fashion. The rescuer takes the weight of the victim on one leg, bent at the knee, with his arms on each side under the victims arms. The rescuer takes the weight of the victim on his arms by squeezing the victim's chest, at the same time stepping down a rung. The victim is then lowered onto the rescuer's knee. This procedure is followed until the victim is brought to the ground.

7.7.6.3 Lifeline with Ladder

Using a lifeline with a ladder may seem slow in comparison to carrying the victim down, but it is much safer and a lot easier on the rescuer. A ladder is raised to a point above the window where the rescue is to be made. The fire-fighter going up the ladder takes the end of the lifeline and passes it through a convenient rung. The rope is then taken up past the next rung on the ladder and is pulled through and then taken up the front of the ladder. When a rung above the window is reached, the rope is then passed over a rung and is handed to the rescue party inside the building. Enough rope is taken into the building so that the rescuers can tie and apply the "rescue hitch", which is a double bowline used as a life basket (Instructions provided in IFSTA publication - see 8.0).

The rescue hitch is used to lower persons from heights or raising victims from wells, tanks, pits, cave-ins, etc. It is a very secure knot and there is no possibility of the victim slipping out of this hitch when it is tied properly.

When the hitch has been properly applied to the victim, he is eased out the window by the rescuer(s) (preferably 2 - one on each side), and the man at the bottom who is handling the lifeline places one foot on the bottom rung of the ladder (to prevent it from kicking out) and allows the lifeline to slip steadily and smoothly through his hands. The victim is gently lowered to the ground.

7.7.6.4 Lifeline and Belt

The use of the lifeline and belt as a rescue method is very worthwhile where ladders are not available on floors above ladder level. It should be used only to rescue fellow rescuers as it is too intricate an operation to be practical for rescuing persons not trained for it.

The rope size and material used in the lifeline should be such that it will stand at least twice the strain that is liable to be put on it in rescue work. The line should be tested before each descent by twice or three times the number of men swinging on it as will be involved in the rescue operation.

Life belts are of two types--that with the hand-brake and that without. The hand-brake permits definite control on the line as it passes through the hook, while with the others, the speed of descent must be applied by friction of the line on the body and through the hand.

Caution should be observed when using a life belt. It should be carefully inspected before each use (including the snap and all buckles). It should be put on so the back of the hook will be toward the controlling rope and be buckled snugly with equal tension on all straps (strap ends secured in their keepers). The top should be properly secured inside the building while the rescuer, wearing gloves, steps into the window, grasps the lifeline above the belt, with his left hand high above the hook and his right hand below the hook pulling the rope across and back of the hips. He is then ready to slide. At the given signal he steps out the window and keeping both feet against the wall, uses the right hand as a brake by pulling the line tightly against the body. Pushing himself away from the wall with his feet, he slides at the desired speed. As an added precaution, a second man should control the line on the ground and can also determine the speed of descent by pulling tension on the rope.

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