SAFETY IN COAL MINING FOR AFGHANISTAN

BY

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UNITED STATES BUREAU OF MINES

For use in cooperation with the

ROYAL AFGHAN MINISTRY OF MINES AND INDUSTRY

IN TEACHING MINE SAFETY

to the men connected with the mining of coal

IN AFGHANISTAN

1956

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SAFETY IN COAL MINING FOR AFGHANISTAN [1]

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INTRODUCTION

Mining is a hazardous occupation because it is carried on underground in confined places. Dangers are always present of explosions, fires, or falls of roof or ribs.

A number of factors tend to increase the danger of accidents at any mine. These include: increasing depth, with consequent heavier roof pressures and higher temperatures; increased concentration of harmful gases in the mine air; and an increase in the practice of blasting off the solid, which leads to greater production of coal dust. However, the most serious safet problem in mine operation results from errors or careless acts on the part of employees. To control this problem most coal mining countries have adopted safety codes or laws.

The purpose of this text is to give all men connected with the mining of coal a general knowledge of ventilation, gases, explosions, coal dust, fires, first aid, and mine rescue so that they will be aware of the dangers which exist. This information, if properly used, will help keep the mining of coal in Afghanistan as free from accidents as humanly possible.

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ACCIDENT STATISTICS, UNITED STATES OF AMERICA

Since its founding the United States Bureau of Mines has gathered information directly from the mining industry regarding accidents at mining operations, and the cause of these accidents.

For the year 1951 the following table will give some idea as to the principal causes of injuries in bituminous coal mines of the United States of America.

CAUSE OF INJURY	FATAL INJURIES		NONFATAL INJURIES	
	Number	Percent	Number	Percent
Underground:				
Falls of roof and face	305	44.59	5,172	18.42
Mine cars & Locomotives	101	14.77	5,575	19.85
Explosions of gas or coal dust	153	22.37	30	.11
Explosives	7	1.02	278	.99
Electricity	18	2.65	720	2.56
Machinery	20	2.92	3,303	11.76
Mine fires	0	0.00	36	.14
Shafts and slopes	6	.88	164	.58
Miscellaneous	8	1.17	8,301	29.56
TOTAL****	618	90.35	23,579	83.97
Stripping or Open-cut mining	31	4.53	1,777	6.32
Surface	35	5.12	2,725	9.71
GRAND TOTAL**	684	100.00	28,081	100.00

SECTION 1. FIRE BOSS

A. GENERAL

The conditions in a coal mine are constantly changing. For this reason a working place that is safe at the end of one shift may be unsafe at the beginning of the next shift. This is especially true when there is a period of several hours between shifts. For this reason, a competent person (known as a Fire Boss) should make an examination of all working places not more than three hours before the men are scheduled to go to work.

In general, it is the responsibility of the Fire Boss to make sure that all working places are safe for the men to work. It is also his responsibility to make sure that other places in the mine besides those that are actively working are free from gas or other dangerous conditions which could cause an explosion, fire, or other accident.

B. QUALIFICATIONS

The qualifications of a Fire Boss are not too extensive; however, a man should have a certain amount of knowledge before he can qualify. In mines where the coal liberates gas or the coal is of such a nature that it fires readily, the responsibility of a Fire Boss is great. A mine fire, or an explosion, or a serious accident may be prevented by the quick action of a Fire Boss.

The following is a list of the minimum requirements that a man should have to be able to qualify as a Fire Boss in Afghanistan;

1. Be a responsible person with at least 3 years of coal mining experience.
2. Be able to at least write his name and date.
3. Have a practical knowledge of mine ventilation and be able to determine the quantity of air with an aneometer.
4. Have a knowledge of the various mine gases.
5. Be able to detect methane with a flame safety lamp.
6. Be able to detect carbon monoxide with a carbon monoxide detector.
7. Have a general knowledge of the causes of mine fires and explosions.

C. DUTIES

Listed below are the duties that a fire boss must perform every day of the year regardless of whether or not the mine is scheduled to work. If the fire boss is unable to perform these duties on any one day, then the mine foreman, or the mine manager must perform these duties.

1. He shall enter the mine not more than 3 hours before the regular shift is scheduled to commence work on working days and every 8 hours on idle days. Upon entering the mine, he will hang at the mine entrance a red danger sign; and, no person, except the mine manager and he only in case of necessity, shall pass beyond this danger sign.
2. He shall examine all main entries or slopes and every working place in the mine for (a) safe roof condition (adequate timbering), (b) dangerous or noxious gases, (c) adequate ventilation, (d) normal mine temperature, (e) coal dust in suspension, (f) any condition which may cause a fire, and (g) any other unsafe condition.
3. He shall also examine any other place in the mine where gas might accumulate or where other dangerous conditions might exist that would cause a mine fire or an explosion.
4. He shall also examine every fire seal in the mine and make sure that each and every seal is air tight.
5. It shall further be his duty to do or cause to be done whatever may be necessary to remove or correct any conditions which he found during his examination to be dangerous. Any dangerous condition must be corrected before the mine is reported safe for the men to enter.
6. He shall leave evidence of his presence at the face of every place examined. This evidence shall include his name or mark and the date.
7. After he has made sure that the mine and all places in the mine are safe, he will return to the outside and take down the red danger sign. After this sign has been removed, the men may then enter the mine to commence their work shift.
8. He shall upon having completed the examination of the mine and the removal of the danger sign, make a written report of the condition of the mine within a book prescribed for this purpose. In the event that the fire boss can not write, he will make his report direct to the mine manager who will in turn make a written record of same.
9. After finishing this written report, the duties of the fire boss are completed for one day. He shall not be required to perform any other duties at the mine except in the case of an emergency.

D. NUMBER OF FIRE BOSSES REQUIRED

There will be at least one fire boss employed for every operating mine. The fire boss examination can not be started more than 3 hours prior to the time for the shift to commence work; therefore, one man can not do a thorough job if his time has to be spent in more than one mine. In the event the mine is of such an extent that one man can not examine each place thoroughly in these 3 hours, additional fire bosses must be employed.

Where there are several mines operating within a small radius, an extra fire boss should be employed. This extra or relief man will make a fire boss run at a different mine each day; thereby, allowing the regular fire bosses one day a week in which he will not be required to work. Also, in the event of illness of a regular fire boss, this extra man can fill in.

E. INSTRUMENTS USED BY FIRE BOSSES

1. FLAME SAFETY LAMP

a. GENERAL

The flame safety lamp is the most widely used device for detecting methane in coal mines. It is also used to a limited extent in testing for oxygen deficiency. The flame safety lamp will not burn in an atmosphere free of explosive gas and containing less than 16 percent oxygen. Because the flame safety lamp can also be used to detect a deficiency of oxygen, usually called "blackdamp" by the miners, it excels any other approved methane detector for practical use in a coal mine. The flame safety lamp is therefore not only valuable for the fire boss and other mine officials to use in their everyday work, but also it is valuable for use in exploring old working and in recovery operations of mine regions that have been sealed.

The history of the development of the present flame safety lamp started back in 1815 when Sir Humphrey Davy developed the "Davy Safety Lamp." At about the same time Mr. Stephenson developed his safety lamp. In both of these lamps, the light or flame is isolated from the outside atmosphere by means of a gauze. Along about this time Dr. Clanny invented what is known as the "Clanny Lamp." However, his lamp was designed with a glass cylinder surrounding the flame with the gauze placed on top of this glass cylinder.

Different devices were added to these lamps from time to time. The first important device was a key lock which prevented a miner from taking the lamp apart while still inside the mine. The "Clanny Lamp" construction improved with an additional gauze and a bonnet (a metal cylinder enclosing the gauze); this was known as the "Marsaut" lamp. The "Mueseler" was similiar to the "Marsaut" except for a metal chimney inside the gauze. This metal chimney was to prevent the feed air coming in the top from mixing with the burnt gases rising in the lamp from the flame. Other improvements such as the magnetic lock, internal igniter, expansion ring for the glass cylinder, under feed gauze to allow the feed air to come in underneath the glass cylinder, and an improved bonnet which permits the lamp to be used in high air velocities led to the development of our present day flame safety lamps.

Of the several present day flame safety lamps the "Koehler" and the "Wolf" are the most widely used in the United States. Both of these flame safety lamps have the approval of the United States Bureau of Mines.

b. PRINCIPLE OF FLAME SAFETY LAMPS

The safety principle in the operation of a flame safety lamp is that the mine air surrounding the lamp has free access to the interior of the lamp and when the atmosphere contains methane the gas burns inside the lamp. The products of combustion from this burning gas must pass thru the gauzes. As these products of combustion issue from the lamp through the gauzes in a series of fine jets, they are cooled below the ignition temperature of the gas-laden atmosphere surrounding the lamp and thus prevent the ignition of gas outside the lamp.

The operational principle of the flame safety lamp is the behavior of the flame. When atmospheric conditions are normal the flame of the safety lamp has a normal flame appearance. However, when the atmosphere undergoes certain changes the appearance of the flame is altered, and it is these alterations in the flame that makes the safety lamp valuable in the testing of mine air.

c. FUELS FOR FLAME SAFETY LAMP

The characteristics of the flame of a flame safety lamp are governed by the nature of the fuels burned in the lamp. All fuels suitable for safety lamps are hydrocarbons. Fuels that have a higher proportion of hydrogen give higher temperatures in burning. Fuels that are higher in carbon give more light and less heat.

High carbon fuels include whale, fish, and cottonseed oils, lard, and kerosene. Fuels high in hydrogen include alcohol and gasolines. The best fuel for the flame safety lamp is either naphtha or heptane.

c. USE AND CARE OF FLAME SAFETY LAMPS

Thousands of flame safety lamps are used in the United States in a great many mines and by all types of men; as far as is known, there has not been an explosion caused by a properly assembled safety lamp having double-gauze and a bonnet, maintained in a permissible condition. The United States Bureau of Mines has also made hundreds of laboratory tests of flame safety lamps and has never been able to get a failure of a properly designed double-gauze, bonneted lamp, even in the most explosive mixtures of gas and with strong air currents striking the lamp in any of several directions. This shows that when rightly made, properly assembled, and properly used, the flame safety lamp is reliable; however, it may be so misused as to become a very definite hazard.

Flame safety lamps should be cleaned, filled, repaired, and locked by a lamp attendent or other competent person. Everyone who uses a flame safety lamp should understand its construction, assembly, and dangers of faulty use.

CLEANING, FUELING, REASSEMBLING

In cleaning, filling, and reassembling the flame safety lamp, the following precautions should be observed:

1. All removable parts should be detached. The top of the font should be opened and the font filled at the filling station with a good grade of naphtha.
2. The gauzes should be cleaned by brushing. They should be examined for broken wires, and enlarged or obstructed holes. A new gauze should have the coating burned off before being used.
3. The glass should be thoroughly cleaned. It should be examined for defects, especially chipped edges. The gaskets should also be examined and cleaned of all dirt, grease, etc.
4. The bonnet or shield should be examined for defects and cleaned of soot or dust.
5. The lower gauze ring should be inspected and cleaned.
6. The internal igniter should be tested.
7. When the font is filled, the fluid should not be allowed to run over.
8. The wick-raising device should be inspected.
9. After the wick has been lighted, it should be adjusted to a low flame, the parts of the lamp put in place, and the lamp locked.
10. As a further precaution, the lamp should be tested in a testing box before being taken into a mine.

COMMON ERRORS IN ASSEMBLING

1. Leaving out one or more gaskets, or using broken gaskets.
2. Leaving out one of the gauzes in double-gauze lamps.
3. Placing on the top of the glass an expansion ring designed to be placed under the glass (old type lamp only).
4. Placing the expansion ring upside down, (on old type lamps) thus destroying its usefulness.
5. Failure to screw the fuel vessel enough to make a tight fit between the glass globe and the gaskets.
6. Leaving off the deflection rings that prevent air from blowing directly into the lamp.
7. Placing a defective gauze in a lamp.

METHOD OF ASSEMBLING

Probably the best method of assembling a flame safety lamp is as follows:

1. Fill font with fuel; thoroughly clean and examine all parts of lamp, making sure that all parts are in good condition.
2. Place inlet gauze and bottom gasket in place.
3. Place glass in position.
4. Place top gasket over glass if separate gasket ring is used, or after assembling gauze place gasket in bottom of outside gauze.
5. Place gauzes on top of glass.
6. Place bonnet, with expansion ring in place, over gauzes.
7. Screw bonnet on font threads until the glass can just be turned by a thumb and one finger; see that the lock operates and that the lamp is locked.

FLAME SAFETY LAMP PARTS AND DIAGRAM OF ASSEMBLY

3.	12. Bonnet 11. Expansion Ring	Read Up ↑
2.	10. Gauze Collar 9. Outer Gauze 8. Inner Gauze 7. Upper Gasket 6. Globe	Read Down ↓
1.	5. Baffle Ring 4. Lower Gasket 3. Gauze Ring 2. Igniter 1. Font	Read Up ↑

EXPLANATION

For Wolf Lamp

1. It is not only necessary that the safety lamp parts be placed in their proper places, but it is also necessary that the parts be handled and assembled in a neat and workmanlike manner.
2. In order to follow the above diagram pick out the parts shown in group No. 1 and assembly these parts upward in the order that they are numbered.
3. In group No. 2 begin with the part shown at the top of the group and assemble downward following the order as shown.
4. After the second group has been assembled, assemble this group to the first group.
5. After the two parts shown for the third group have been assembled, connect to groups 1 and 2 completing the assembly.
6. During the above procedure, test all parts for defects and cleanliness and test the globe for proper tightness.

This method permits building the lamp from the bottom up and observing that each part is in its proper place up to the instant of locking the lamp.

PRECAUTIONS IN USING

When using a flame safety lamp there are certain precautions which must be followed if the lamp is going to operate efficiently and at the same time remain a safe light. The following listed precautions are among the most important.

1. Be sure that the lamp is locked before taking it into the mine.
2. Examine it carefully yourself to see that it is in good condition, even though it has been passed by the lamp inspector. Test in a testing cabinet if available.
3. Do not carry a magnet or other device for unlocking the lamp.
4. If you have to prepare the lamp yourself, put the parts together carefully; be sure that the glass is not cracked and that the gaskets are good and properly placed. Any carelessness in these matters may cost you your life and the lives of others.
5. Do not carry matches, a patent cigarette lighter, or any other igniting device into the mine.
6. Do not attempt to open a lamp within a mine unless at a regular lamp station where the rules of the mine permit lamps to be opened and relighted.
7. Do not set your lamp on the floor in the mine; it may accidently be upset and extinguished, and the glass may be broken. It is better to hang the lamp on a timber by means of a stout nail; even then the lamp should hang free and never in an inclined position.
8. Do not use a lamp that has rust, dirt, or oil on the gauzes.

9. When testing for the presence of gas in a mine, hold the lamp firmly by the bottom.
10. When testing for gas, be careful to prevent dripping water from striking the glass.
11. Do not allow the flame to smoke; soot may fill the gauze and you will have poor light.
12. Before entering a room or tight end, examine the flame of your lamp, and as you advance make frequent tests for gas. Make frequent tests during the shift and always before and after firing a shot.
13. If possible, avoid testing for gas while shots are being fired; the flame of your lamp may be driven through the gauze and gas outside the lamp may be ignited.
14. The flame safety lamp should not be used in high places where it is necessary to attach the lamp to a pole. Testing in such places preferably should be made with one of the other devices for detecting methane.
15. When the gas flames in your lamp, withdraw the lamp slowly and carefully; if the flame goes out retire to fresh air before attempting to relight it with the relighting device.
16. If your lamp flames up and goes out, be sure to examine the gauze, because the gas may be burning within the gauze. To extinguish the flame, shut off the air supply or take the lamp to fresh air.
17. To avoid being left in the dark, fire bosses and others working alone should carry an approved electric cap lamp or at least a permissible flashlight.
18. Lamps that have not been used for some time often have rusty gauzes, a hardened wick, or gummy oil. Do not take a lamp in such condition into a mine.
19. Having detected gas, do not repeatedly put your lamp into it; but arrange for the removal of the gas by ventilation.

e. GAS DETECTION WITH A FLAME SAFETY LAMP

Because of the wide occurrence and dangerous characteristics of methane, the detection and determination of the amount present in mine air is vitally important during both normal operating conditions and abnormal conditions following mine fires and explosions.

The flame safety lamp has definite limitations as a gas detector; it is doubtful whether the average observer can detect less than 1 percent of methane with the ordinary lamp.

When there is sufficient methane present to be detected with a flame safety lamp, the amount may be roughly estimated by the height of the "cap" or elongation of the flame, but these estimates are likely to differ considerably from the true value. Men charged with the responsibility of detecting methane with a flame safety lamp should be thoroughly competent and experienced in the use and care of such lamps. They should, before being employed and periodically thereafter, furnish proof that they have good eyesight and are not color blind.

A reduction of oxygen below normal (20.94 percent) will materially affect the efficiency of gas detecting with a flame safety lamp, because the lower oxygen rapidly affects the illuminating power and consequently the heat of the flame. Burrell states that the effect of the reduction of oxygen on the illuminating power of a flame lamp is as follows:

Percent Oxygen	Percent Illumination
20.94	100
20.70	90
20.30	75
19.90	70
19.30	40
18.90	28
18.30	12

In view of the rapid decrease of illumination with a small reduction of oxygen, it is obvious that the flame safety lamp will be anything but an efficient device for detecting methane in any appreciable oxygen deficient atmosphere. A flame safety lamp cannot be relied upon to detect methane efficiently when the oxygen content has been reduced to less than 20 percent. Because of the low oxygen content, therefore a low temperature flame, no "cap" or other indications of the presence of methane are noticeable on the flame of the lamp.

HANDLING A LAMP DURING TESTS

After a lamp has been properly prepared for use it may be raised slowly into the place to be tested. The lamp is generally grasped firmly by the fuel vessel or lower portion and held upright. The lamp must be raised slowly. It is very unwise to place a lighted safety lamp in a mine atmosphere known to be explosive; by raising the lamp slowly the atmosphere can be explored, and when the behavior of the flame indicates that a dangerous amount of gas is being approached the lamp should be withdrawn slowly. Should a safety lamp be thrust inadvertently into an explosive mixture, which may be indicated by the lamp filling with flame or the wick flame "going out", it should be withdrawn slowly. Hasty withdrawal will tend to drive the flame through the gauzes. The lamp should be taken to fresh air or be extinguished by shutting off the air supply.

METHODS OF DETECTION

Two different methods are employed for testing for gas with an ordinary flame safety lamp; use of a short almost nonluminous flame, and use of a normal flame about 1 inch high. The short flame is better suited for accuracy and from the standpoint of safety.

NORMAL FLAME

For even approximate detection, the height of the flame in fresh air should first be noted, after which the increase in flame length due to the presence of gas will indicate the percentage of gas present. This method can only be an approximation, since fresh air may be some distance from the gaseous mixture tested, and accurate results could be obtained only by use of a measuring device to show the lengthening of the flame.

"CAP" OR NONLUMINOUS FLAME

The cap flame is by far the most reliable for gas detection, since it requires no previous adjustment in fresh air. The normal flame is reduced until the yellow color disappears and a blue flame remains. This flame does not interfere with seeing the "gas cap".

The height of the gas cap determines the amount of methane in the mine air. However, each different type of lamp gives a different height gas cap in the same percentage of methane. For instance, a flat wick lamp will not necessarily give the same results as a round wick lamp. Also, two lamps of the same type but burning two different types of fuel will give different height gas cap in the same percentage of methane. This is because the temperature of the flame determines the height of the gas cap and the temperature is dependent upon the type of fuel used. The proper procedure is to have each person authorized to carry a safety lamp issued the same lamp every shift; then, have that person test his lamp quite frequently in gaseous mixtures of known methane content. In this manner more accurate results will be possible for every day testing.

Quite often a small cap is noticed in fresh air over the regular cap flame. This is due to the heat of the flame turning some of the fuel into gas which forms the fuel cap. This cap depends on the kind and quality of fuel being used and is quite often distinct in a naphtha or gasoline burning lamp. Practice in fresh air in observing this fuel cap will remove the tendency to count it as a gas cap in making a gas test, since it has a round or mushroom appearance, whereas a gas cap has a pointed appearance.

f. DETECTING OXYGEN DEFICIENCY WITH A FLAME SAFETY LAMP

As the percentage of oxygen in the air becomes less than normal, the illumination of the flame becomes less until the percentage of oxygen reaches 16, in an atmosphere free of explosive gas, at which time the flame will go out.

When the percent of oxygen has dropped from normal (20.94 percent) to 20 percent the flame will have lost between 25 and 30 percent of its heat and illuminating power. When the oxygen content drops to 19 percent the flame will have lost between 60 and 70 percent of its heat and illuminating power.

It must be remembered that a flame safety lamp only can be used as an indication of a deficiency of oxygen and cannot be used as final proof OF OXYGEN DEPLETION. The presence of methane will permit the flame of the lamp to burn freely in an oxygen content below which it would not have burned in air containing no methane. However, irrespective of the percentage of methane present, a flame safety lamp is extinguished when the oxygen content falls below 13 percent.

g. MISUSE OF FLAME SAFETY LAMP

Although numerous accidents and disasters have been caused by flame safety lamps, generally they can be traced to the fact that miners, fire bosses, shot fires, safety engineers, or mine foremen have attempted to use lamps that were defective, dirty, or not properly assembled or have taken them apart and attempted to relight them in an explosive mixture. Safety lamps are safe only when properly cleaned, assembled, locked, and in the hands of competent persons who have good eyesight and realize the limitations of the lamp.

Several serious mine disasters have been caused by persons who opened their flame safety lamps and tried to relight them inside the mine. The man who opens a safety lamp inside a mine deliberately endangers himself and his fellow workmen, and the man who strikes a match inside a mine to relight a lamp should be classed as a criminal.

The following three accounts of mine explosions are given here as an example of misusing a flame safety lamp:

(1) An explosion in a coal mine in Colorado, U.S.A., caused the death of 121 men. The fire bosses of this mine were accustomed to report the mine free of gas if not more than a 5/8 inch cap showed in their lamps. This criterion in itself was unsafe, because a cap of this height means that there is at least 3 percent, already a dangerous percentage, of gas present; and, a slight change or rearrangement in ventilation could easily increase the proportion of gas to an explosive mixture. The safety inspector, a trusted man who also acted as safety instructor, carried a key-locked lamp. After the explosion this lamp was found taken apart near his body, and there were 22 matches in his clothing. Undoubtedly the flame on his lamp had been extinguished while he was testing for gas, and instead of leaving the mine entirely or proceeding to a lamp station he had retreated a short distance from the supposed location of the gas, had taken the lamp apart, and had tried to relight it with a match, this igniting the gas and causing a terrific explosion which killed every man in the mine. There had been a methane explosion in this mine about 5 years before, and the cause of ignition was an incorrectly assembled flame safety lamp.

(2) An explosion in a coal mine in West Virginia, U.S.A., killed the mine foreman and six others. A fire boss had

reported gas in one of the rooms, and the mine foreman went to that section of the mine to put up a brattice to remove the gas. After the explosion the foreman's lamp was found disassembled, and matches were discovered in his clothes. Evidently the flame of his lamp had been extinguished, and he was unable to relight it with the igniter, so he had opened the lamp and attempted to relight it with a match.

(3) An explosion in a coal mine in Wyoming, U.S.A., killed a shot firer and 98 other men. After the explosion a burned match was found near the shot firer's disassembled lamp, which apparently had been taken apart for relighting. The shot firer evidently had tested for gas and had the flame of his lamp extinguished and, thinking that he was on the fresh-air side of a brattice, had taken his lamp apart and tried to relight it. The flame of the burning match ignited gas which probably had accumulated when a rock fall tore down a line brattice.

2. ANEMOMETER

The form of anemometer generally used in coal mining consists of a metal ring within which is set a rotating propeller or blade. The air current striking the inclined blades rotates the vane, the number of revolutions being recorded on the face of the dial by means of a series of gears. The instrument is so calibrated that each revolution of the vane corresponds to one lineal foot of air travel. The instrument is employed to measure the velocity of the air current in mine airways as expressed in feet.

In taking a reading a place is first found where the air has a straight course and will not be deflected unequally to either side, and where the area of the airway can be measured.

Hold the anemometer at/arm's length in such a way that the blades will turn in a plane at right angles to the air current, using reset lever on anemometer, so all dial hands will be on zero, the brake lever near handle is released and anemometer exposed to the air current for one full minute, moving about so as to obtain an average reading for the entire sectional area of the airway after which the brake is applied. The reading of the anemometer times the area of the airway in square feet gives the quantity of air passing in cubic feet per minute.

3. CARBON MONOXIDE DETECTOR

Because of the dangerous characteristics of carbon monoxide, means for its detection are vitally important especially following mine fires and explosions. Also, it is important to be able to detect the presence of carbon monoxide when investigating sealed off areas and old workings.

There are several methods used for detecting carbon monoxide; but, for the purpose of this work only the iodine pentoxide (hoolamite) detector will be explained.

The hoolamite or activated iodine pentoxide indicator for carbon monoxide is commonly just called the carbon monoxide detector. Hoolamite ($I_2O_5 + H_2SO_4 + SO_3$) is a mixture of iodine pentoxide and fuming sulphuric acid on granular pumice stone. In contact with carbon monoxide iodine is liberated, changing the originally white granules to bluish green of increasing depths, then violet brown, and finally black, depending upon the concentration of carbon monoxide.

Hoolamite averages approximately 12.29 percent of iodine pentoxide, 51.89 percent of sulphuric acid (47 percent of SO_3) and 35.82 percent of pumice granules. As moisture causes deterioration of hoolamite, it is marketed in small glass tubes tapered at the ends and hermetically sealed. The complete indicator comprises a metal barrel filled with activated charcoal, through which air is drawn by means of a rubber hand bulb. The inlet end of the barrel has a corrugated tip, to which a rubber tube may be attached. The air is then discharged by the same means through a small glass tube containing hoolamite. A comparison color tube is placed alongside the hoolamite tube. The scale and tube are kept in position by holders firmly attached to the metal barrel.

a. INSPECTING DETECTOR BEFORE USE

Before a hoolamite detector is taken underground it should be inspected carefully to make sure that the aspirator bulb does not leak and has the proper resilience; that the valves of the instrument are tight and function properly; that the color tube is held securely in place; and that the activated charcoal is in good condition.

When the aspirator bulb is squeezed, a current of air should issue from the rubber connecting joint into which the hoolamite tube is to be inserted; and when the bulb is released a current of air should enter the inlet opening. Hence, the condition of the bulb may be determined by testing it with both of these openings closed. If the bulb is sound, it cannot be squeezed flat; if it lacks resilience, it will not go back into shape promptly after being collapsed. A bulb that is found to be defective should be replaced.

If the inlet valve is tight, no air will be lost when the aspirator bulb is squeezed, as long as a finger is held tightly over the opening in the connecting joint. If the valve is functioning properly and the inlet aperture is open, the aspirator bulb after being collapsed will refill rapidly as soon as the hand pressure is withdrawn. If the parts of an inlet valve leak or stick they should be removed, wiped clean with a cloth, and replaced. In reassembling, care should be taken to replace the spring in the proper position to hold the valve seat in place.

If the outlet valve is tight and the inlet aperture is closed, the aspirator bulb should remain collapsed when the pressure that deflated it is released. If the parts of the outlet valve leak or stick they should be removed, wiped clean with a cloth, and replaced.

If the material in the hoolamite tube becomes discolored when squeezed 20 times in pure air the charcoal container should be refilled with fresh activated charcoal. In reassembling the instrument care should be taken to replace the spring that holds the charcoal in place correctly, otherwise air channels through the charcoal might result.

b. USE OF DETECTOR IN MINES

Assuming that the operator is protected by a suitable respiratory apparatus when working in an atmosphere liable to contain carbon monoxide, he should use the detector in the mine in the following manner:

1. Squeeze the bulb once or twice to remove any moisture and to fill the instrument with air identical with that to be tested.
2. Break both tips of a hoolamite tube and insert it firmly in the instrument with the shoulder securely seated in the rubber connecting joint.
3. Squeeze the bulb 10 times in succession, collapsing it completely each time. This will force about 350 cc of air through the impregnated pumice. A slight amount of smoke or fume should issue from the hoolamite tube when the bulb is squeezed. Although this smoke is harmful, if breathed directly, under ordinary conditions it will be diluted so quickly by the mine air that no symptoms other than coughing are likely to be noted. Observation of the smoke, however, is often advantageous as indicating the direction and velocity of the ventilating current in the mine.
4. After squeezing the bulb the full number of times, compare the resulting color with the permanent colors in the color tube and note the corresponding percentage of carbon monoxide. At low concentrations of carbon monoxide the color in the hoolamite tube fades rapidly, hence the comparison with the color tube should be made at once.
5. If no color comparable with those in the color tube results from 10 squeezes, repeat the test, using some multiple of 10 and making the corresponding correction in the percentage indicated by the color obtained. For example, if a color corresponding to that for 0.1 percent is obtained with 20 squeezes, the amount of carbon monoxide in the air sampled is about 0.05 percent; or, if a color corresponding to that for 1.0 percent is obtained with 5 squeezes, approximately 2.0 percent of carbon monoxide is indicated in the mine air. As stated, the operator should be protected by a gas mask or breathing apparatus while working in an atmosphere suspected of containing carbon monoxide.
6. Remove the hoolamite tube from the instrument promptly, as it should not be left in place longer than the time necessary to make the test. If the color in the tube does not fade or if a yellow discoloration appears the tube should be discarded. As the iodine pentoxide mixture is highly acid, a discarded tube should not be thrown where it can do any damage. If the tube

is to be used again, the tips should be covered with rubber caps to prevent deterioration of the contents through entrance of moisture.

7. The detector does not indicate a deficiency of oxygen in the atmosphere or the presence of such other gases as carbon dioxide or hydrogen sulphide,

Although the iodine pentoxide indicator is used more or less generally, it should not be forgotten that it does not work continuously to indicate the presence of carbon monoxide; therefore, frequent determinations are necessary to indicate the presence of carbon monoxide. Furthermore, persons with poor eyesight or color blindness may be unable to read the scale and make the necessary color comparisons; persons so affected should not be entrusted with this device.

SECTION 2 COAL MINE VENTILATION

A. GENERAL

Adequate and proper ventilation is the best defense against coal mine fires and explosions; it is also essential for the health and safety of the men working in the mine. Therefore; the first consideration in developing a coal mine must be the installation of a good ventilation system.

One way to be sure that the ventilation system is adequate is to have the proper amount of air at the working face for the number of men at work in the face.

The physical conditions of the mine will determine the method of coursing and controlling the flow of air thru any part of the mine, be it one split or several splits of air. However, the observations of the behavior of air flow in the face regions are more important and contribute more to the improvement of face ventilation than a mathematical analysis of the situation.

Air supplied to the working face should contain not less than 20 percent oxygen, not more than 0.50 percent of carbon dioxide, and no harmful amounts of any other dangerous or noxious gases.

If at any time more than 1.0 percent of methane gas is found in the mine air, the men should be withdrawn until this percentage is lowered by the mine ventilation system.

B. AMOUNT OF AIR REQUIRED

While working hard a man requires between 30 and 40 cubic feet of fresh air a minute. That amount, however, does not nearly meet a man's needs underground as the gases given off in his working place must be swept away, and the oxygen absorbed by the coal and by oxidation of the timbers must be replaced. It is a generally accepted fact that you should have at least 6000 cubic feet of air passing through the last cross-cut every minute.

The volume of air entering the mine should be measured at the foot of the shaft or just inby the entrance of a slope or drift. Good practice requires that at least 50 percent of the air entering a mine shall reach the face.

C. MEASURING MINE AIR

1. GENERAL

Mine air is measured by a standard anemometer as described in part E-2 of Section 1.

The best practice in measuring the mine air is to measure the main intake at the foot of the shaft or just inby the mouth of the slope or drift; and also, the amount of air passing through the last crosscut or break-thru nearest the working face of each split of air. These measurements should be made every day by the mine foreman or some one he designates and an accurate record kept showing the time, place, and results of these measurements.

In addition to these measurements it is advisable to periodically measure the air entering each and every working place. When this is done, it should also be recorded.

2. WHERE TO MEASURE

The measurements of air should be taken in the same place each day; thereby, providing a basis for comparing the daily readings. A place should be chosen that has smooth walls in order to avoid turbulence of the air. Also, the place chosen to make the readings should be of such a nature as to provide easy access to the whole entry and easy to measure the cross-sectional area at the exact place the measurement is taken.

3. HOW TO MEASURE

To get a good average measurement of the velocity of the air, care should be used in making the reading with the anemometer. The anemometer should be kept away from the body; it should be held at right angles to the direction of the air flow; and it should be moved slowly zigzag across, up, and down the cross-section of the entry while the reading is being made. This process should be repeated in the same place at least three times and the final reading recorded should be the average of these various readings.

If the anemometer is held in the center of the entry for the measuring period instead of moving it around as described above, the reading is liable to be incorrect by as much as 50 percent.

4. HOW TO CALCULATE

The amount of air or the volume of air is calculated from the readings on the anemometer and the cross-sectional area at the place where the measurement was made.

The results obtained from the anemometer is the veolocity of the air stream in feet per minute; the cross-sectional area is measured in square feet. Multiplying the velocity in feet per minute by the cross-sectional area in square feet gives you the cubic feet of air per minute (cfm). This is the term used to designate the quantity of air.

D. VENTILATING SYSTEM

1. MINE OPENINGS

The prime objective of a ventilating system is to have an adequate quantity of air delivered to the working faces. In order to have this air delivered to the faces, a current of air must be circulated through the mine; therefore, it is necessary to provide at least two separate openings into the mine, one for the air to enter and the other for the air to leave the mine.

Openings into a mine for ventilation are usually easier to make at a slope or drift mine than at a shaft mine. However, experience has shown that without careful planning this advantage can be turned into a distinct disadvantage. Openings at many mines have been made so close together that fumes or smoke from an explosion or fire covered both openings. Also, there is usually a tendency to make the coal pillars between the intake and return so thin that air leaks through the crevices of the coal and partially destroys the ventilating system.

Slopes and drift openings should be separated by at least 50 feet of rock or coal and it is better to have a hundred foot barrier.

Also, in order for the air to circulate through the mine it is necessary to have at least one distinct air passage leading from each of these openings into the mine. These are necessary to conduct the air current to and from the working faces.

Another mistake that is commonly made due to improper planning is the driving of rooms directly off the slope or drift in order to obtain "easy" coal. In later work this very often makes it difficult to drive additional places needed for ventilation.

2. VENTILATION PLAN

The ventilation plan should be given as much careful thought as development and production plans. There are generally three basic considerations to take into account when planning a ventilating system, they are as follows:

1. The length and condition of the airways. They should be as short as possible and as free from obstructions as possible so that the air resistance will be minimized.
2. Leakage between the air intake and air return must be as little as possible.
3. The amount of air should be distributed among the various splits according to the needs of each individual split. This is done with regulators.

The ventilation of a mine, unless the mine is especially small, should be done with two or more splits of air instead of trying to ventilate with one continuous current of air.

If there is only one continuous current of air, gas and dust explosions or fumes and gases from a fire may spread to the entire mine before they can be brought under control. However, if the mine is divided into sections with a separate split of air on each section, the effect of fires and explosions are not so likely to be widespread. Also, the amount of power needed to ventilate a mine is reduced considerably when separate splits of air are used.

The advantages of a split system over a continuous current system is as follows:

1. A much larger volume of air can be circulated without increasing the power.
2. The sections of a mine can be isolated.
3. The effects of fires and explosions are more likely to be localized.
4. Interruptions to air flow in one split will not seriously affect other splits.
5. Efficiency of the system will be improved.
6. The system is very flexible and can be controlled more easily.

3. VENTILATING PRESSURE

In order to circulate a current of air you must have pressure exerted. This pressure is usually referred to as the "ventilating pressure" or "water gage" and is the difference between the intake pressure and the discharge pressure.

There are two methods of producing this pressure in use today; the blowing system and the exhaust system. In the blowing system, the fan creates a pressure above that of the atmosphere and the air is blown through the airway by the pressure created. In the exhaust system, the fan reduces the pressure below that of the atmosphere and the air flows toward the end where the pressure is the least.

This difference in pressure is measured by an instrument known as a water gage. The water gage consists of a glass tube with about a 3/8-inch inside diameter and bent in the shape of the letter "U", mounted on a solid base and half filled with water. One end of the "U" is left open and the other end is bent at right angles so that a piece of pipe or hose can be connected to it and then put through a stopping or brattice; thus, exposing one side of the "U" to the intake airway and the other side of the "U" to the return airway. The distance between the water level of one side of the "U" and that of the other side, in inches, is the water gage reading. This then is the difference in pressure between the intake and the return airways at the point where the reading is taken.

This difference in pressure is the pressure that is required to circulate the air between the point on the intake airway and the point on the return airway, or in other words, the pressure required to circulate the air inby from the point where the reading was taken. The nearer this reading is taken to the working face, the closer it will approach zero; therefore, at the next to the last cross cut or break-thru the reading should be almost zero.

The circulation of a large quantity of air with a small water gage indicates the most efficient and economical conditions for the ventilation of the mine; conversely, the circulation of a small quantity of air with a large water gage indicates a waste of power and is definitely not economical.

If in a mine operating on a fairly low water gage there is a noticeable increase in the water gage, it is a pretty good indication that there is an obstruction in one of the airways.

4. MINE RESISTANCE

The mine resistance is the resistance to the flow of air offered by an airway. There are two kinds of mine resistance, natural and artificial.

a. NATURAL RESISTANCE

Natural resistance is due to the rubbing of the air on the inner surface of the airway. The friction thus produced is the basis for calculating the natural resistance.

It can be assumed that when the velocity of the air is doubled the amount of the resistance will be four times as great. This is proven if you consider that each resisting particle in the airway is struck twice as hard, twice as often.

b. ARTIFICIAL RESISTANCE

Artificial resistance is the resistance caused by the air stream striking against obstructions such as timbers, roof falls, abrupt changes in direction, etc.

This resistance is the chief cause of inefficiency in the ventilating system; however, often the fan is blamed for the inefficiency caused by this artificial resistance.

The chief causes of artificial resistance arranged in order of importance is as follows:

1. Roof falls and debris.
2. Door frames and remnants of temporary stoppings.
3. Abrupt changes in direction.
4. Constrictions.
5. Deposits of dirt on the fan blades.

Recognizing these causes is not difficult, and their removal or at least a reduction of their effects usually pays off in the reduction of resistance and consequently the reduction of power.

Abrupt changes in direction of the airway causes turbulence and contraction of the air stream and should be avoided wherever possible. A turn consisting of a series of obtuse-angle deflections is preferable to a right-angle turn in the main airway.

Constrictions caused by variations in the cross-sectional area of an airway also causes turbulence and increases the resistance.

5. CONTROL OF THE AIR

Natural distribution of air currents is usually unsatisfactory because the quantity of air is not sufficient in all parts of the mine; therefore, the direction and quantity of flow must be controlled. The control of the air currents is carried out by the use of stoppings, doors, overcasts, line brattices, seals, regulators, and check curtains.

a. STOPPINGS

A stopping is a wall or barrier placed in an opening to prevent the flow of air through that opening; thereby, conducting the air along the proper airway. Permanent stoppings are those that fit into the overall ventilating system and usually will remain for the life of the mine. Temporary stoppings are those that are needed for a short period of time, such as the time required to mine the coal from one room panel.

Stoppings should be built as air tight as possible so that the air will not leak around or through them. They should be built out of sufficiently strong material to resist the pressures from the ribs and roof; also, the material used should be fire-resistant and incombustible.

b. DOORS

The use of too many doors to direct the flow of air not only affects the efficiency of the ventilating system, but interfers with the hauling or hoisting of coal. Also, the use of doors could introduce a very definite fire hazard, unless the doors were made out of fire proof material.

In the event of an explosion or a fire, too many doors could result in the explosion or fire spreading over the entire mine if a door is left open.

c. OVERCASTS

Overcasts are employed to carry one current of air over another, usually return air over intake air, and should be constructed of substantial, incombustible material.

The use of undercasts accomplish the same purpose by carrying one current of air under another and should be constructed out of the same material as an overcast.

Both an overcast and an undercast should have a cross-sectional area equal to or greater than the cross-sectional area of the entry approaching and leaving the overcast or undercast. The approaches to the overcast or undercast should be graded so as not to cause an abrupt change in the direction of air flow.

d. LINE BRATTICE

A line brattice is used to direct the flow of air from the last cross cut to the working face. It is usually constructed out of brattice cloth and is hung along one side of the entry; thus, permitting intake air to go to the face on one side of the line brattice and return air to leave the face on the opposite side.

e. SEALS

The most practical method of preventing intake air from mixing with bad air from abandoned areas is to seal off such areas. The seals should be constructed very strong and completely air tight. The materials used in the construction should be incombustible and fire proof.

Seals are also used to isolate areas of the mine where there has been a fire or explosion.

A pipe should be placed in the seals so that the air can be sampled periodically and any pent-up gases found can be bled off.

f. REGULATORS

Regulators are necessary to control the amount of air so that each split will have sufficient air for its needs.

Regulators are usually a sliding door; however, they can also be a series of slats spaced uniformly in the opening so as to vary the flow of air passing through the opening.

The opening for a regulator is usually placed in approximately the center of a stopping and has an area of approximately 10 square feet, depending of course on the amount of air that must flow thru the regulator.

Where the intake and return airways of a split are parallel, it is best to place the regulator in the return airway as near to the main return as possible because here the difference of pressure is the least.

g. CHECK CURTAINS

Check curtains consist of one or more layers of brattice cloth and are often used in place of a temporary door or stopping. The use of check curtains should be avoided as much as possible because they will not withstand rough usage; however, for temporary use they are economical and easy to install.

6. SPLITTING THE AIR

Splitting the air means dividing the main air current into two or more separate ventilating currents, each separate current ventilating a different district of the mine. By doing this each different district of the mine can be supplied with the correct amount of air that is needed on that particular district.

By splitting the air a larger total quamtity of air can be circulated at a lower velocity and with less power expended at the fan. Smoke and gases given off by one district of the mine are not carried to another district but go directly to the main return and thence to the outside. A local or dust explosion or fire in one district of the mine is not as liable to spread through out the entire mine as it would if the whole mine were on one continuous circuit of air.

a. REQUIREMENTS FOR SPLITTING

All that is required to split an air current is to have two or more separate routes for the air to follow. Each path of the air is then called a "split". When two or more separate routes are available for the air to travel, the air will automatically travel thru them all; however, regulators must be used if the amount of air through each place is to be controlled.

b. NATURAL SPLITTING

When all airways or routes are open for the free passage of air you will have natural splitting with each airway or split taking a portion of the total volume of air. The portion for each route being determined by the amount of mine resistance in that route.

c. CONTROLLED SPLITTING

When any division of air is wanted other than that produced by natural splitting, it is necessary to put regulators in one or more of the splits. By doing this the flow of air is obstructed in those splits that naturally take more than the desired amount of air. When these splits are so obstructed it increases the volume of air passing in the other splits until the desired amount of air is obtained in all splits.

The split which does not have a regulator is called the "free split".

d. PRIMARY AND SECONDARY SPLITTING

When two or more splits are taken off of the main air current, they are called primary splits. If a primary split is divided into two or more splits, these are called secondary splits.

If the splits have the same volume of air flowing thru them, they are called equal splits; but, when the amount or volume of air flowing through the splits is different, they are called unequal splits.

7. MINE FAN

The fan is the most important factor in a ventilating system. It is what moves or circulates the air, and without it the satisfactory ventilation of a mine is impossible. Everything possible should be done to assure continuous and efficient operation of the fan.

The fan is what creates the difference in pressure between the intake and return openings as explained in part D-3 of this section.

Fans in use today may be divided into two general groups: The centrifugal and the axial-flow. At first the majority of the fans were in the first group, but their popularity is disappearing in favor of the second group because the axial-flow fans have certain features that improve the economy and efficiency of the ventilating system.

a. CENTRIFUGAL FANS

Forward-curved multiblade types of centrifugal fans are the type that are most widely used because they were the most economical type available when most centrifugal fans were installed.

In the centrifugal fan the blades are all set at right angles to the plane of revolution. The blades can be either radial blades, sometimes called paddle blades, or they may be inclined either forward in the direction of revolution, or backward.

Centrifugal fans can be either exhaust or blowing.

b. AXIAL-FLOW FANS

In the axial-flow fan the path of the air flow is parallel to the axis of the fan rotor. The disk fan and the propeller fan are both axial-flow fans.

The propeller type axial-flow fan is the lastest result of research in air flow and fan blade design. This type of fan has the following advantages:

1. High efficiency.
2. Ease of reversing.
3. Low initial cost of complete installation.
4. Adjustable blades to meet changing mine conditions.
5. Suitability for direct drive.

c. LOCATION OF FAN

The location of the fan does not influence the overall mechanical efficiency of the fan because this efficiency is based on the relationship between the size of the fan and the mine resistance; however, the location of the fan is important with respect to the mine openings.

A mine fan should be installed on the surface and offset 15 or more feet from the mine opening. The offset distance is the distance between the nearest side of the mine opening and a vital part of the fan nearest to the mine opening. A vital part of the fan means a part without which the fan could not operate.

The reason for this offset is that if the fan was placed in a direct line with the mine opening it may be damaged in the event of a mine explosion.

It is also important to locate the fan so that the return air from the mine cannot be drawn into the intake openings; therefore, the intake opening should be a minimum of 50 feet from the fan location.

d. EXPLOSION DOORS

Offsetting the fan from the mine openings does not assure the safety of the fan in the event of a widespread explosion. However, the degree of protection can be increased by installing explosion doors in the connecting duct in line with the mine opening. Where the fan is offset and the connecting duct is equipped with explosion doors, the fan is usually fairly well protected from serious damage.

A weak wall placed in the connecting duct in line with the mine opening will substitute for explosion doors. The wall should be constructed out of brick or rock put together with little or no mortar.

e. OPERATION

Mechanical ventilation of a coal mine, if properly controlled, will provide a healthful atmosphere through out the mine when the fan is in operation. Fans should be operated continuously.

Intermittent operation of a fan is often responsible for accumulations of explosive atmospheres or the over heating of a portion of the mine;

thus, an explosion or fire may result from such operations.

The mine workers should be withdrawn from the mine when the fan stops for more than a few minutes; and, should not return until ventilation has been completely restored and the mine examined and reported safe by the fire boss.

f. BOOSTER AND AUXILIARY FANS

Booster and auxiliary fans, first used extensively and appropriately in metal mines, have been installed underground in some coal mines, especially in those where additional ventilation is needed and can not be obtained from the main fans.

BOOSTER FANS

Booster fans are those that raise the pressure, either positive or negative, of the air current or a split of the current at and from a point where the pressure imparted by the main fans is insufficient to force the air current into distant parts of the mine or through some restricted airways. It should always be placed on the intake air and the entry should be fireproofed 50 feet from the fan in each direction.

Only under very exceptional conditions, however, is a booster fan a proper means of ventilation, and the use of such a fan should be avoided whenever possible.

AUXILIARY FANS

Auxiliary fans are small portable fans; virtually all are blowers and are electrically driven. They are used with canvas tubes or metal pipes to ventilate headings or narrow workings that are without cross-cuts or break-thrus or have them more than the normal distance apart.

Fans and tubes have been substituted for line brattices in headings and rooms in some mines.

Here again these should only be used when absolutely necessary and should not be part of the standard ventilation system because of the dangers of recirculating the air locally and of ignitions from electric arcs at the fan motor.

E. VENTILATION SUGGESTIONS FOR THE MINE MANAGER

1. Be sure that the ventilating fan is running at its regular speed all the time. The fan should run 24 hours a day, whether men are in the mine or not. There is always a chance that gas may accumulate or places

get hotter than normal if the fan is idle while the men are out of the mine.

2. In the purchase of supplies for the ventilating system be as liberal as possible. If the foreman requests canvas for curtains, wood for doors, or material for stoppings, get it for him.
3. It is a good plan to have a map of the mine, showing the course of the ventilating current, hung on a board near the mine entrance where the miners can see it and learn the courses of the currents so that if a fire or explosion occurs they will know the safest direction to take.
4. The fan should not be placed over the shaft or in front of a drift or slope opening to the mine, but should be placed at one side, out of line, so that it will not be destroyed or disabled if an explosion takes place.
5. Never reverse the fan while men are in the mine without full knowledge of the conditions and for the benefit of the men. Generally it is a serious mistake to reverse the air current. If there is a fire in the mine and the current is reversed, it is apt to drive inflammable gases over the fire and cause an explosion.
6. In addition to the daily inspection by fire bosses, you should inspect all airways and escape ways at least once each week.
7. Airways should have as large a cross-section as is practicable, and dirt or slate should not be permitted to accumulate in them. Falls should be removed as soon as discovered. Remember that falls or obstructions in the air courses reduce the quantity of air passing in a given time.
8. A single door left open may disarrange the entire ventilating current in a mine; therefore, the doors should be carefully watched.
9. All stoppings and overcasts should be made of noninflammable material and the sides should be cut into the solid coal at least 6 inches; the entire stopping or overcast should be made as nearly air-tight as possible.
10. In driving entries and rooms, all cross-cuts and break-thrus should be closed by good stoppings as soon as a new cross-cut or break-thru is opened.
11. A supply of curtain material, as well as materials for building stoppings, should always be kept in the mine so that it will be at hand in time of disaster.
12. You should have a copy of the mine map with you at all times. On this map the course of each ventilating current should be traced with red pencil or shown in some distinct way. Such a map will be a great help in repairing the damage after any accident that disarranges the ventilation.
13. Measure the quantity of air coming into the mine once each day and record the figure in the mine report book. Also measure the current in the last working place of each split to make sure that enough air reaches the men. The important thing is to see that the ventilation reaches the working places, and is not lost by leakage before getting there.
14. Have a separate split of air for every 80 men or when otherwise needed.
15. If you find that the ventilation is defective in any part of the mine

or in the entire mine, do not hesitate to withdraw the men from that part of the mine or from all the mine.

16. Never allow miners to turn rooms beyond the last open cross cut.
17. If there is a fire in the mine see that the air current is so conducted that inflammable gas in the mine is not passed over the fire. If the mine ventilation can not be so arranged that the gas will not pass over the fire, then it should be stopped until the fire is put out or sealed off.
18. In order that each district of the mine may have fresh air, you should split the air current. By this system each district has its own air and the men working in it are not compelled to breathe air that has been breathed by men in another district. However, you should not split the air current too much as the split will have too low a velocity. An air current must have a velocity of at least 100 feet per minute in order to move any accumulated gas properly.
19. When pillars are being drawn the roof is apt to break suddenly and an outburst of gas may follow. Gas is difficult to remove in pillar workings, but conditions can be improved by line brattices.
20. Take your safety lamp and anemometer with you at all times. Check frequently the amount of air at various places and for gas.
21. Do not test for gas with the high flame of the safety lamp, but turn the wick down until only a small flame shows.
22. Never permit men to go into places filled with standing gas or where there is reason to believe that gas is present in dangerous quantities.
23. Clear a place of gas by means of the ventilating current only.
24. If there is a large volume of standing gas in any part of a mine or if the mine is extremely dusty it is best to remove every person from the whole mine.
25. Do not allow the men to go back too soon after shots have been fired. Have them wait until the smoke has cleared away, so that they will be able to see the roof and can avoid possible danger from roof falls.
26. When you find a curtain hung up or torn badly, so that it does not direct the air as it should, have it attended to at once.
27. If the lower edge of a curtain has been raised so that air passes under it, drop it in place.
28. When working a place where there is a line brattice, see that the brattice is hung close to the roof, extends to the floor, has no holes in it, and is always kept up.
29. See to it that all men under you practice safe mining at all times and that they are all aware of the dangers of improper ventilation.

SECTION 3 COAL MINE GASES

A. GENERAL

The subject of mine gases is a most important one for every person engaged in mining. Not only should the manager, foreman, and fire boss be thoroughly familiar with the various gases that are met with in coal mining operations, but every man in the mine should possess at least a small knowledge of the subject. Even though gas has never been found in a mine, there is always the possibility that gas will occur.

B. NORMAL AIR

The study of mine gases will be made easier if the air we breath is first considered. It is a fact that air, on the outside, is one of the things that varies very little in composition wherever we may go; provided that it is not mixed with smoke, fumes from furnaces, or the products of breathing of persons in a closed room; it does not matter whether we are in Washington, D. C., U. S. A., or Kabul, Afghanistan, the composition of the air is the same.

Pure, dry air at sea level contains the following gases: oxygen (O_2), 20.94 percent; nitrogen (N_2), 78.09 percent; carbon dioxide (CO_2), 0.03 percent; argon (A), 0.94 percent by volume. Traces of helium (He), neon (Ne), krypton (Kr), xenon (Xe), hydrogen (H_2), hydrogen peroxide (H_2O_2), ammonia (NH_3), and ozone (O_3) are also present. For all practical purposes air consists mainly of oxygen and nitrogen with a small amount of carbon dioxide and water vapor.

It is interesting to note that air that is exhaled from the human body contains about 16.3 percent of oxygen, 79.32 percent of nitrogen, and 4.38 percent of carbon dioxide.

C. MINE AIR

The pure outside air that enters a coal mine contains oxygen, nitrogen, and carbon dioxide in the proportions stated above, but the mine air that leaves the mine is somewhat different from the air that enters.

Normal air when circulated through a mine loses some of its oxygen by the breathing of the men and a certain amount is absorbed by the coal and timbers; also, some oxygen is taken from the air by the oxidation of fine particles of sulphur (iron pyrite), such as occur in many coal seams. The absorbed oxygen is largely replaced by carbon dioxide, which is given off by the breathing of the men, by the coal, and by decaying timbers. To this may be added large or small quantities of methane (CH_4), depending on the volume of the air current and on the amount of methane that is being liberated. Most coal mines give off methane in greater or smaller amounts or are likely at any time to give off methane.

As the air travels through mines small amounts of carbon monoxide (CO) also may be added, even during normal operations, due to the gases from the explosives used when blasting coal or rock; however, during such abnormal conditions as a mine fire or an explosion, dangerous amounts of carbon monoxide may be present.

In addition to the gases already mentioned as being present during normal or abnormal conditions in mines, others may be found occassionally in mine air. These include oxides of nitrogen (NO, NO_2, etc.) after blasting with certain high explosives or after-burning rather than detonation; hydrogen (H_2) during coal-mine fires and after explosions; and hydrogen sulphide (H_2S) in stagnant water in coal mines or by emission from the strata.

The air of all mines carries some moisture or water that can not be seen because it is in the form of vapor, and the proportion of moisture in the air varies with temperature and pressure. Cold air can not carry as much moisture as warm air; for this reason mines are naturally drier in winter than in summer. In winter the outside air, which is colder than the mine, holds little water. When this cold air enters the mine it is heated by the mine walls; consequently, as it gets warmer it can hold more water, which it takes from the floor, roof, and ribs, thus drying the mine. Under such conditions, the coal dust is very dry and if it is raised in the air in the presence of a flame, a dust explosion may occur.

In the normal everyday working of a mine the most important changes that air undergoes after it enters a mine are those that have been mentioned. If a mine is not well ventilated, the air in the rooms and entries will contain less oxygen and more carbon dioxide than it should; explosive mixtures of methane and air may gather; and, powder smoke, warm or stagnant air may stay in the working places.

D. MINE GASES

There are four dangerous gases found in coal mines which are generally common. In addition to these four, there are numerous others found more rarely, but their chief characteristics greatly resemble some one of the four. These four gases are generally what are spoken of if a question is asked relative to the dangerous gases met with in coal mines. They are methane, carbon dioxide, carbon monoxide, and hydrogen sulphide.

Other gases met with in small quantities in mines are acetylene or carbide gas, and hydrogen.

There are other gases which occur only very rarely such as ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and other heavier members of the methane or paraffine series which are components of natural gas. These gases are sometimes found in small quantities in connection with methane in gases from mine fires and explosions. They tend to increase the explosibility but are usually not present in amounts large enough to be dangerous or even to be easily detected. However, when more than 1 percent is found in a mine, it is suggested that the surrounding area be examined for leakage from a gas or oil well. Air that contains from 3.2 to 12.5 percent of ethane is explosive.

1. PHYSICAL PROPERTIES OF GASES

a. SPECIFIC GRAVITY

Specific gravity is one of the most important of the physical properties of gases, or solids. It is defined as the relative weight of a substance as compared to some standard. For liquids and solids, water is taken to be the standard. For gases, air is taken for the standard.

SOLIDS

If a certain piece of coal is said to have a specific gravity of 1.5, it means that for a given volume, such as a cubic foot, the coal will weigh 1.5 times as much as the same volume of water.

Since a cubic foot of water weighs approximately 62.5 pounds, a cubic foot of solid coal with a specific gravity of 1.5 will weigh 1.5 x 62.5 or 93.75 pounds. Consequently, a ton (2000 pounds) of solid coal with a specific gravity of 1.5 will occupy 2000 divided by 93.75 or 21-1/3 cubic feet.

GASES

Since gases are very light compared to water it would not be satisfactory to give their specific gravity as compared to water; therefore, the specific gravity of gases is always given with air as the standard of comparison. Thus, if it is said that carbon dioxide has a specific gravity of 1.53 it is meant that a given volume of it is 1.53 times as heavy as the same volume of air at the same temperature and pressure.

In considering the specific gravity of gases it is very important to remember that the figures given for specific gravity are true only when the air and the gas are at the same temperature and when their pressure is the same. It is common knowledge that gases expand when heated and contract when cooled, so it is very possible that a gas which is heavier than air under the same conditions of temperature may be lighter than air if heated sufficiently.

While it is safe to say that the weight of a cubic foot of water is approximately 62.5 pounds because the weight of water does not vary much at ordinary temperatures, yet it is impossible to give an average figure for the weight of a cubic foot of air because its weight changes rapidly with variations in temperature and pressure of the atmosphere. As an example; however, the approximate weight of a cubic foot of pure, dry, air at 62 degrees and a barometer reading of 30 inches is 0.076 pounds, or about an ounce and a quarter.

The following table gives the specific gravity of the important mine gases:

NAME	CHEMICAL FORMULA	SPECIFIC GRAVITY
Oxygen	O	1.105
Nitrogen	N	0.967
Carbon dioxide	CO_2	1.529
Carbon monoxide	CO	0.967
Methane	CH_4	0.555
Acetylene	C_2H_2	0.906
Hydrogen	H	0.070
Hydrogen sulphide	H_2S	1.191

b. DIFFUSION

Diffusion of gases may be defined as the gradual mixing of two or more gases which are in contact. This mixing is not dependent on the specific gravity of the gases, for if we fill a jar with a heavy gas like CO_2 and another jar with a light gas like N and then bring the mouths of the jars together, the jar containing the N being on top, we shall find that in a comparatively short time the two gases have become thoroughly mixed and the composition of the gas in each jar will be exactly the same; that is, 50 percent CO_2 and 50 percent N. After gases have become mixed by diffusion they will not again separate. This property of diffusion is what makes possible the efficient removal of gases from mines. If, for example, methane, which is only about half as heavy as air, would always stay at the roof and not become mixed with and swept away by the air current we would have a dangerous condition continually present.

The rates at which gases diffuse has no practical value to the coal miner; it is sufficient to know that gases will mix when in contact, and also that the speed of mixing can be very greatly increased by mechanical means, such as an air current that has a good velocity.

c. OCCLUSION

Occlusion means the absorption of gases by solids. Some substances have the power to absorb many times their own volume of gases. It is stated that very porous wood charcoal, for example, will absorb possibly more than a hundred times its own volume of various gases.

The significance of occlusion as a subject of interest to the coal miner is that coal occludes gas, mainly methane, which was developed long ago from coaly matter and is held within the coal itself. Tests show that the total volume of gas occluded in the coal may be equal up to two times the volume of the coal itself.

E. MINE GASES DEFINED

Mine gases have a definite chemical formula but many of them are referred to as "damps" by a majority of the coal miners.

1. OXYGEN

Chemical symbol - - - - - -	O
Specific gravity - - - - -	1.105
Is it combustible - - - - -	No
Will it support combustion	Yes
Will it support life - - -	Yes
Is it poisonous - - - - - -	No
Color - - - - - - - - - - - -	None
Odor - - - - - - - - - - - -	None
Taste - - - - - - - - - - - -	None

As has been previously mentioned, oxygen is the most important gas there is, for it is absolutely necessary to support life and to support combustion.

Most miners know that some mine fires have to be sealed off in order to extinguish them; the reason that they are extinguished by this means is due to the fact that the seals prevent fresh air reaching the fire and the coal in the sealed off area absorbs the oxygen from the enclosed air and the lack of oxygen prevents the fire from burning.

It has been shown that mine air may contain anywhere from 20.94 percent of oxygen down to almost none at all. The effect of a reduction in the amount of oxygen as given by Haldane, the eminent English chemist, shows that a decrease from 20.94 to 15 percent oxygen by volume has practically no effect on man; however, a candle or wick fed flame is extinguished. As the decrease of oxygen proceeds further, certain effects begin to be noticed; such as, the breathing becomes deeper and more frequent, the pulse more frequent, and the face somewhat dusky. As the percentage of oxygen gets lower the symptoms are more pronounced, and a person's life becomes in great danger.

While the reduction of a few percent in the amount of oxygen present in the air has little effect on man, yet the effect on a flame of a lamp is very noticeable. When the percentage has fallen to 19 it has been found that the light given by a safety lamp is only about one-third of the amount usually emitted when the lamp is burning in pure air.

It should be mentioned that the effects here discussed are based on the supposition that there are no other poisonous or semipoisonous gases present, but that the decrease in the amount of oxygen is the only change from normal air.

2. NITROGEN

Chemical symbol - - - - - -	N
Specific gravity - - - - -	0.967
Is it combustible - - - - -	No
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - - -	No
Color - - - - - - - - - - - -	None
Odor - - - - - - - - - - - -	None
Taste - - - - - - - - - - - -	None

As mentioned before, nitrogen forms about 80 percent of the atmosphere. We know from actual experience that nitrogen has no color, taste, or odor, and that it is therefore impossible to detect it by our senses. In fact, it serves simply to dilute the oxygen of the air so that combustion will not take place so rapidly and so that we are not injured by breathing pure oxygen continuously.

There is no simple test for nitrogen. If a safety lamp burns dimly or goes out it is certain that the air does not contain the normal amount of oxygen. When this happens it is possible that the air does contain a higher percentage of nitrogen than the normal 80 percent; however, other gases present in the air can also give this same impression.

From a practical point of view, since nitrogen forms such a large part of the atmosphère, we can assume that the mine air contains at least 79 percent nitrogen.

3. METHANE

Chemical symbol - - - - - - -	CH_4
Specific gravity - - - - - -	0.555
Is it combustible - - - - - -	Yes
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - -	No
Color - - - - - - - - - - - - - -	None
Odor - - - - - - - - - - - - - -	None
Taste - - - - - - - - - - - - - -	None

Methane or marsh gas, commonly called fire damp or just simply gas, is also known as light carburetted hydrogen and is found in all coal mines. It may be safely asserted that chemical analysis will prove its presence even in a mine where traces of methane have never been found by the workers. Its chemical formula is CH_4 denoting that it is a chemical compound made up of one atom of carbon combined with four atoms of hydrogen. When vegetable matter decomposes under water, as at the bottom of a stagnant pond or march, methane is formed. This is the reason that it is some times called marsh gas. It is found in large quantities in coal seams, because coal represents the remains of plants that grew many years ago.

This gas escapes from coal by coming through the very small spaces or pores between the coal grains and through very small fissures or cracks. Very often, in mining gaseous coal, the gas issues from the fresh working face through many small fissures with a hissing sound. Such large flows of gas are called "blowers" or "feeders".

Methane is the only inflammable gas coming from coal. Since it is only about half as heavy as air, it has a tendency to be found in rise workings and in holes or cavities in the roof. If the gas is given off in the upper part of the coal seam it will usually take a longer time to mix with the air than if given off from the bottom. When given off near the floor it tends to rise quickly, since it is so much lighter than air, and therefore diffusion takes place easily.

Always remember that a good air current greatly assists in the diffusion of methane and all other gases, and that if there is a brisk air current the tendency of gases to stratify on account of their specific gravities is of no importance.

Methane is a combustible gas, that is, it will burn. If mixed with air in proper proportions the burning will be so rapid that the flame will spread to all parts of the mixture very quickly. Very rapid combustion is called an explosion. It has been found by experiment that when mixtures of air and methane containing from 5 to 15 percent of CH_4 and 12.1 percent or more of oxygen are ignited, an explosion will result. These percentages of CH_4 are known as the lower and upper explosive limits. Near the lower limit the explosion is not as violent; however, when about 9 percent of methane is present in the mixture the explosion will be the most violent. The reason for this is because that mixture has just enough oxygen to burn all of the methane almost instantaneously. Methane can not be ignited unless heated to about 1000 degrees Fahrenheit. If it is cooled below this point the flame will be extinguished.

It should be noted that while a mixture of air and methane is not explosive until 5 percent of CH_4 is present, yet experiments have shown conclusively that the presence of less than this amount of methane greatly increases the chances of a dust explosion. In other words, 1 or 2 percent of methane, with fine coal dust suspended in the air, may mean an explosive mixture.

While methane is combustible, yet it will not support combustion, because it contains no oxygen. If a safety lamp is suddenly raised into a hole in the roof which is filled with methane, the light will be extinguished on account of lack of oxygen. However, although methane will not support life, it has no poisonous effects. Experiments have been made in which men breathed a mixture containing a high percentage of methane, with sufficient oxygen, without any harmful effects.

Methane can not be detected by the physical senses, for it has neither taste, color, nor odor. The miner who foolishly trusts to his sense of smell to warn him of the presence of "gas" or methane not only endangers his own safety but that of all the men in the mine. The easiest and best way to detect the presence of methane is by observing the effect produced on the flame of a flame safety lamp. Methane burns with a pale blue flame, and if the wick of the safety lamp is turned down until all the yellow color has disappeared there will be noticed a "gas cap" above the lamp flame if sufficient CH_4 is present in the air. The height of this cap is a measure of the amount of methane present. The presence of gas is also indicated by the lengthening of the normal walking flame of the safety lamp.

a. FIRE DAMP

Any inflammable or explosive mixture of mine gases and air is usually referred to by miners as fire damp. This is the same thing that is referred to as gas.

4. CARBON DIOXIDE

Chemical symbol - - - - - -	CO_2
Specific gravity - - - - -	1.529
Is it combustible - - - - -	No
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - - -	No
Color - - - - - - - - - - - -	None
Odor - - - - - - - - - - - -	None
Taste - - - - - - - - - - - -	An acid taste when moist and present in considerable quantity.

The carbon dioxide found in the return air of a coal mine comes from several sources. It is one of the gases given off by the coal, it is formed by the breathing of the men, it is always present in large proportions in the fumes of explosives, it comes from the decaying of timbers, it is formed by the action of oxygen on the carbon of the coal, and it is always a product of combustion, therefore, present after a mine fire or explosion.

While carbon dioxide is said to have an acid taste when moist, yet it must be present in considerable amount for this taste to be noticeable. The air we breathe out from our lungs contains about 4 percent CO_2, and yet we never are conscious of an acid taste from this. It is seldom that as much as 4 percent will be met with in a coal mine, so that the sense of taste can not be relied upon as a detector.

Carbon dioxide may be said to be the regulator of our breathing. An increase in the amount of carbon dioxide breathed results in an increase of breathing. When about 3 percent is present breathing will become noticeable deeper and more frequent. At about 5 or 6 percent there is marked panting and a more rapid pulse. At 10 percent there is violent panting, throbbing, and flushing of the face. Headache is also produced, noticed especially on the return to fresh air. With from 12 to 15 percent the patient soon becomes unconscious.

It is often stated the carbon dioxide is the gas that dims and puts out lights. This is not true; for, providing sufficient oxygen is present, the carbon dioxide has practically no effect in extinguishing the flame. A lamp, therefore, is not an indicator for carbon dioxide.

Since carbon dioxide is more than one and one-half times as heavy as air, it has a tendency to collect at the floor and in dip workings. Being a heavy gas, it diffuses much more slowly with the air than a lighter gas and requires a ventilating current with a good velocity to assist the diffusion and sweep it away.

a. BLACK DAMP

Black damp has been generally taken to mean carbon dioxide by most miners, but as Haldane, an English chemist, first pointed out, it is really a mixture of nitrogen and carbon dioxide. It is called black damp because it extinguishes a lamp. The extinctive effect of black damp is not due to the carbon dioxide which it contains, but rather to the fact that so much oxygen has been taken from the air that there is insufficient remaining to cause the lamp to burn.

The amount of black damp present in mine air is variable. Some will always be present. The atmosphere in a mine which has been sealed up for a few months may consist almost entirely of black damp, because practically all the oxygen has been absorbed by the coal. Average black damp is usually considered to be from 10 to 15 percent carbon dioxide and from 85 to 90 percent nitrogen.

It is difficult to give definite figures for the effects of black damp, for other gases such as CH_4 may be present and vary the figures. In general, it may be said that if no methane is present 10 percent of black damp will dim a lamp considerably.

The specific gravity of black damp is not constant, but will vary according to the relative proportions of N and CO_2. It is possible for it to have a specific gravity slightly less than 1, so that black damp may sometimes be found near the roof.

The presence of a considerable quantity of black damp does not necessarily mean that the mixture will not explode. It has been found by experiment that atmospheres containing only 13 percent of oxygen may be explosive when enough methane is also present.

4. CHOKE DAMP

Choke damp is approximately the same as black damp except that it probably contains a higher percentage of carbon dioxide than usually found in black damp. The name origninated in England.

5. CARBON MONOXIDE

Chemical symbol - - - - - - -	CO
Specific gravity - - - - - -	0.967
Is it combustible - - - - - -	Yes
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - - - -	Yes
Color - - - - - - - - - - - - -	None
Odor - - - - - - - - - - - -	None
Taste - - - - - - - - - - - -	None

Carbon monoxide, known to most coal miners as white damp, is also sometimes called carbonic oxide gas. Its chemical formula is CO, which indicates that it is composed of one atom of carbon united with one atom of oxygen.

Carbon monoxide is always formed as the product of incomplete combustion. It is produced by mine fires and explosions, and also, by the explosion of black blasting powder, permissibles, and dynamite. In all of these cases the reason for the production of CO is that there was not sufficient oxygen present to completely burn the carbon.

Carbon monoxide is combustible because, since it is the product of incomplete combustion, it can still take up more oxygen and burn to carbon dioxide.

Since carbon monoxide is a gas that will burn, it will also explode under certain conditions. It has been found that mixtures of air and CO containing from 15 to 73 percent carbon monoxide are explosive. Explosions of such mixtures are uncommon in mines, because CO is not often found in any considerable quantity. However, a mixture of CO and air containing less than 15 percent of CO may become explosive by the addition of Methane.

Practically the only poisonous gas with which a coal miner is concerned is carbon monoxide. Even minute percentages will produce harmful effects if breathed for a few hours. Dr. Haldane states that a man at rest and breathing air containing only 0.1 percent CO would be unable to walk in about two and one-fourth hours, while if he was walking instead of resting his legs would give way in about an hour.

When breathed in larger quantities, a person may be overcome almost instantaneously. The CO acts without warning and cases are on record where men have simply fallen in their tracks on walking into an atmosphere containing considerable CO from an explosion or fire. In air containing about 0.5 percent CO unconsciousness would occur after a few breaths had been taken.

Men overcome by carbon monoxide generally have more color than usual on account of the blood being made a brighter red by the gas. Artificial respiration should be given promptly, and pure oxygen administered if any is at hand, for the pure oxygen will displace the CO in the blood five times as fast as normal air.

Carbon monoxide burns with a pale blue flame. The flame above a fire of anthracite or coke is due to the burning of CO. Many persons have thought that the presence of CO could be detected by a safety lamp in the same way that methane is detected. It is absolutely impossible to detect the presence of CO in mine air by the cap on the flame of a safety lamp, for no cap can be seen unless more than 1 percent of CO is present, and if this much were present the miner making the test would be instantly overcome and death would ensue.

When modern CO detectors are not available, small birds such as canaries can be used as a working test for CO. They will exhibit signs of distress and usually fall from their perch before sufficient CO is present to affect a man.

Another source of carbon monoxide should be mentioned very emphatically, the exhaust gases from gasoline engines. These gases, whether from automobiles, gasoline locomotives, or gasoline engines used to operate underground pumps or fans, contain a high percentage of CO.

a. WHITE DAMP

The same as carbon monoxide, that is a mixture of carbon monoxide and air. Probably its association with steam and light-colored smoke in fumes from mine fires led to its being popularly termed white damp.

b. AFTERDAMP

Afterdamp is any mixture of gases resulting from a mine fire or explosion. It may contain nitrogen, oxygen, carbon dioxide, carbon monoxide, methane, hydrogen, hydrogen sulphide, etc.

6. HYDROGEN SULPHIDE

Chemical symbol - - - - - - H_2S

Specific gravity - - - - - -	1.191
Is it combustible - - - - - -	Yes
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - - - -	Yes
Color - - - - - - - - - - - - - -	None
Odor - - - - - - - - - - - - - -	That of rotten eggs.
Taste - - - - - - - - - - - - - -	It is slightly sweetish.

Hydrogen sulphide or sulphuretted hydrogen is called stink damp by the miners, due to its very disagreeable smell. Being readily soluble in water, it is sometimes given off by stagnant water. It is occassionally detected in very small quantities in afterdamp from coal dust explosions. It is sometimes found dissolved in mineral waters, and in some cases such underground waters seep into the mine and give off their hydrogen sulphide.

Hydrogen sulphide ignites at 500 degrees Fahrenheit and burns with a bluish flame, but although combustible it will not support combustion or life. When H_2S burns, the hydrogen unites with oxygen to form water and the sulphur forms sulphur dioxide by its union with oxygen.

It is fortunate that hydrogen sulphide is seldom found in coal mines in dangerous quantities, as it is extremely poisonous. When only 0.05 percent of the gas is present alarming symptoms such as giddiness, vomiting, etc. are quickly produced, and Lehmann states that air containing 0.07 percent is sufficient to cause death in an hour.

It is easy to detect hydrogen sulphide by its unmistakable odor. Even very minute quantities can be detected by the sense of smell.

a. STINK DAMP

Stink damp is a mixture of hydrogen sulphide and air.

7. ACETYLENE OR CARBIDE GAS

Chemical symbol - - - - - - -	C_2H_2
Specific gravity - - - - - -	0.906
Is it combustible - - - - - -	Yes
Will it support combustion	No
Will it support life - - -	No
Is it poisonous - - - - - - -	No
Color - - - - - - - - - - - - - -	None
Odor - - - - - - - - - - - - - -	A peculiar and characteristic one.
Taste - - - - - - - - - - - - - -	None

Acetylene is never found naturally in mines, but since it is used to some extent a miner should know its characteristics. Acetylene is a compound composed of two atmos of carbon and two atoms of hydrogen, C_2H_2.

The substance put into carbide lamps is known as "carbide" to the miner; but, it is actually CaC_2, calcium carbide. When the water from the lamp comes in contact with the CaC_2 a chemical reaction takes place, acetylene is generated, and the substance left in the lamp is slaked lime or CaO.

Acetylene ignites at 650 degrees Fahrenheit and burns with a brilliant flame and produces no smoke in a properly designed burner. It will, of course, not support combustion or life. It is not poisonous if breathed in small quantities, although suffocation would result if a very high percentage were breathed.

Acetylene has the widest explosive range of any of the gases ever met with in mines, that is, from 3 to 73 percent acetylene. If carbide is never permitted to be stored underground there seems little likelihood of sufficient C_2H_2 being generated to cause an explosion of any great consequence.

8. HYDROGEN

Chemical symbol - - - - - - - -	H
Specific gravity - - - - - - -	0.070
Is it combustible - - - - - - -	Yes
Will it support combustion -	No
Will it support life - - - -	No
Is it poisonous - - - - - - - -	No
Color - - - - - - - - - - - - - -	None
Odor - - - - - - - - - - - - - -	None
Taste - - - - - - - - - - - - - -	None

Hydrogen is the lightest gas known, being less than one-fourteenth of the weight of air. It is seldom met with in mines.

Occassionally small quantities are produced by blasting and from explosions. The most important source of hydrogen, as far as mines are concerned, is the charging of electric storage-battery locomotives. Here the passage of the electric current breaks down some of the water in the batteries into its two elements, hydrogen and oxygen.

Hydrogen burns with an almost colorless flame and produces a great deal of heat. When the mixture of air and hydrogen contains between 10 and 66 percent hydrogen the mixture is explosive.

While it will burn, it will neither support combustion nor life. It has no poisonous effect on the human system, although it could not be breathed in a pure state because suffocation would result. It has neither color, odor, nor taste, and there is no simple test for its detection.

9. OXIDES OF NITROGEN

Oxides of nitrogen are formed in mines by the burning, afterburning, and, under certain conditions, by detonation of high explosives. They can usually be detected by the "burned-powder" odor and may also be identified by the reddish color of nitrogen peroxide (NO_2) which is formed when nitric oxide (NO) comes in contact with air.

Oxides of nitrogen corrode the respiratory passages, and the breathing of relatively small quantities may cause death. Nitrogen peroxide probably is the most irritating of the oxides of nitrogen. Its effects on the respiratory passages usually are not noticed until several hours after exposure. 0.01 percent of nitrogen peroxide may cause dangerous illness if breathed for a short time, and 0.07 percent is fatal if breathed for about 30 minutes.

The specific gravity of nitrogen peroxide (NO_2) is 1.589.

When high explosives burn, high percentages of oxides of nitrogen may be formed; hence, gases from burning high explosives should not be entered without adequate respiratory protection.

When explosives having properly proportioned components are detonated they usually produce exceedingly small percentages of oxides of nitrogen, which are considered harmless; however, "shucked" (wrapper removed from cartridge) explosives may produce harmful percentages of oxides of nitrogen, even when detonated; hence explosives should never be used with the wrapper removed in places where the gases can not be diluted immediately and adequately.

10. SULPHUR DIOXIDE

Sulphur dioxide (SO_2) is a colorless, suffocating, irritating gas, with a strong, pungent, sulphurous smell. It is sometimes given off by explosives, and may be present when there are gob fires in which iron pyrite is burning.

The specific gravity of sulphur dioxide is 2.264.

Sulphur dioxide is very poisonous, even when present in small percentages; however, it is so irritating to the eyes and respiratory passages that it is very noticeable before it reaches concentrations that are dangerous.

F. METHODS FOR DETECTION OF MINE GASES

Various methods and devices are in use for detecting mine gases. However, accurate means for detecting oxygen, carbon dioxide, methane, carbon monoxide, and probably hydrogen sulphide are the most important during both normal mining conditions and rescue and recovery operations.

Other gases that may be found in mines, such as oxides of nitrogen, sulphur dioxide, etc., usually occur in small quantities and unless present in amounts large enough to be detected by smell require collection and the analysis of air samples. The collection and analysis of these gases requires special processes entirely different from the usual procedure; therefore, a chemist of considerable experience should perform the work.

1. METHANE DETECTORS

Because of the wide occurrence and dangerous characteristics of methane, the detection and determination of the amount present in mine air is vitally important during both normal operating conditions and abnormal conditions following mine fires and explosions.

a. FLAME SAFETY LAMP AS A DETECTOR

For the use of a flame safety lamp please refer to Section 1, part E-1.

b. ELECTRIC METHANE DETECTORS

There have been several of these detectors developed and approved by the United States Bureau of Mines; however, some of them are now out-dated, but will nevertheless be mentioned.

BURRELL METHANE DETECTOR

This detector is a simple device that will quickly and with reasonable accuracy determine small quantities of methane in mine air. The detector is essentially a water filled U-tube, one end of which terminates in a gas reservoir or combustion chamber and the other end in a gage glass having a calibrated scale. To make a test, water is forced into the gas reservoir and also up into the valve cup by blowing into the rubber tube that is connected to the opposite arm of the U. When the water is allowed to return to its original position, it draws a measured sample of mine air through the valve into the combustion chamber. The level of water always returns to the same mark on the gage glass and therefore defines the volume of the sample taken. The valve is closed and the methane burned out of the sample by closing a switch and electrically heating a platinum glower. The contraction in volume after burning, which results if methane is present, is shown by the new position of the water level in the gage glass next to the scale; this indicates the percentage of methane in the sample.

U. C. C. METHANE DETECTOR

This detector is essentially a portable wheatstone bridge, one arm of which includes a heated platinum filament. This bridge, with its meter adjusted to zero in air, becomes unbalanced when in a combustible gas due to the effect of the burning of the gas on the surface of the heated filament, which increases the temperature and resistance of the filament proportional to the percentage of the gas present.

The change in the resistance of the filament causes a deflection of the needle of the meter in the bridge circuit. The meter scale, graduated from 0 to 7 percent, is calibrated to show directly the percentage of methane present.

M.S.A. (Mine Safety Appliances Co.) METHANE DETECTOR (AP-6)

The operation of this detector is based on the burning of the methane on the surface of a platinum wire filament heated to a definite initial temperature by the current from a cap lamp battery. When air containing methane is brought in contact with the platinum wire filament the gas burns, thus increasing the temperature of the wire and its electrical resistance. The increase in resistance is in proportion to the amount of methane in the sample and is measured by a milliameter, the scale of which is calibrated to give accurate readings in direct percentage of methane.

Two calibrated scales are used on the indicating meter. These are provided as an aid in more accurately reading low percentages of methane. One scale is graduated in 40 divisions (each being 0.05 percent), from 0 to 2 percent. The second is graduated in 30 divisions (each being 0.10 percent), from 2 to 5 percent.

M.S.A. METHANE DETECTOR TYPE W-8

This detector employs a circuit, the basis of which is the wheatstone bridge. The detector unit has a filament of specially activated platinum, which is heated to a definite working temperature by the current supplied by a cap lamp battery. When air containing methane comes in contact with the activated platinum filament of the detector unit, the gas burns, thus increasing the temperature of the wire and its electrical resistance. The change of resistance unbalances the electrical circuit of the instrument. The amount of unbalance which is proportional to the amount of methane present, is indicated on a meter graduated directly in percentage of methane.

Two calibrated scales on the indicating meter are provided as an aid to more accurate reading of low percentages of methane. One scale is graduated in 40 divisions (each being 0.05 percent), from 0 to 2 percent; the second is graduated in 30 divisions (each being 0.10 percent), from 2 to 5 percent.

M.S.A. METHANE DETECTOR TYPE E-2

The electrical circuit of this detector is a balanced electrical bridge, of which the electrically heated platinum filament unit forms a part. The current is supplied by a cap lamp battery. The burning of methane on the activated filament increases both its temperature and its electrical resistance, thus unbalancing the circuit. The degree to which the circuit is unbalanced is proportional to the amount of methane in the sample and is measured on a meter scale calibrated to read directly in percentage of methane.

The scale range is from 0 to 5 percent, with more than one-half of the scale graduated from 0 to 2 percent in 0.2 percent divisions and the balance of the scale is marked in 0.5 percent divisions.

M.S.A. METHANE ALARM

This is an instrument that gives warning to the miners when a dangerous percentage of methane is present in the mine air. It is operated from a self-contained battery (the same type battery that is used for the cap lamp).

It samples the mine air continuously and when any sample shows a dangerous concentration of methane gives a warning in the form of a flashing red light.

2. CARBON MONOXIDE DETECTORS

Because of the dangerous characteristics of carbon monoxide, means for its detection are vitally important both during normal mine operations and following mine fires and explosions.

It is also valuable to mining men to be able to determine the amount of carbon monoxide in the mine air. There are numerous occasions during known or suspected mine fires and after the sealing of mine fires when a method for accurately showing low percentages of carbon monoxide is of utmost importance. Many incipient mine fires could be prevented from reaching serious proportions, with consequent loss of property and even of lives, if an efficient means of detecting low percentages of carbon monoxide is employed. The presence of carbon monoxide in the return airway of a mine is almost a sure indication of fire. Several mine disasters have caused loss of life because sealed fire areas have been opened before the fire was completely extinguished. Some of these might have been prevented had the composition of the air behind the seals been determined, especially as to its carbon monoxide content.

a. SMALL BIRDS AND ANIMALS

The use of small birds and animals, especially canaries and mice, has long been recognized as a means of detecting carbon monoxide; small animals are not, however, safe indicators of oxygen-deficient atmospheres, as some small animals thrive in atmospheres where the oxygen content would cause death to human beings.

Tests show that small animals may be used repeatedly in mines to indicate that carbon monoxide is present without danger of losing their susceptibility to that gas. Canaries are by far the best of all the live detectors tested, as mice, which are the next best, are difficult to manage and have other undersirable characteristics. Canaries usually show symptoms of distress sooner than other small animals; they are easily obtainable, and if intelligently handled seldom die as a result of exposure to atmospheres containing carbon monoxide.

Numerous tests with small animals have shown them to rank about as follows as regards to susceptibility to carbon monoxide poisoning:

Canary - - - first
Mouse - - - second
Chicken - - third
Small dog - fourth
Pigeon - - - fifth
English sparrow - sixth
Guinea pig - seventh
Rabbit - - - eighth

However, even these at times may be unreliable as indicators of CO.

b. IODINE PENTOXIDE (HOOLAMITE) DETECTOR

Please refer to Section 1, part E-3 for information about this carbon monoxide detector.

c. M.S.A. COLORIMETRIC CARBON MONOXIDE DETECTOR

The basis of this detector is the replaceable indicator tube which contains a yellow impregnated silica gel.

In use, the sealed ends of a detector tube are broken and the tube is inserted in the tube holder. An air sample, controlled by a specially designed metering orifice, is then aspirated through the tube. When the air contains carbon monoxide, the yellow silica gel turns to a shade of green, the intensity of which indicates the concentration of carbon monoxide.

Mounted beside the detector tube is a color scale. The varying shades of green shown on the scale are easily distinguishable and the comparable carbon monoxide concentrations which they indicate are clearly marked in percentages.

The detector is capable of indicating the presence of carbon monoxide in air from 0.001 to 0.10 percent by volume.

d. M.S.A. HAND-OPERATED CARBON MONOXIDE INDICATOR

Precise indications of carbon monoxide anywhere in a mine is possible by this indicator, without connections to batteries or any outside power source. This instrument is safe to use even where flammable gases may be present.

The air sample first passes through a dehydrating canister which removes any moisture. From the canister, it enters the cell containing a catalyst known as "Hopcalite", and then passes through the pump and out the exhaust valves. In the cell, carbon monoxide is oxidized to carbon dioxide by the catalytic action of the Hopcalite. Heat, liberated by this oxidation, is directly proportional to the amount of carbon monoxide present, and is measured by differential thermocouples in series with the indicating meter.

The percentage of carbon monoxide, if any, in the atmosphere under test is indicated on a direct reading calibrated meter, which has a scale range from 0 to 0.15 percent carbon monoxide. The meter can be read directly to 0.005 percent and estimated to 0.001 percent.

3. HYDROGEN SULPHIDE DETECTOR

The method of detecting hydrogen sulphide by sense of smell is lost in from 2 to 15 minutes of exposure in an atmosphere containing from 0.01 to 0.015 percent hydrogen sulphide; therefore, some other means of detection must be used.

a. M.S.A. HYDROGEN SULPHIDE DETECTOR

This detector consists of a small inlet metal barrel corrugated on the end to permit a rubber tube to be attached, to which is attached a rubber aspirator bulb, a movable scale, and a tube containing a white granular chemical.

The chemicals used in the hydrogen sulphide detector tubes consist of silver cyanide ($AgCN_3$) on activated alumins (Al_2O_3). The reaction of the silver cyanide in the presence of hydrogen sulphide turns the white granules to a dark gray, beginning at the end where the sample enters.

It should be noted that when the detector is used in the presence of hydrogen sulphide, hydrogen cyanide (HCN) is liberated. As this is a very deadly gas some anxiety may be felt regarding the use of the detector, particularly where there is little or no air movement; however, the amount of hydrogen cyanide liberated is so small that the amount that could be formed by an entire tube is harmless, even if the user inhaled the entire amount.

4. OXYGEN DETECTOR

The detection or determination of the amount of oxygen in mine air may be of considerable importance during both normal operating conditions and after mine fires or explosions.

An accurate determination of the amount of oxygen in mine air can only be made by collecting and analyzing air samples; however, it is obviously that this cannot be used when immediate information is desired.

The only device known that can be used with relative safety underground for immediate detection of the presence of enough oxygen to support life safely is the flame safety lamp, and it has definite limitations. In the hands of an experienced user, the action, color, and illuminating power of the flame of a flame safety lamp indicates roughly the amount of oxygen within a range of 20.94 percent to 16.25 percent when the flame will be extinguished by lack of oxygen.

The extinguishment of the flame of the lamp because of insufficient oxygen furnishes no information as to how much less than 16.25 percent may be present. Consequently, no one should work or remain where a flame safety lamp will not burn unless adequately protected with self-contained oxygen breathing apparatus.

5. CARBON DIOXIDE DETECTOR

The only method for the absolute detection of carbon dioxide is the collection and analysis of a sample of mine air. However, a deficiency of oxygen can be detected to a certain extent with a flame safety light down to 16.25 percent oxygen at which time the light will go out.

6. SULPHUR DIOXIDE DETECTOR

The maximum allowable concentration of sulphur dioxide gas for working atmospheres is approximately 10 ppm (parts per million) for an 8-hour exposure.

The M.S.A. sulphur dioxide gas detector consists of an aspirator bulb which will draw air through the replaceable sampling tube attached. Any sulphur dioxide in the air will turn the reagent granules in the sampling tube white. The length of travel of this discoloration is proportional to the percentage of concentration of the SO_2. The scale, attached next to the sampling tube, is graduated from 0 to 50 ppm.

G. PROTECTION AGAINST MINE GASES

In mines operating under normal conditions the best method of protection against mine gases is adequate ventilation to dilute them below a dangerous proportion and remove them.

Under abnormal conditions, as during mine fires and following explosions, gases and atmospheres depleted of oxygen may be encountered.

There are generally four methods used for protection against carbon monoxide and other mine gases; however, all of these are not useful in atmospheres deficient in oxygen. These methods and devices are not all adapted for use under all circumstances, each one having a field of its own. The methods and devices are as follows:

1. Erection of baricades
2. Self-rescuer
3. Self-contained oxygen breathing equipment
4. Gas masks for protection in air against all gases, smokes, and vapors.

For the purpose of this section detailed information will not be given for the use of these devices and equipment used for the protection against mine gases. This detailed information will be found in later sections.

SECTION 4 COAL MINE EXPLOSIONS

A. GENERAL

The lives of all the men working in a mine at the time of an explosion or fire may be endangered. In addition to this danger to the men, property damage and loss of production are also very likely to occur. In some cases the destruction of property has been so great that the mine was never reopened.

There are many things which the mine owners, mine managers, and the mine workers can do to help eliminate the causes of mine explosions and fires; however, it is almost impossible to completely eliminate these causes because of the inherent dangers which exist in the mining of coal.

Coal mine owners or operators are largely responsible for the prevention of explosions; however, the mine workers have caused many explosions by unsafe practices and careless acts. The causes of such disasters should be known by everyone connected with the mining of coal so that they will recognize any dangerous conditions which exist and also so that they will take whatever precautions that are possible to help prevent explosions.

Explosions in coal mines are sometimes classified as (1) gas explosions, (2) coal-dust explosions, or (3) a combination of gas and dust explosions.

B. GAS (Methane) EXPLOSIONS

A combination of the following three factors are necessary to produce a gas explosion in a coal mine: (1) sufficient oxygen in the air, (2) 5 to 15 percent of methane in the air, and (3) a source of ignition. If a variation occurs in any one of these three factors it is quite likely that an explosion will not result even though the other two factors are "right" for an explosion.

1. EXPLOSIVE LIMIT OF METHANE AIR-MIXTURES

The explosive limits of a methane-air mixture are usually given as 5 and 15 percent methane with the maximum violence occuring at about 9.4 percent methane; however, it has been found by experiments that certain factors change these limits to an extent.

It has been stated by J. S. Haldane that a mixture of air containing 7.5 percent methane would explode violently at atmospheric pressure (30 inches of mercury) but would not explode when the pressure was reduced to 8 inches of mercury.

G. A. Burrell found that if a mixture of methane and air was heated to 500° C. the lower explosive limit was between 3.75 and 4 percent methane.

It has also been found that the presence of carbon dioxide effects the explosive range of methane. If the percentage of oxygen remains the same, an increase in the percentage of carbon dioxide will shorten the explosive range, that is, raise the lower limit and reduce the upper limit with the upper limit being reduced more than the lower limit is raised.

The decrease in the percentage of oxygen also influences the explosive range of a methane-air mixture, that is, if the percentage of oxygen is reduced the explosive range of methane is also reduced until at 12 percent oxygen the methane-air mixture will not explode.

2. TEMPERATURE OF IGNITION

The source of ignition is heat; it must be hot enough and last long enough to ignite the methane-air mixture. This heat cannot be dark heat but must be an open flame, such as a match or a carbide light; an electrical arc; or a spark, such as might be produced by rocks striking one another during a fall of roof.

The temperature of this heat must be at least 588° C. or about 1000 degrees Fahrenheit or it will not ignite the methane in the air.

C. COAL-DUST EXPLOSIONS

Coal dust by itself can cause explosions even when the atmosphere contains no methane; however, methane in mine air not only increases the possibility of dust explosions but also greatly increases the violence of dust explosions.

Coal dust is explosive only when raised as a dense cloud in air, and a certain minimum concentration in the cloud must be reached or exceeded before flame will ignite it. To start a dust explosion the cloud need not be large, but it must be dense surrounding the ignition source; however, once ignited the pressure produced raises additional dust in advance of the flame and thus carries along or propagates the explosion.

Tests have shown that all coal dusts, except anthracite dust, if suspended in a dense enough cloud can be ignited and may produce a violent explosion.

1. FACTORS INFLUENCING DUST EXPLOSIONS

Generally there are seven factors that influence dust explosions in a coal mine, these are:

1. SIZE OF THE COAL DUST PARTICLES;

   As the coal dust becomes finer the surfaces exposed for reaction with the oxygen of the air is increased; thus, the finer the coal dust, the more explosive it is. In tests, it has been shown that any bituminous coal dust that is finer than 20-mesh (0.025inch openings) is explosive when in a dust cloud in air.

2. COMPOSITION OF THE COAL DUST;

   In a coal dust cloud, the higher the percent of incombustible material (such as rock dust) the less explosive the mixture. Tests have shown that when the incombustible part of coal dust is 65 percent or over the mixture will not explode.

   Also, the higher the percentage of volatile matter (gassy matter given off by the coal when heat is applied) in the combustible part of the coal dust the more explosive the mixture. Tests have shown that when the volatile matter is over 12 percent of the combustible part of a coal dust cloud, it is explosive.

3. METHANE OR GAS IN THE MINE AIR;

   The presence of a small percentage of methane in the mine air will increase the explosibility of the coal dust suspended in the air. The higher the percentage of methane, the more explosive the mixture.

4. QUANTITY AND CONCENTRATION OF THE COAL DUST;

   A very small quantity of an explosive coal dust mixture will propagate an explosion. On an average 0.05 ounces of coal dust per cubic foot of air space is a sufficient amount. Larger concentrations of coal dust will propagate more violent explosions.

   However, regardless of the quantity, the coal dust cloud must be very dense immediately surrounding the ignition source.

5. DISTRIBUTION OF THE COAL DUST;

   Dust on the ribs, overhead timbers, cribbing, and lagging is usually more dangerous than dust found on the bottom. There are generally two reasons why this is so; (1) the dust that settles on the ribs, overhead timbers, etc. is much finer; and (2) the dust on the bottom is usually diluted by shale, sand, and other impurities.

6. SOURCE AND TYPE OF IGNITION;

   The source that causes ignition may also be the agency that raised the dust from its resting place, such as a local gas explosion, or certain blasting powders. Also a match, open light, electrical arc, or a spark can ignite coal dust.

7. SURROUNDING CONDITIONS;

The character of the surfaces of the entries influences dust explosions. These surfaces may be coal or rock, hard or friable, wet or dry, rough, smooth, or timber lined. The condition of these surfaces will either add inert dust, add more fuel, or change the rate at which the heat is absorbed from the moving flame of the explosion.

D. PREVENTION OF COAL MINE EXPLOSIONS

Despite all efforts, gas and dust occasionally accumulate in coal mines. It is imperative, therefore, that good ventilation should be maintained, that the coal dust hazard should be minimized, and that ways and means should be devised to prevent all possible sources of ignition from coming into contact with explosive gas or coal dust.

1. ADEQUATE VENTILATION

Adequate ventilation is the foremost requirement in the prevention of a gas or coal dust explosion in a mine; it dilutes and makes harmless any methane that may be given off; it carries away coal dust thus preventing it from reaching a dangerous concentration.

2. USE OF WATER

Coal dust particles that are thoroughly wet will cling together, thus making the formation of a dust cloud difficult.

Water sprayed on the coal at the working face and at the loading points is most effective because it is here that most of the dust is formed. However, wet dusts are still nevertheless explosive. Water does not prevent an explosion if a coal dust cloud of sufficient concentration comes into contact with some form of ignition. Water prevents coal dust explosions only when it wets the dust enough to prevent its being raised into the air by a blast or concussion.

It is recommended that water be used on (1) the dust as it emerges from the various machines at the face, (2) the coal face before and after blasting, (3) the coal pile before and during loading, (4) the loaded and empty trips, (5) the coal at any transfer points, and (6) the face region, back to the last application of rock dust.

3. USE OF ROCK DUST

To help prevent or check mine explosions, all bituminous coal mines should use rock dust (incombustible). The value of rock dust application is based upon the fact that coal dust when mixed with sufficient incombustible dust will not explode, burn, or aid in propagating an explosion; and also, that dry, fine, incombustible dust suspended in air in a sufficiently dense cloud will tend to check and stop a coal dust explosion.

All mines should be kept thoroughly rock dusted in all open, unsealed places to within at least 40 feet of the face (water should be used in the remaining 40 feet). When rock dust is applied it should be distributed upon the top, bottom, and sides of all places and maintained in such quantity so that the incombustible content will not be less than 65 percent. When methane is present in the ventilating current, the 65 percent minimum incombustible content should be increased 1 percent for each 0.1 percent methane.

The first application of rock dust is not sufficient over a period of time as additional coal dust settles on top of the rock dust and before long there is not 65 percent incombustible material; therefore, rock dust should be applied over the entire mine at intervals ranging from 3 months to a year, depending on the amount of coal dust in the mine.

a. HOW AND WHERE TO ROCK DUST

Before rock dust is applied in a partly developed mine all accumulations of fine coal, as far as possible, should be loaded out, and the passageways should be sprayed with water. Rock dusting should begin in the sections of a mine where explosions would be most likely to originate, producing entries, generally, should be the first entries dusted. A mine should be rock dusted from the faces outward to the mine entrances and also inby as the faces advance. All crosscuts, rooms, pillar workings, and entries should be dusted to within 40 feet of the face.

Rock dust can be applied by hand or by air pressure machines that blow the rock dust through tubing; this tubing can be several hundred feet in length. If a mine has electric power available a portable rock-dusting machine has proven to be very convenient.

All men applying rock dust by hand or by machine should wear a dust respirator.

b. QUANTITY OF ROCK DUST APPLIED

The quantity of rock dust required in a mine will depend upon the amount of incombustible matter in the mine dust and the day-to-day possibility of coal dust deposition. A minimum of 65 percent incombustible should be maintained at all times, and an additional 1 percent rock dust should be applied for each 0.1 percent methane in the ventilating current.

Rock dust in excess of this minimum should be applied to eliminate the necessity of immediate redusting.

Usually 3 to 4 pounds of rock dust per linear foot of entry is the minimum to apply when first dusting.

c. SUITABLE ROCK DUST

Rock dust used in coal mines should have the following specifications:

> The dust to be used shall not contain more than 5 percent of combustible matter nor more than 25 percent of quartz or free silica; all of the dust shall pass through a sieve having 20 meshes per linear inch, and 60 percent or more shall pass through a sieve having 200 meshes per linear inch; the dust shall not absorb moisture from the air to such an extent as to cake and destroy its effectiveness as a dry dust. It should be light-colored so that accumulations of coal dust over it can be seen more readily. The rock dust should be prepared from limestone, gypsum, anhydrite, or shale, sufficiently free of silica.

4. ELIMINATE USE OF OPEN LIGHTS AND SMOKING

A great many explosions are ignited by open lights and smoking. Most mine explosions initiated by open lights have been methane ignitions; however, numerous ignitions of coal dust by open lights and electric arcs have been reported for mines in which methane was never detected, and dust explosions of considerable flame and violence have occurred in surface tipples where methane is not found.

It is recommended that all persons use only a permissible portable electric cap lamp. These lamps give a very good dependable light and they cannot ignite explosive gas or dust-air mixtures.

All smoking should be prohibited in every coal mine, regardless of whether it is gassy or not, or whether the coal dust is held to a minimum. Experience has shown that violations of this have been quite common and have caused numerous explosions and fires.

a. EXAMPLES OF EXPLOSIONS CAUSED BY OPEN LIGHTS AND SMOKING

A gas and coal-dust explosion that occurred in a mine resulted in the death of 74 men. Investigators concluded that the source of the explosion was a gas ignition by a carbide light.

21 men were killed and three injured by a gas and dust explosion. The section of the mine affected was examined for gas about 4 hours before the explosion and was found clear of gas. Subsequent investigation disclosed that the operator of a mining machine attempted to light a cigarette in a

place that had just been cut. Apparently, an accumulation of methane was ignited, and the initial explosion was propagated by coal dust. Rock dust had not been applied in the explosion area, and tests for methane were not made immediately before or after the place was cut.

5. USE OF PERMISSIBLE EXPLOSIVES

For blasting coal permissible explosives are recommended for use because they are less liable to ignite the explosive mixtures that may be found in coal mines.

Permissible explosives are those that produce a flame that is comparatively short in length and duration. They are designed especially to prevent ignition of gas or coal dust when blasting in coal mines. They should be used for all blasting in a coal mine regardless whether it is in rock or coal. Permissible explosives are compounded and prepared with certain dampening ingredients that shorten their flames and lower their combustion temperatures; however, they should not be fired in a place where methane can be detected with a flame safety lamp or where there is considerable coal dust.

An example of an explosion caused by the use of explosives is as follows:

> Six men were killed and five were injured by a dust explosion initiated by the firing of two mud-capped charges of 40 percent gelatin dynamite placed on a fall of sandrock. The shot firer prepared the two charges, using two sticks of dynamite for each. He covered the charges with clay, placed a large piece of shale on top, connected the detonators in series, and fired electrically. The liberal use of rock dust throughout the other parts of the mine prevented a widespread explosion.

6. SAFE USE OF ELECTRICAL EQUIPMENT

In mines where electricity is used to a great extent, it has caused the ignition of many gas and coal dust explosions. As the mechanization of coal mining increases so does the use of electricity; with this increase of electricity, the danger of a gas or coal dust explosion being ignited by an electric arc or spark is also increased.

Some of the ways in which electricity is responsible for the ignition of explosions and fires are such things as arcs or sparks from the electrical parts of cutting, drilling, and loading machines; trolley wires and other electric power conductors caught under falls of roof or ribs and short-circuited; sparks and arcs from trolley poles on electric locomotives; short-circuit of poorly insulated electrical conductors that pass through wooden doors and brattices; short-circuit or burning out of auxiliary fan motors placed underground; and many more such conditions that cause an electrical arc or spark.

It is recommended that all electrical equipment in a mine be maintained in as near perfect condition as possible so as to prevent any arcs or sparks. Also, all forms of electric conductors should be carefully inspected and maintained in excellent condition so as to prevent short-circuiting.

E. COURSE OF ACTION AFTER AN EXPLOSION (or fire)

When an explosion or fire occurs in a mine the first impulse of the survivors is to rush toward the nearest exit to get out of the mine. Ordinarily this is the best thing to do, but at other times it may be better to stay in a working place or some other suitable location.

It is very important that underground employees be familiar with escapeways, manways, and other exits in addition to those commonly used. Many lives have been lost unnecessarily in a disaster because workers did not know of an exit that they could have used.

A mine worker who has survived an explosion or mine fire has a choice of two ways of saving himself, (1) taking a chance of getting out of the mine through passageways in which the atmosphere is not contaminated with afterdamp or using a self-rescuer in passageways containing some contamination, and (2) erecting a barricade to keep out afterdamp and await restoration of normal ventilation and arrival of a rescue party.

1. SELF-RESCUER

The two main hazards that threaten the miner who has been entrapped behind a fire or survives an explosion are asphyxiation by carbon monoxide and suffocation from lack of enough oxygen to support life.

The purpose of the self-rescuer is to help miners escape at times of mine fire or explosion by providing temporary protection from carbon monoxide gas. It is actually a pocket-size gas mask containing the chemical known as "hopcalite".

The self-rescuer respirator removes the hazard of carbon monoxide for one-half hour or more and accordingly greatly increases the miner's chance of escape to the surface or to a portion of the mine that still contains fresh air.

However, the self-rescuer cannot and must not be worn where there is insufficient oxygen to support life. Generally though, there is enough oxygen during mine fires or after explosions to support life. This is indicated by the fact that flame safety lamps will usually burn in any section of a mine during recovery operations.

2. ERECTION OF BARRICADES

The decision of virtually sealing one's self in a mine after a disaster is difficult to make. In general, barricading after a mine fire should not be done except as the last resort when it is certain that escape from the mine is impossible; however, when the decision has been made to build a barricade, the men should retreat to a part of the mine where the air is still "good" and immediately start the erection of the barricade.

A barricade must be gas tight and include as large a territory as possible so as to provide the largest volume of uncontaminated air. It should not have any unsealed connections to the rest of the mine.

A barricaded area forms a refuge chamber for the men within, and the cubic content of the enclosed space determines the number of men and length of time they can safely remain there. In breathing, the men consume oxygen from the air and exhale an almost equal amount of carbon dioxide. Experiments have shown that a man in a confined space requires approximately 1 cubic yard of air per hour. At the end of an hour this cubic yard of air will contain about 14 percent of oxygen and 5 percent of carbon dioxide.

All open lights should be extinguished, (except one flame safety lamp) as these lamps consume oxygen. All but one or two electric cap lamps should be turned off to conserve the charge in the batteries of the other lamps. After the barricade is finished, the men should remain as quiet as possible because a man exerting himself uses about twice as much oxygen as when at rest; however, someone should walk around occasionally to mix the air.

Following is an example of how men can save their lives by barricading themselves in a place free from dangerous gases caused by an explosion.

At the time of the explosion in No15 mine at Eccles, W. Va., U. S. A., 74 men were in No 6 mine above it; of these men, 8 were overcome by afterdamp, 31 were rescued, and 35 saved themselves by retreating from the hot afterdamp to a sump room where they barricaded themselves off with brattice cloth.

SECTION 5 COAL MINE FIRES

A. GENERAL

Mine fires, second only to explosions, are the happenings most dreaded in coal mining. These fires can never be absolutely eliminated because of the highly combustible nature of coal, timber, explosives, and other materials usually abundant in coal mines. Most of these materials are more readily ignitible than the coal itself and often are the source of a mine fire that eventually spreads to the coal. Therefore, since fires are an ever-present hazard in coal mining, certain precautions must be taken to eliminate as far as possible those factors which cause a fire.

There will always be sources of ignition in a mine, and the danger of spontaneous combustion is always present, however, these hazards can be minimized by known means. Many of the measures recommended for the prevention of explosions will also aid in the prevention of fires, such as rock dusting and the wetting down of the coal.

The heat evolved from a fire liberates volatile constituents from bituminous coal that are flammable and explosive. A mine that under normal conditions does not liberate explosive gas may during a fire become an extremely gassy mine because of the distillation of the volatile constituents of the coal. When this happens, there is not only the danger of a gas explosion but the greater hazard that even a small gas explosion may ignite coal dust, or a fall of roof may throw a cloud of coal dust into the air which may come in contact with the flame of the fire and produce a widespread and destructive explosion.

Many mine fires can be extinguished in their early stages by direct attack with water, chemicals, rock dust, or sand. Failure to extinguish fires by direct attack usually is due to late discovery, lack of water or means of applying it promptly, lack of fire extinguishers or other facilities, and improper fire-fighting procedure. If a fire cannot be extinguished in a few hours by direct attack it generally is advisable to resort to some other method of handling the fire.

Mine fires should be sealed when progress cannot be made by fighting them directly or when other conditions, such as inaccessibility and probably accumulations of explosive gas, make sealing advisable.

The most common hazards in connection with mine fires are the asphyxiation of men by smoke and fumes, often in distant parts of the mine as well as in proximity to the fire; injury or death of men by falls of roof while fighting, sealing, or unsealing the fire; or ignition of an explosive mixture of gas or coal dust that may injure or kill underground workers.

It is far more hazardous work in fighting a fire than recovery work after an explosion; because, an explosion has usually done its harm while the mine fire may at any time cause an explosion or other dangerous condition with possible death to those engaged in fighting the fire.

B. CAUSES OF MINE FIRES

The primary causes of coal mine fires are electricity, open flames, explosives, friction, spontaneous combustion, and possibly incendiarism.

1. ELECTRICITY

The two primary electrical causes of mine fires are arcs and short circuits.

Arcs can come from the electrical parts of cutting, drilling, and loading machines; from trolley poles of locomotives; and from certain types of electric motors. Any of these can start a mine fire if the arc comes into contact with combustible material.

There are many sources of short circuits, all of which could start a fire if the short circuit occurs in a electrical conductor that was in contact with the coal, timber, brattice, track ties or other combustible material.

2. OPEN FLAMES

There are many cases on record where a mine fire has been started from an open flame. The use of carbide or other open lights have caused many of these. Others were started from a match which mine workers had used to light a cigarette or to relight a flame safety lamp which had gone out. Also, lighted cigarettes that had been thrown away have come into contact with the coal, paper, wood, or oily rags and started a fire.

3. EXPLOSIVES

Through the improper use of explosives the coal at the working face may be set on fire, particularly if the detonators are too weak. The use of a weak detonator may cause the explosive to burn and thus set fire to the coal.

Black blasting powder has caused many a fire because of the long-flame which is produced when the powder is exploded. Also, black blasting powder itself is easily ignited by an open flame and if the powder is not stored in a fire proof container it becomes another dangerous combustible material found inside of a mine.

4. FRICTION

This is not too common a source of mine fires, but nevertheless has been the cause of some.

The heat generated from the friction between a hoisting rope and a "frozen" roller has caused a fire. Also, a hoisting rope that is improperly guided and continuously rubbing on a mine timber may cause the wood to catch fire.

There are other cases where the heat developed by friction or a spark caused by friction has resulted in the combustible material in contact with the heat or spark to begin burning.

5. SPONTANEOUS COMBUSTION

Spontaneous combustion, or the heating of coal or waste material that burns easily, has long been known to cause underground fires. In some kinds of coal, especially when loose and finely divided, chemical changes occur that produce heat enough to cause a fire. It has been proven that the composition of coal has much to do with its liability to heat and take fire spontaneously; in some coals, heating will result and a fire occur if fine coal collects to small depths only. Waste timber, such as props and ties which may be partly or wholly covered with dust, and fine coal in the gob assist the spontaneous firing of the coal. Also, any greasy or oily rags greatly assist in causing spontaneous combustion.

6. INCENDIARISM

It has never been proved that any mine fires have been set intentionally; however, it has been suspected that several fires have started in this way. Therefore, in considering the various sources of mine fires, incendiarism can not be overlooked.

C. PREVENTION OF MINE FIRES

If the above listed causes of mine fires are carefully considered, it is seen that many mine fires can be prevented.

As the use of electricity increases in mining, so do the hazards of mine fires; therefore, proper safeguards and preventive measures must be used. Among these are the prevention of bare wires coming into contact with any combustible material, the use of permissible electric motors and maintaining these in a permissible condition, the use of battery locomotives in atmospheres where an arc from a trolley pole is liable to ignite a gas-air mixture, a careful and continuous check of all electrical conductors to be sure that the insulation is in good shape, and the general application of good mining practices.

Fires from open flames can be minimized by the use of battery powered electric cap lamps, the use of permissible flame safety lamps with a magnetic lock, the prohibiting of mine workers from carrying matches and smoking tobacco underground, and generally prohibiting the use of any open lights underground.

In shooting the coal only permissible blasting powder should be used, that is, a blasting powder with a short duration flame; and, only one hole should be fired at a time. The use of black blasting powder underground should be prohibited as it has caused many mine fires. The detonator used to detonate the permissible powder should be sufficiently strong so that the powder will not burn, but will explode.

Any hoisting cables that are used should be properly guided so that they do not rub on any timbers or other combustible material. All guides and rollers should be checked often enough to be sure that they are not "frozen"; thereby, causing friction between the guides or rollers and the hoisting cable.

In preventing fires from spontaneous combustion the best and most effective method is to have adequate ventilation to carry away any heat that is formed from the chemical reaction that takes place within the coal. Also, waste material such as old timbers, ties, oily or greasy rags, and papers should not be allowed to collect within a mine. Coal dust should never be allowed to accumulate, but should be loaded up and hauled to the outside.

D. FIGHTING MINE FIRES

There is no set pattern that can be followed in fighting mine fires. Almost all fires have their own characteristics and the plan of attack in getting the fire under control varies with each fire. All that can be given here is general recommendations for controlling and extinguishing a mine fire.

1. METHODS OF FIRE FIGHTING

The common methods of controlling and fighting mine fires are as follows:

a. Direct attack.
b. Enclosing the fire area with tight seals.
c. Flooding the fire area with water.

a. DIRECT ATTACK

Many mine fires have been extinguished immediately or very shortly after they have started with water, fire extinguishers, rock dust, or other smothering materials. This is by far the best method of fighting a mine fire; however, it is not always possible to extinguish a fire by direct attack. Failure to extinguish a mine fire by direct attack is generally due to late discovery; lack of water or other materials, equipment, or essential facilities; or improper procedure in the early stages of the fire.

WATER

An ample supply of water at the mine for fighting fires on the surface or underground is very desirable. Where the natural supply of water is small or non existant, provisions should be made to have a large quantity, say 10,000 gallons, stored to be used for emergencies only. This emergency storage should be located at a point where the water will flow by gravity to the mine and should be treated with calcium chloride to prevent the formation of ice.

If possible a mine should have a water pipe layed to each section with enough flexible hose in each section so that any part of the mine can be reached and sprayed with water when necessary.

Where a mine is not equipped with water pipes and hoses it is very important that water boxes be located through-out the mine especially near the face regions where many of the fires start. These can be mounted on wheels and pushed or hauled along the track to the fire, or they can be in the form of water barrels located at very regular intervals through-out the mine.

At all such water boxes or barrels two large buckets (2 gallon capacity) should be located to be used for fire fighting only. Also, if possible, a hand pump with 50 feet of flexible hose should be located in each section of the mine so that in the event of a fire the pump could be placed on the water box or barrel and water pumped on the fire.

FIRE EXTINGUISHERS

If it is not possible to have water available at all times throughout the mine, portable self-contained fire extinguishers should be kept at various locations in the mine. When a fire starts, immediate action is vital; and, during the first few minutes of a fire, almost any extinguisher will put it out unless a large quantity of gas is burning.

There are many different types and sizes of fire extinguishers available. One type has either carbonic gas under pressure or the gas is generated chemically by action of acid on soda to force out the water through the hose and nozzle. The carbonic gas in solution helps the water to extinguish the blaze.

Fire extinguishers filled with carbon tetrachloride are used to a great extent especially in connection with electrical equipment because carbon tetrachloride is a nonconductor of electricity. However, this type of extinguisher should not be used unless there is a sufficient ventilating current to carry away the carbon tetrachloride vapors. Also, these vapors may be decomposed by the heat thus producing hydrochloric acid, chlorine, or phosgene. All of these are dangerous to the respiratory system of the men around the fire extinguisher.

The foam-type extinguisher comprises an outer tank filled with an aqueous solution of sodium bicarbonate containing a foaming ingredient and an inner cylinder containing an aqueous solution of aluminum sulfate. The inner cylinder is filled with a loose stopper so that when the extinguisher is inverted and its hose directed toward a fire a foam blanket containing carbon dioxide can be spread over the surface of the fire to smother it. The foam is an electrical conductor similar to water and should not be used as a stream on an electrical fire because of the electrical-shock hazard to fire fighters. The foam-type extinguisher is particularly suitable for extinguishing oil and other petroleum-products fires.

The carbon dioxide extinguisher is a heavy-duty steel cylinder filled with liquid carbon dioxide under very high pressure. When the discharge hose and nozzle are directed toward a fire and the discharge valve is opened the carbon dioxide issuing from the cylinder is gasified because of the reduction in pressure. The carbon dioxide settles on a fire as a cloud of gas and carbon dioxide snow and smothers it.

All portable types of extinguishers are used for direct fire fighting; the carbon dioxide type must be used within a range of 6 to 8 feet of a fire and the soda-acid and foam-types, from 30 to 40 feet. Their use, therefore, is restricted largely to attacking fires before they have obtained much headway.

ROCK DUST

Rock dust is effective in fighting all fires when they first start and especially effective in electrical fires. Limestone rock dust which is very fine covers the fire and smothers it. At the same time when limestone is heated it gives off carbon dioxide which also aids in smothering the fire.

Since rock dust is being used in increasing quantities for the prevention of coal-dust explosions, it is one of the most readily available fire fighting materials for underground use. There should be a very liberal supply of rock dust stored near each working face and at all places throughout the mine where a fire might start.

b. ENCLOSING THE FIRE AREA WITH TIGHT SEALS

When direct fighting is impracticable the most effective method for controlling and extinguishing a mine fire is to seal the affected region, if possible, or the entire mine. Sealing with airtight stoppings excludes air from the fire and extinguishes it through the lack of oxygen necessary to support combustion. The correct procedure in sealing a fire, that is, whether to seal the intake first or the return first or to seal both intake and return simultaneously can not be given as specific conditons must be studied to determine the proper method of fighting a particular fire. A cardinal principle to adopt in all fire sealing procedure is to act without delay.

Temporary seals should be built,then all men removed from the mine for 24 hours before the permanent seals are built; however, all workmen except those engaged in fire fighting should be removed from the mine as soon as possible after the fire is discovered.

The reason for leaving the mine after temporary seals have been built is that behind the seals there develops a race between decreasing oxygen and increasing explosive gas, an especially critical time in a mine known to liberate methane. However, as mentioned earlier, the heat from a mine fire will distill from any bituminous coal volatile constituents that are explosive, so that behind a seal explosive gases are evolved in a mine normally nongassy. One of the most hazardous phases of mine-fire fighting develops within a short time after temporary seals are erected. The men should be withdrawn promptly because an explosive mixture may form behind the seals before the oxygen is sufficiently depleted; such an explosive mixture can be ignited by the fire, and a disastrous explosion may result. This is the greatest uncontrollable factor in fire fighting; many men have been killed as a result of such an explosion because they did not leave the mine promptly after erecting temporary seals.

Tight permanent seals are necessary to exclude oxygen from a sealed fire. These should be built where the roof is sound and unlikely to be disturbed to minimize the possibility of leakage of air through the strata overlying the coal bed. Provision should be made for sampling gases and for taking water-gage and temperature readings behind fire seals. Leaks around or through the seals, cracks, or breaks in the roof from the fire region to the ventilated part of the mine or breaks to the surface from the fire region will defeat the efforts to deplete oxygen, and the fire will be difficult or impossible to extinguish.

An important and often disregarded factor in sealed mine fires is the effect of ventilation on the seals and the fire territory behind the seals. Where the ventilating current passes by two sides of the sealed fire, such as an intake on one side and a return on the other, a resultant difference in pressure on the fire region may cause leakage through the seals or the surrounding strata. It is desireable to have the same air current pass on all sides of a sealed fire or to equalize the air currents so that essentially the same pressure will be exerted on all sides of the sealed territory. Failure to provide for equalization of air pressure in many instances has disrupted the control of oxygen within a sealed-fire region, so that unsealing and recovery operations were delayed unnecessarily. Obviously, the foregoing conditions would not apply to a fire near the faces of a pair of entries; seals would be erected in the entries, and the air pressure would be on only one side of the fire seals.

Samples of the atmosphere in a sealed-fire territory should be collected only when the pressure is outward because if samples are collected when the pressure is inward they will be contaminated by the air outside the seals and the results of analysis will be misleading. Samples should be collected at least once every 24 hours for several days after sealing. Analysis that show a continual reduction in oxygen indicate tight seals, and the collection of samples can proceed at more lengthy intervals up to a week apart.

Interpretation of analysis of fire area gases is of utmost importance in determining when it is reasonably safe to unseal the affected area. Carbon monoxide in the analysis indicates an active or a recently active fire; its absence is not conclusive evidence that the fire is extinguished but indicates that flame and active combustion probably have ceased. A fire region should not be unsealed to ventilate it until carbon monoxide has disappeared and enough time has been allowed for the heated section to cool. Before it is unsealed the oxygen content must be low enough to prevent the formation of an explosive mixture and its possible ignition. Available information on this subject indicates that when the oxygen content of a sealed fire territory has been reduced to 12 percent there is little, if any, likelihood that an explosion will occur. However, it is desirable to reduce the oxygen content to below 3 percent and preferably below 1 percent before an attempt is made to unseal; the lower percentage of oxygen will provide a larger factor of safety in unsealing. The influence of carbon dioxide on the explosive range of methane-air mixtures within a sealed area is very slight. In general, carbon dioxide can be disregarded in interpretation of air analysis from fire regions except for the knowledge that it displaces oxygen and thus is incidental to the reduction in oxygen content.

c. FLOODING THE FIRE AREA WITH WATER

To control a mine fire by flooding (1) the fire location must be such that water pumped or allowed to flow into the mine will flood the affected region, and (2) enough water must be available for flooding. Sometimes a fire territory is thought to be flooded, but the hot gases were dammed back and sufficient gas pressure was developed so that the hydrostatic pressure was balanced. When the mine was unwatered and air reached the hot gases that had been dammed back the mine fire broke out again. A mine should not be flooded unless direct attack or sealing has failed, not only because of the uncertainty of its effectiveness but also because of the damage to the mine and its equipment, and reconditioning is costly. In some instances recovery is not possible.

2. PROCEDURE

Following is a generalized procedure to follow once a fire is discovered. This procedure may have to be altered some for specific cases; however, it will serve as a guide in such cases.

1. The person who discovers the fire should use water, rock dust, fire extinguishers, or whatever is at hand to smother it if it

is small, at the same time calling for help.

2. If the fire is too large when first seen to be extinguished by simple means, he should run to the nearest telephone, if available, calling to the miners in the working places along the way to get out at once. If no telephone is available he should run to the men nearest him giving them the information and then sending them to inform the other men in the mine.
3. The mine foreman should also be notified immediately.
4. The mine foreman should notify the mine manager and also organize the fire fighting party without delay.
5. As soon as the fire fighting crew is organized they should start work immediately to extinguish the fire.
6. When the fire fighting crew has started to work the mine manager should then notify all officials so that they can stand by to offer any additional assistance that might be required.
7. All men should be withdrawn from the mine except those actually engaged in fighting the fire.
8. The fire should be fought direct with water, chemicals, or rock dust as long as progress can be made.
9. The ventilation should not be altered or reversed unless life is involved, and then only if it is reasonably certain that men will be able to escape and will not be caught by the reversal. If reversal is to be made, it must usually be within 10 or 15 minutes after the fire starts. Later is generally too late. The fan should be stopped or the air current reversed only when the man officially and legally in charge authorizes it.

3. PROTECTION OF THE FIRE FIGHTERS

Permissible oxygen breathing apparatus is highly important for all coal mines. There should be at least 6 units of approved self-contained oxygen breathing apparatuses, 6 units of approved all-service gas masks, and, if possible, all men should be equipped with approved self-rescuers.

All fire fighting crews should be thoroughly trained in the use of this equipment and no one not so trained should attempt to use said equipment.

The self-contained oxygen breathing apparatus will protect a person in any atmosphere and the all-service gas mask will protect a person in almost any atmosphere which contains sufficient oxygen for a flame safety lamp to burn. The self-rescuer will protect a person in an atmosphere containing carbon monoxide for about a half hour providing sufficient oxygen is present for a flame safety lamp to burn.

E. UNSEALING MINE FIRES

1. GENERAL

The knowledge of when and how to unseal a mine fire is of extreme importance in the mining of coal. If a fire area is unsealed too soon, the danger to life and property is increased. The premature opening of sealed mine fires is due most frequently to lack of knowledge of the inherent dangers involved and to extreme eagerness to restore the sealed area to a production basis. The control of fires by sealing and the time for unsealing are based on established laws of physics and chemistry, as well as experience and sound judgment of surrounding circumstances.

After the right time for unsealing is determined, an efficient organization with all necessary equipment and materials must be formed to undertake this task. Because unsealing a mine fire is hazardous, those engaged in the work should be safeguarded in every possible way.

2. FACTORS GOVERNING TIME FOR UNSEALING

Experience and scientific study have shown that no attempt should be made to unseal a mine fire until the oxygen content of the sealed atmosphere is low enough to make explosions impossible, until the carbon monoxide gas has disappeared, and the sealed area given time to cool. Other factors that govern the time for unsealing fire areas are: (1) Extent and intensity of fire at time of sealing; (2) character of burning material and overlying strata; (3) tightness of seals and enclosed area; (4) influence of barometric pressure on the enclosed area; (5) position of the fire area with respect to ventilation; (6) sampling and analysis of the atmosphere under seal; and (7) composition of fire gases in the sealed area.

a. EXTENT AND INTENSITY OF FIRE AT TIME OF SEALING

The extent and intensity of the fire at the time of sealing will have a definite effect upon the sealed area. A large amount of burning material will hasten the reduction of oxygen but will lengthen the time required to cool. A fire that is active at the time of sealing will cause oxygen to diminish more rapidly than will a smoldering fire.

b. CHARACTERISTICS OF THE BURNING MATERIALS

The character of the burning material, the rate of burning, and the change of gas composition are factors that may influence rekindling when air is again admitted. Coals that are high in volatile-combustible matter burn faster and are more likely to rekindle.

The character of the strata overlying the coal bed and the composition of the bottom also play an important part in determining the time for unsealing. Where the roof material is combustible, such as an oily shale, or alternating bands of combustible material, the heat generated by the fire will be retained much longer; thus, increasing the chances that the fire will be rekindled when air is admitted. Combustible floor material also retains heat; therefore, when the top or floor of the coal seam is of a combustible nature, the length of time that should elapse between sealing and unsealing is lengthened.

c. TIGHTNESS OF SEALS

Tight seals are essential for control of oxygen. They should be made of incombustible material; well hitched into ribs, floor, and roof; and should be built where the roof, floor, and ribs are sound. If there are excessive leaks at the seals or if there are openings to the surface that are not sealed any effort to control oxygen and extinguish the fire will be wasted.

Provisions should be made for collecting air samples and taking water gage readings by placing pipes with suitable valves, reducers, etc., in one or more of the seals. There should be a constant decrease in the percentage of oxygen in the samples collected from behind the fire seals. If this does not occur it usually can be attributed to leaky stoppings or breaks in the strata permitting air to enter the sealed area. If the stoppings are leaky or if the fire is likely to burn around the stoppings that have been erected, it is advisable to erect double stoppings.

d. INFLUENCE OF BAROMETRIC PRESSURE AND TEMPERATURE

If barometric pressure increases in excess of the pressure behind the seals, air is likely to enter the sealed region. Similarly, if barometric pressure decreases to less than that of the sealed region outward leakage through or around the stoppings will result. The latter condition assists materially in reducing the oxygen and aids dissipation of carbon monoxide.

When the temperature outside of the mine is considerably lower than the mine temperature, inward pressure on the fire seals is likely to occur, and if the outside temperature is somewhat higher than the mine temperature outward pressure will result.

The temperature within the sealed territory also has influence on the direction of pressure on the stoppings. When a fire is extinguished within a sealed region and cooling progresses, there is a decrease in volume and pressure inside the sealed region, which undoubtedly will cause inward pressure on the stoppings.

Temperatures on the outward side of the seals do not necessarily indicate the temperature within the sealed territory; however, if any of the stoppings are hot or warm, it is evident that the temperature within the sealed region is high.

e. EFFECT OF VENTILATION

If the fire area is located where the intake current passes on one side and the return current on the other side, the extinguishment of the fire may be prolonged due to leakage through the strata or stoppings induced by the difference of pressure on the two sides of the fire area.

f. SAMPLING AND ANALYSIS OF ATMOSPHERE

It is very important that proper sampling and accurate analysis be made of the gases in the sealed area. Samples should be collected from behind stoppings only when the pressure is outward, as samples collected when there is inward pressure usually are inaccurate; consequently, they are not representative of the sealed atmosphere.

g. COMPOSITION OF GASES IN THE SEALED AREA

It is recognized that the presence of carbon monoxide indicates active or recently active fire; the absence of carbon monoxide does not always mean that the fire has been extinguished, but rather that flame and more or less active combustion have ceased. It is not safe to unseal any fire until the carbon monoxide has disappeared. Even after the carbon monoxide has disappeared it is advisable to allow ample additional time for the heated material and strata to cool before the sealed area is opened and ventilated.

The gases found in sealed regions contain, in addition to varying percentages of methane, small quantities of hydrogen, carbon monoxide, and other combustible gases. Before an attempt is made to unseal a fire, the oxygen in the sealed region should be low enough to prevent the possible ignition of any explosive gases. It is desirable that the oxygen be reduced to at least 3 percent and preferable below 1 percent before an attempt is made to unseal.

Carbon dioxide contained in fire gases has little, if any, influence other than the displacement of oxygen in the extinguishment of a fire under seal.

3. PREPARATION FOR UNSEALING

Before a fire area can be unsealed there are a few preparations which must be made: (1) an organization must be formed including oxygen breathing apparatus and gas mask crews and other necessary personnel; (2) all personnel not a part of this organization should not be permitted in the mine; (3) all necessary equipment and material should be assembled outby the sealed area; (4) all electric current to the mine should be cut off during the unsealing operations; (5) all slopes, entries, and crosscuts leading to and from the fire area should be heavily rock dusted; (6) any stoppings or brattices needed to insure that the gases from the fire area will go directly to the outside should be made before any attempt to unseal; (7) an attendant should be placed at the mine fan to warn the men immediately if the fan does not continue to operate properly.

4. METHODS OF UNSEALING MINE FIRES

Before the seals are broken, a method must be outlined in detail for the recovery of the fire area. There are two methods in general use today, (1) recovery by use of air locks, and (2) recovery by use of reventilation.

When the fire area is large, the fire inaccessible, or bodies to be recovered, the air lock method is preferred. The reventilation method is used when the fire area can be explored by rescue crews under reasonably safe conditions and when there is every indication that the fire has been extinguished.

a. RECOVERY BY USE OF AIR LOCKS

An air lock consists of two stoppings about 15 feet apart each equipped with doors through which apparatus crews can enter or take material. One door of the air lock is kept closed at all times.

An air lock is first constructed a short distance behind the seal on the intake side of the fire area.

After this is completed and tests show that the oxygen content of the fire area is sufficiently low so that there will be no danger of an explosion, a fully equipped oxygen breathing apparatus crew proceeds through the air lock and begins to remove the seal. During all of the recovery or unsealing operations a fully equipped oxygen breathing apparatus crew must be kept in reserve.

After the seal has been removed the oxygen breathing apparatus crew, using a life-line or portable telephone, should explore to the point where the next air lock is to be erected, a distance not over 500 feet. Here they should determine the amount of material that will be needed to build the inby stopping of the next air lock. After close observations of the conditions which exist in this explored area, they should then return to fresh-air.

Next an apparatus crew, with a reserve crew at the fresh-air base, should construct the inby stopping of the new air lock at the place selected by the exploring apparatus crew. They should also construct any necessary stoppings in openings on the intake side and on the parallel entry on the return side opposite the point selected for the air lock to insure resealing of the inby area.

After this a seal on the return side should be opened by an apparatus crew and then the doors of the first air lock opened to admit air to reventilate this new area between air locks. The apparatus crew should then erect brattice cloth stoppings in any crosscuts between the intake and return entries to advance air to the last crosscut, which is left open. The amount of air admitted through the air lock doors should be carefully controlled, keeping the oxygen content low, until it is sure that there will be no explosion or reoccuring fire.

When this area between the air locks is completely reventilated the outby stopping of the new air lock should be erected. Also suitable stoppings can now be erected to replace the brattice cloth stoppings erected by the apparatus crew.

In like manner, with the exception that no seal need be broken on the intake side, advances should be made by successive blocks until the entire area is recovered.

b. RECOVERY BY USE OF REVENTILATION

When recovering a sealed fire area by direct ventilation an air lock should be constructed just outby the seal on the intake side of the fire area.

A fully equipped oxygen breathing apparatus crew, with a fully equipped oxygen breathing apparatus crew in reserve, should go through the air lock and remove the fire seal. Then using a life-line or a portable telephone the apparatus crew should explore and observe conditions within the fire area.

If the observations of the fire area are favorable, then the apparatus crew can remove the seal on the return side of the fire area and open the doors of the air lock.

SECTION 6 RESCUE AND RECOVERY OPERATIONS

A. GENERAL

The necessity of prompt and correct procedure to save live men who may be trapped, the safety of those engaged in the work, and the prevention, as far as possible, of additional property damage make rescue and recovery operations after mine fires and explosions extremely important.

Immediately following the occurrence of a mine fire or explosion, and probably for some time thereafter, there is likely to be excitement, confusion, and disorganization among the officials and workmen. Naturally, when mine management and workmen are confronted with conditions that are unusual, wrong methods are likely to be used.

The most important things for speedily, safely, and efficiently conducting rescue and recovery operations after mine fires and explosions are: (1) Efficient organization, (2) adequate and proper equipment, (3) sufficient materials, and (4) proper procedure in performing the work.

B. ORGANIZATION

1. PRELIMINARY ORGANIZATION

The necessity for a capable and efficient organization to carry on rescue and recovery operations after a mine fire or an explosion cannot be overemphasized. The personnel comprising the organization should be of the highest type obtainable and members of oxygen breathing apparatus crews should be selected carefully and should receive thorough training and instruction in the use and care of oxygen breathing apparatus and rescue and recovery procedure. They should be physically sound and fit to perform strenuous labor under oxygen and should have good judgment and a cool, calm disposition.

To know what to do and how to do it and to apply such knowledge promptly often may save the lives of trapped men and prevent needless risk and possibly loss of life by men engaged in rescue and recovery work. Lack of efficient organization after mine disasters frequently has resulted in loss of life and property and in unnecessarily prolonged recovery operations.

Every mine should have an emergency organization of officials, oxygen breathing apparatus crews, and other selected employees who are trained to take charge and immediately start recovery operations after a disaster; therefore, before a fire or explosion has occurred considerable thought and attention should be devoted to perfecting an organization to function satisfactorily if a disaster should take place.

Local mine personnel including surface personnel should receive instruction and training in the duties they are to perform individually and collectively should a mine fire or explosion occur in their mine. They should be informed where tools, brattice cloth, and other equipment and materials may be obtained. All personnel should be instructed that in the absence of superior authority they are to attend promptly to the most important things and notify immediately all officials, oxygen breathing apparatus crews, doctors, and any other interested personnel.

After the personnel has been organized and other important matters have received attention from the person in charge, or have been delegated to responsible, reliable, and competent persons, preparations should be made to enter the mine and start recovery operations. When experienced underground employees, fully equipped oxygen breathing apparatus and gas mask crews, gas detecting devices, and other necessary equipment and materials are assembled and ready, recovery work should be started.

Arrangements should be made to obtain names of all men entering the mine when recovery work is started. A reliable man should be designated to check men in and out of the mine, to search men going underground for matches, lighters, and smokers' articles, and to prevent any but permissible electric cap lamps and flashlights and properly assembled permissible flame safety lamps in good condition from being taken into the mine.

2. UNDERGROUND ORGANIZATION

The personnel comprising the underground organization is of the utmost importance as the progress of the work, as well as the safety of all concerned, will depend on their knowledge and efficiency.

A man experienced in mine rescue and recovery work should be in charge of each underground shift as assistant to the man in charge of the entire recovery operations. One or more competent assistants and such other personnel as may be necessary to conduct recovery work safely and efficiently should be assigned to the man in charge of the shift. The man in charge of the shift should be provided with an up-to-date mine map on which should be marked, as the work progresses, the areas explored, stoppings erected, ventilation restored, location of bodies, cars, pumps, mining equipment, falls, and other important data. Change of underground shifts should be made as quickly as possible so as to prevent interruption of the work. The man in charge of the shift being relieved should discuss with the man in charge of the oncoming shift the progress made and plans for future work. After completing his shift and reaching the surface, the man in charge of a shift should report at the general headquarters to the man in charge of operations and convey to the latter the data noted on the mine map used on the shift and any other information of importance.

a. OXYGEN BREATHING APPARATUS CREWS

Well trained crews, physically sound and experienced in the use and care of oxygen breathing apparatus and gas masks, are an essential part of any organization engaged in rescue and recovery operations. They should be provided with all the equipment, in excellent condition, necessary to conduct the work successfully. When explorations are being made or other work being carried on with oxygen breathing apparatus crews ahead of fresh air, at least two complete crews with adequate apparatus should be available. No oxygen breathing apparatus or gas mask crew should make an exploration or work in advance of fresh air without a reserve crew at the fresh air base equipped with oxygen breathing apparatus in good condition.

b. BRATTICE CREWS

Brattice men, in charge of a foreman, should be provided to erect temporary stoppings and line brattices of canvas or other suitable material where necessary. Temporary stoppings should be reinforced as soon as possible by stoppings of more substantial construction. As the work advances, men should be assigned to patrol and keep tight the temporary stoppings that have been erected.

c. TRACK CREWS

Track men, in charge of a foreman, should repair and clean track to facilitate the movement of material to the advance workers and to remove bodies as they are recovered.

d. MATERIAL CREWS

Material crews, in charge of a foreman, should be provided to handle and transport promptly and efficiently material such as brattice cloth, boards, timbers, nails, food, tea, water, and other material from the mine portal to the advance crews.

e. MISCELLANEOUS CREWS AND PERSONNEL

Miscellaneous underground crews, as timbermen, laborers to clean up falls, electricians, stretcher bearers, and others if necessary should be provided in charge of foremen. All of the foremen in charge of the different crews, as well as the various members of crews and other underground personnel, should be under the direction of the man in charge of the shift and his assistants, who, in turn, should be under the direction of the man in charge of operations.

No person other than those directly engaged in the recovery operations should be permitted underground.

3. SURFACE ORGANIZATION

The surface organization should include the personnel necessary to handle the equipment and materials required in recovery work underground, to provide facilities for housing and feeding the underground and surface organizations, and to perform various other necessary duties.

a. GENERAL HEADQUARTERS

A room or building near the mine entrance should be designated and used as headquarters for the man in charge of operations and his assistants; it should have tables, chairs, and telephones. Two or more men should be available at general headquarters for errand duty and messenger service. An up-to-date mine map should be provided and all important data placed thereon to indicate the progress of recovery operations. The men in charge of different shifts, foremen of crews, etc., should report progress to the general headquarters at the end of each shift so that officials, inspectors, etc., may be informed of what has been accomplished.

b. LAMP HOUSE

A suitable building or room should be provided for charging, issuing, receiving, and repairing electric cap lamps and flame safety lamps. Enough lamp house attendants should be on duty at all times to distribute lamps promptly to men entering the mine, to collect from those leaving the mine, and properly clean, charge, and repair the lamps being used; this lamp service is important and it should be done well.

c. MESS ROOM

Members of the underground and surface organizations, officials, and visitors must be fed. For this purpose there should be a mess in charge of some designated person. The mess should be housed in a suitable building, room, or tent and be provided with tables, benches, stoves, cooking utensils, dishes, etc., so that the persons assigned to this duty can have a supply of hot, wholesome food available at all times for those engaged in the recovery work.

d. SLEEPING QUARTERS

Men engaged in recovery work should have a comfortable place to rest and sleep where they will not be disturbed by the other workers. This is important because the work performed is strenuous and demands expenditure of both physical and nervous energy. Therefore, if possible, separate sleeping quarters should be provided for the men of each shift in order that they may obtain the maximum amount of rest while off duty.

e. APPARATUS ROOM

A room should be available in which to store, charge, and repair oxygen breathing apparatus, gas masks, and accessories. There should be on each shift at least two men competent to clean, recharge, test, and repair oxygen breathing apparatus and gas masks worn by the underground crews.

f. EMERGENCY HOSPITAL

A fully equipped emergency hospital, with doctors and nurses in attendance, should be established in a suitable building. Men found alive in the mine may be affected by noxious gases, severely burned, or otherwise injured; also, some of those engaged in recovery work may require immediate hospital attention for injuries or effects of irrespirable gases. Provision should be made for receiving the bodies of those killed in a mine disaster and preparing them for burial.

g. MISCELLANEOUS CREWS AND PERSONNEL

Miscellaneous surface crews, responsible to foremen, should be appointed to obtain, handle, and transport material required underground to the mine opening or to the bottom of the shaft, to pass out and check equipment and supplies, and to perform other necessary duties.

All of the officials, foremen in charge of crews, and other surface workers, as well as the underground workers, should be under the direction of the man in charge of operations.

C. EQUIPMENT

The safety and protection of men engaged in rescue and recovery operations demand that an ample supply of the proper type of protective, detective, lighting, and fire-fighting equipment in first-class condition be available.

1. SELF CONTAINED OXYGEN BREATHING APPARATUS

The self-contained oxygen breathing apparatus is the oldest device by which man is enable to live and work when surrounded by asphyxial gases and is still the only device that will protect the wearer against poisonous mine gases regardless of concentration or against atmospheres containing little or no oxygen.

With this apparatus the wearer is furnished an adequate supply of oxygen direct from the apparatus. Therefore, the supply of oxygen is completely independent of the atmosphere in which the wearer is working; thereby, protecting him in any type of atmosphere, whether deficient in oxygen or highly concentrated with poisonous gases.

There have been several such apparatus developed since the first by Professor Schwann was displayed at a fair in Belgium in 1853. Today there are still several different types on the market.

a. TWO HOUR McCAA

This is a compact, self-contained unit carried on the back with enough supply of oxygen to give full protection for a minimum period of two hours. The apparatus consists essentially of a steel cylinder containing the supply of oxygen under high pressure (2250 pounds per square inch when fully charged), valves to control the pressure and circulation of the oxygen, a cooler and rubber breathing bag which functions as a low pressure oxygen reservoir, breathing tubes and mouthpiece, and a regenerator for purifying the expired breath by removing carbon dioxide from it. The total weight is approximately 40 pounds.

CIRCULATION OF AIR

Oxygen from the cylinder passes through the closing valve into the reducing valve; from the reducing valve, at lowered pressure, through the oxygen supply tube to a metal tube, enclosed in the cooler, to the admission valve; operation of this admission valve is controlled by the wearer's lungs and when opened by an inhalation admits oxygen to the breathing bag and then to the cooler, from whence it goes through the inhalation tube and the inhalation valve in the mouthpiece to the lungs.

On exhalation, the air, somewhat diminished in oxygen and containing from 4 to 6 percent carbon dioxide passes through the exhalation valve and then the exhalation tube and on into the bottom of the regenerator. The air, still containing carbon dioxide, then passes upward in the regenerator through the "cardoxide" which absorbs the carbon dioxide; then the purified air passes to the cooler where it joins and is enriched with oxygen supplied through the admission valve as required. Then the air passes to the breathing bag from which breathable air is drawn by the wearer at the next inhalation. The by-pass valve furnishes oxygen direct to the wearer independent of other working parts of the apparatus.

b. M.S.A. ONE-HOUR OXYGEN BREATHING APPARATUS

The operating principle of this machine is very similiar to the two-hour McCaa. It is smaller and more compact and is made in two models, one to be worn on the back (24 pounds) and the other to be worn on the chest (18 pounds).

This apparatus is especially adaptable as an official's apparatus for initial exploratory work and in directing rescue operations.

c. M.S.A. DEMAND APPARATUS

In this apparatus air is supplied from a bottle of compressed oxygen through a demand type regulator to the face piece of the wearer. The exhaled breath is expelled directly to the atmosphere through an exhalation valve in the facepiece. It is good for only 30 minutes and weighs 32 pounds.

CIRCULATION OF AIR

Oxygen or air flows from the cylinder through the high pressure connecting hose, past the by-pass and mainline valves to the demand regulator. Here, the pressure is reduced to breathing pressure and supplied to the wearer upon his inhalation demand, passing through the breathing tube into the facepiece and across the lenses where it removes any fogging produced by the moisture in the exhaled breath. On exhalation, the flow to the wearer stops and the exhaled breath passes to the outside air through the exhalation valve.

d. M.S.A. CHEMOX OXYGEN BREATHING APPARATUS

This apparatus has a breathing circuit which operates independently of the outside air even though it does not contain a supply of compressed oxygen. The oxygen is furnished from a replaceable canister that contains a chemical which liberates oxygen in more than sufficient amounts when this chemical comes into contact with the moisture from the exhaled breath. The chemical in the canister also absorbs the carbon dioxide from the exhaled breath; therefore, chemox gives complete protection for the wearer in all atmospheres. It weighs only 13½ pounds.

OPERATION OF CHEMOX

The chemox self-contained oxygen breathing apparatus is approved by the United States Bureau of Mines for a period of 45 minutes and at temperatures above 20 degrees below zero. The Chemox apparatus is equipped with a timer that tells when the 45 minutes is up; however, in the event that the timer fails, there are also other indications that show that the canister is approaching the end of its service life. First the lens of the facepiece will begin to fog during inhalation and then the breathing bag will start to gradually deflate.

The canister of Chemox can be stored indefinitely until it has been opened; however, once a canister is opened it will last for only 45 minutes to an hour and even though it is only used for a fraction of that time it must be thrown away as the chemical action still continues to take place. When throwing away a Chemox canister it should first be punctured on the front, the back, and on the bottom with a small clean nail or tool and placed in a nearly full bucket of water. After the bubbling ceases, indicating complete exhaustion of the chemical, the canister can be discarded. The water, which is caustic, should be poured down a drain or disposed of in some other satisfactory manner.

After the chemical action has started in the canister there may be an excess of oxygen admitted to the breathing bag. When this happens there will be heavy resistance to exhalation; however, there is a pressure relief valve that will release the excess pressure and make breathing once again easy.

In the Chemox self-contained oxygen breathing apparatus there are several parts, whose purpose is as follows:

Breathing bag -- To provide a breathing reservoir and to cool the oxygen coming from the canister.

Hard rubber tubes in the breathing bag -- To insure proper circulation of the oxygen through the breathing bag.

Plastic spacer between the inhalation elbow and the plunger casting -- To serve as an insulator using the air space to prevent heat transfer and thus aid in maintaining cooled oxygen for breathing.

Metal deflectors in the facepiece -- To insure that the dry inhaled oxygen is directed across the lenses preventing fogging.

Lip around the inside edge of the facepiece -- To prevent leakage and provide a comfortable fit.

CIRCULATION OF AIR

The circulation through the Chemox self-contained breathing apparatus is as follows: The exhaled breath passes from the facepiece through the exhalation check valve and exhalation breathing tube to the canister, passing down the center and up through the chemical removing the exhaled carbon dioxide and moisture, and evolving oxygen to mix with the exhaled oxygen. The oxygen flows into the bottom of the breathing bag on the exhalation side through a hard rubber tube and is directed to the inhalation breathing tube then through the inhalation check valve to the facepiece.

USING

In putting on and using the chemox self-contained oxygen breathing apparatus the following is the recommended procedure as outlined by the United States Bureau of Mines:

1. Unfasten and straighten all harness straps.
2. Hold apparatus and slip web harness over head.
3. Fasten snaps on harness straps to Dee ring on each side of canister holder and adjust straps, positioning apparatus to permit free head movement when facepiece is put on.
4. Attach waist strap to small Dee ring on bottom of canister holder and pull up to a snug fit, tucking in the loose ends.
5. Remove the metal tear-off cap on the canister by pulling the metal tab straight out, then straight back across the top of the cap. Make sure that the metal and cardboard discs are removed exposing the copper foil seal. Insert the canister into the canister holder with the smooth side to the front, and screw up the hand wheel until the canister is firmly engaged.
6. Put on the facepiece as follows: See that straps lie flat against head; tighten lower or neck straps; tighten the side straps; place both hands on headband pad and push in toward the neck; repeat operations of tightening lower straps and side straps; tighten forehead or front strap if necessary.
7. Squeeze both breathing tubes with one hand, break the seal of the facepiece against the cheek with finger and inhale, then releasing breathing tubes and facepiece exhale into the apparatus. This must be done in fresh air. Repeat this procedure until the breathing bag is fully inflated. Depress the pressure relief valve and force the air from the breathing bag. Reinflate the breathing bag by repeating the starting instructions. The chemox should be stored and started at temperatures above 32 degrees Fahrenheit. When the apparatus is stored and started at temperatures above 32 degrees Fahrenheit, it may be worn in temperatures down to minus 20 degrees Fahrenheit. When starting the apparatus at temperatures near freezing, more inhalations from the outside air, with exhalation into the canister, may be required to produce the proper chemical reaction. The best procedure is to keep fully inflating the breathing bag, then deflating it with the elbows until a total of about 15 exhalations have been put through the canister.
8. To check the complete apparatus for tightness do as follows:
   a. Grasp the lower end of the inhalation breathing tube and squeeze it tightly. Inhale, and if the facepiece collapses, the facepiece seal is sufficiently tight and the exhalation valve is functioning properly. This will also test the upper part of the inhalation breathing tube for leaks.
   b. Continue to squeeze the lower end of the inhalation breathing tube. Depress the pressure relief valve button. It should then be possible to exhale through the valve. While still

holding the button down, inhale, and if the facepiece collapses, the relief valve is functioning properly.

c. Release the inhalation tube and squeeze the lower end of the exhalation breathing tube. Inhale, and then exhale forcibly. The exhaled air should be forced out between the face and the facepiece only. This will indicate that the inhalation valve is functioning properly and the upper end of the exhalation tube is free of leaks.

d. With the bag well inflated, grasp the upper ends of both breathing tubes and depress both sides of the breathing bag with the elbows. If the breathing bag does not deflate, the complete apparatus is tight.

9. Breathe normally as the apparatus furnishes enough oxygen to meet any breathing requirements.
10. Set the timer at the stop and when it rings, return to fresh air-(45 minutes).
11. There is no need to purge nitrogen manually from the system as more oxygen is produced than is consumed, and excess pressure is released through the pressure relief valve simultaneously purging nitrogen.

2. GAS MASKS

a. GENERAL

The limitations of a gas mask in air are exceedingly important, because gas masks do not supply the oxygen necessary to support life and they can remove only relatively small percentages of poisonous gases from air otherwise suitable to breathe.

For these reasons the gas mask is limited to respiratory protection in coal mine atmospheres where a flame safety lamp will burn and can be used safely; also, to atmospheres that do not contain a high concentration of poisonous gases.

b. M.S.A. ALL-SERVICE GAS MASK

The all-service gas mask is approved for respiratory protection to the wearer in mine atmospheres containing smokes, dusts, vapors, or mists only if (1) a flame safety lamp will burn, (2) there is not more than 2 percent by volume of organic vapors, acid gases, or carbon monoxide, (3) there is not more than 3 percent by volume of ammonia, and (4) there is not more than a total of 2 percent by volume of any combination of poisonous gases.

The nominal service time of each canister is two hours total service (continuous or intermittent); however, if any unbreathable gases are noticed by the wearer the canister should be changed immediately.

The timer on the all-service gas mask is a mechanical device which registers the number of respirations. This is then transmitted to a pointer which makes a complete revolution on the dial in about 2 hours.

To test the all-service gas mask for leaks you should (1) see that all gaskets are in place at all joints, (2) connect timer to canister and then to the mask, (3) adjust mask to face and head, (4) hold hand over opening in bottom of canister and inhale gently. If there are no leaks the facepiece will collapse on the face.

After a canister has been used it should be plainly marked and then thrown away.

3. SELF-RESCUER

a. GENERAL

Although the self-rescuer is not actually a piece of equipment essential to rescue and recovery operations, it is nevertheless a very important piece of equipment used for protection of a person. Members of the self-contained oxygen breathing apparatus crew and the gas mask crew should each have a self-rescuer. Also, sufficient units should be stored in the rescue station so that mine rescue and recovery crews could take the units underground in case of fire or explosion, thus giving trapped men an opportunity to leave a barricaded section.

The purpose of the self-rescuer is to provide an individual with protection from carbon monoxide for at least a half-hour in an atmosphere containing enough oxygen to support life, and thus help him to escape from a mine in which a fire is burning, an explosion has occurred, or his other protective devices have failed. It is not intended for use by parties attempting the rescue of others, but was designed purely as an emergency device for self-rescue purposes.

b. M.S.A. SELF-RESCUER

The M.S.A. self-rescuer is approved by the United States Bureau of Mines for self-rescue from carbon monoxide and smoke for a period of one-half hour providing there is sufficient oxygen in the atmosphere for a flame safety lamp to burn. It weighs $13\frac{1}{2}$ ounces ready for use.

The replaceable cartridge of the self-rescuer contains cotton filter pads for protection against smoke. It also contains a chemical (hopcalite) which changes carbon monoxide into carbon dioxide.

To inspect this cartridge to be sure that it is still usable, remove the cartridge from the body of the self-rescuer. Examine the lids of the cartridge, which are vacuum sealed, if the lids are tight the vacuum has not been broken and the cartridge is in condition to use. Before putting the cartridge back into the body of the self-rescuer examine the rubber parts of the body, mouthpiece, and latex diaphram of the exhalation valve.

The procedure for putting the self-rescuer into service is (1) remove the unit from the case and plastic bag, (2) break seal of cartridge by lifting up the lever, (3) push plunger located at center of cartridge, (4) place mouthpiece and nose clip in position, and (5) tighten neck strap.

4. GAS DETECTORS

Safety and good mining practice require that ample means be provided for the detection of mine gases by competent persons designated to use them. The necessary devices for detecting mine gases are permissible flame safety lamps, U.C.C., M.S.A., or Burrell methane indicators, carbon monoxide detectors or canaries, and possibly portable gas-analysis outfits. Sufficient supplies and spare parts to insure efficient operation of the gas-detecting devices should be available at all times. These devices should be used only by persons fully acquainted with them and their limitations.

5. LIGHTS

Men engaged in rescue and recovery operations in coal mines should be provided with permissible electric cap lamps or flashlights, or both, for illumination. In some instances permissible floodlights can be used to advantage. Where permissible electric cap lamps are not regular mine equipment, at least 50, with necessary equipment for charging and repairing, should be provided for use in recovery operations.

6. FIRE EXTINGUISHERS

Several portable fire extinguishers, rock dust, and water should be available for use by the rescue and recovery crews. This is essential as when exploring areas that have once been under fire the fire may reoccur. Also, it is possible that after an explosion while rescue and recovery operations are going on a fire will start and if the proper equipment is at hand this fire can be stopped before it gets out of control.

7. TOOLS

An adequate supply of hammers, axes, saws, sledges, hatchets, picks, shovels, bars, bricklayers' hammers and trowels, pipe wrenches, and other necessary tools should be available.

8. TELEPHONES

Enough telephones always should be available, if possible, at the base of operations and at such other places as may be necessary to keep contact between those engaged in the recovery work underground and those assisting in various capacities on the surface. After an explosion, as recovery work progresses, the telephone system should be kept in proximity to the fresh-air base; however, under certain conditions the common types of outside and mine telephones can ignite an explosive mixture of gas. Therefore, permissible type telephones should be used in mines during rescue and recovery operations.

Portable telephones that operate without batteries have been developed so that they can be used efficiently and satisfactorily for communication between oxygen breathing apparatus or gas mask crews and the fresh-air base. One such type that is approved by the United States Bureau of Mines is the M.S.A. Maskfone. It permits clear, two-way voice communication between men equipped with masks or breathing apparatus. Sound-powered and completely self-contained it employs no batteries or other external power source. A revolving reel is used to play out cable as the mask wearer moves about. The cable connection to the mask can be broken quickly to provide complete working freedom. This type of telephone can be worn by anyone wearing a M.S.A. all-service gas mask or a chemox self-contained oxygen breathing apparatus providing they are equipped with a cleartone speaking diaphragm facepiece.

9. MAPS

Mine maps, with the latest possible extensions of surveys, should be provided as soon as possible after a mine fire or explosion. One of these should be posted in the general headquarters on the surface and additional copies should be available for the men in charge of the underground shifts, captains of oxygen breathing apparatus crews, inspectors, and others who may require a copy.

A disaster map for emergency use, on which is noted the direction of ventilation in each entry, location of overcasts, doors, pumps, elevations, and other information may be of much value after a fire or explosion.

10. LOCOMOTIVES, ANIMALS, CARS

To expedite the movement of material, bodies, etc., after a mine disaster, means of transportation should be provided. After a mine fire or an explosion, all electric power should be cut off the mine; it will be unsafe to use trolley-pole or cable-reel locomotives. That there may be motive power for haulage purposes, permissible storage-battery locomotives or animals, such as mules or horses, should be provided. Enough mine cars in good condition should be available for transporting equipment, materials, bodies, etc.

11. PUMPS

Mine pumps of various designs and sizes should be available. Main pumps should be put in operation as soon as possible to prevent flooding of the mine or sections of a mine. Field or gathering pumps also should be provided to remove water collected in places that would interfere with recovery work and to supply water for fire fighting and other purposes.

12. MISCELLANEOUS EQUIPMENT

Additional miscellaneous equipment and devices that may be required and should be provided as needed are anemometers, thermometers, water gages, oxygen inhalers, stretchers, blankets, first-aid supplies, life lines for apparatus crews, mortar boxes, buckets, etc.

D. MATERIALS

The materials required for conducting recovery operations to a considerable extent will depend upon local conditions and the nature of the work. Every effort should be utilized in procuring and making available, when and where needed, the materials required to conduct recovery work efficiently. Lack of necessary materials will retard recovery operations unduly and also will add to the hazard of those engaged in the work.

1. BRATTICE CLOTH

Brattice cloth will be required for temporary stoppings when a mine fire must be sealed. If the area or mine involved in an explosion is extensive, a large amount of brattice cloth will be required for temporary stoppings, line curtains, and other purposes. An ample supply of this important material should be available at all times.

2. LUMBER

An adequate supply of boards of various sizes, planks, two-by-fours, etc., should be provided as required for the construction of doors, for repairing or rebuilding overcasts and air locks, and for other uses.

3. NAILS AND SPIKES

An ample supply of nails and spikes of various sizes should be available. If numerous stoppings are to be erected and other construction work is necessary, a large supply of nails will be necessary.

4. BRICKS

Bricks, are very useful for building permanent stoppings and overcasts following an explosion and for erecting fire seals when a fire must be sealed. Therefore, a good supply should be kept on hand at all times.

5. CEMENT

Sufficient cement should be available for mortar when brick, rock stoppings or other masonry work are to be erected and for more extensive use if concrete stoppings or other concrete work is necessary.

6. POSTS AND TIMBERS

A generous supply of mine posts, cap pieces, wedges, and heavy timber should be provided for roof support and for erecting canvas or board stoppings.

7. PIPE AND PIPE FITTINGS

Pipe of various sizes, with an ample supply of sleeves, elbows, tees, unions, reducers, valves, etc., should be provided for extending water lines, for suction and discharge lines for pumps, and for other purposes as may be required.

8. MISCELLANEOUS MATERIALS

In addition to the above, other miscellaneous materials such as rock dust, ties, rails, frogs, switch points, track spikes, etc., and repair parts for equipment, devices, and machinery should be provided as required.

E. RECOVERY PROCEDURE

Proper recovery procedure is very important as improper procedure may sacrifice possible chance of rescuing persons left alive in a mine after an explosion and may also result in loss of life of men engaged in recovery work. As soon as possible after an explosion the fan should be inspected and kept running with an attendant in charge; electric current should be cut off from the mine; and a checking in and out system established.

Rescue and recovery crews, with other personnel and necessary equipment and material, should be assembled promptly as indicated in previous discussion of organization, equipment, and materials.

1. RESCUE AND RECOVERY CREWS

Rescue crews comprise men equipped with gas masks or oxygen breathing apparatus and especially trained and equipped to make explorations, perform work in bad air, and, when the occasion arises, to rescue living men.

Recovery crews are composed of brattice men, men for handling and transporting material and bodies, drivers, telephone attendants, timbermen, trackmen, road cleaners, and other miscellaneous personnel.

Rescue crews work in close cooperation with recovery crews by making explorations ahead of fresh air to reach live men, locate bodies, test the mine air, look for fires, and erect stoppings where respiratory protection is required.

2. ESTABLISHING VENTILATION

If the ventilating fan has not been destroyed or damaged it should be kept running; with the fan running normally, ventilation will be established only to the point where stoppings have been destroyed by the force of the explosion.

If it is impossible to operate the fan, repairs or replacements should be made immediately as little or no recovery progress can be made without adequate ventilation. Advantage should be taken of any natural ventilation that may be established to make a preliminary examination of the region of mine openings and for a short distance inside the mine.

3. ENTERING MINE AND ESTABLISHING FRESH-AIR BASE

When the necessary organization has been formed equipment and materials assembled, and ventilation established, exploration of the mine should be started.

The officials in charge of the shift should check the crews going underground to see that everyone is properly equipped for the work at hand and that only persons whose services may be of definite use are allowed to go into the mine.

On entering the mine, the rescue and recovery crews should advance in fresh air to the point where ventilation has been destroyed and establish a fresh-air base outby that point.

4. ESTABLISHING TELEPHONE COMMUNICATIONS

Portable telephones may be used to advantage to keep in touch with the outside when the crews are first advancing; however, as recovery work progresses, the telephone system should be extended and additional telephones installed so that there will always be telephone communication between the advance crews and the fresh-air base or the outside. Ordinary type telephones should not be installed or left where they are likely to come in contact with explosive gas.

5. EXPLORATIONS AHEAD OF FRESH AIR

a. GENERAL

After a fresh-air base has been established, exploring should be done ahead of fresh air by rescue crews wearing oxygen breathing apparatus or gas masks to look for live men and fires, locate bodies, and observe conditions. Exploration trips ahead of fresh air may be performed largely by gas mask crews if it is fairly definitely known that masks can be used safely. Oxygen breathing apparatus crews should be held in reserve to support gas mask crews. When oxygen breathing apparatus crews are working ahead of fresh air, another oxygen breathing apparatus crew, fully equipped with apparatus adequately charged and in good condition, always should be held in reserve at the fresh-air base.

It is always advisable to make short trips ahead of fresh air unless a longer trip is absolutely necessary to save life or to do other work positively required for the continuance of the recovery operations.

b. PRECAUTIONS

Before actual starting an exploration ahead of fresh air all members of the rescue crew should carefully examine their oxygen breathing apparatus or gas masks, life line, portable telephones, and any other equipment to make sure that everything is in perfect working condition.

The captain of the rescue crew should then be given definite instruction by the man in charge of the fresh-air base. These instructions should include such things as the extent of the trip, distance to travel, things to observe, time to be taken in making the trip, emergency signals, etc.

c. PROCEDURE

On leaving the fresh-air base the rescue crew should travel but a very short distance ahead of fresh air and then stop. They should then examine their apparatus to make sure it is airtight and functioning properly. Then carrying a life line and a batteryless-type portable telephone, if possible, they should proceed slowly, in single file, about 6 feet apart.

As the rescue crew advances they should mark with chalk (1) the direction of travel, (2) arrows pointing to the fresh-air base, (3) the name of the crew captain at the farthest point of the trip, and (4) the day, month, and year on the faces of all rooms, entries, etc. They should examine the roof and roadway and carefully note the conditions so they can report their observations to the man in charge when they return to the fresh-air base.

Good judgment and common sense are required to conduct exploratory work ahead of fresh air safely and efficiently. The rescue crews should have regard at all times for their own personal safety and should not act in haste, but in accordance with previous instructions and training.

6. RESTORING VENTILATION

If no fires are found after exploring ahead of fresh air for some distance, possibly through several break-thrus or crosscuts, to ascertain conditions, the next step is to erect the necessary stoppings to ventilate the explored region. After ventilation is thus restored, the fresh-air base is then advanced and the process of exploring ahead of air is again repeated. This process is kept up until ventilation is restored throughout the entire mine.

a. STOPPINGS

If an explosion has affected a large area, many temporary stoppings will be required to restore ventilation. Temporary stoppings should be made as nearly airtight as possible and strong enough to withstand the pressure that will be required to carry air to the face regions. Temporary stoppings should be set far enough inside of crosscuts or other openings to leave space for the later construction of stronger and tighter stoppings.

As recovery work progresses, a large number of temporary stoppings may be in use, and to insure that these are kept tight and in good condition, men should be appointed on each shift to patrol and keep the temporary stoppings as nearly airtight as possible.

b. REMOVAL OF AFTERDAMP

In ventilating any portion of a mine after an explosion, the afterdamp should be conducted to the outside by the most direct route. Permitting the poisonous gases to travel through other sections of a mine may seriously endanger the lives of survivors of the explosion or persons engaged in the rescue or recovery work. It is extremely dangerous after an explosion, to permit air to travel through unexplored portions of the mine. Unless this vital precaution is taken, an explosive mixture of gas may be brought in contact with a fire, thereby causing another explosion.

All entries and rooms, if possible, should be cleared of afterdamp as work advances. If this is not done explosive, asphyxiating, or poisonous gases may seep from bratticed-off areas, enter the ventilating current outby the point where recovery work is in progress, and seriously affect members of the rescue or recovery crews or possibly cause an explosion.

7. EXAMINING FOR AND EXTINGUISHING FIRES

Since timbers, gob, dust, and coal are likely to be set on fire by the heat and flame of an explosion, smoldering fires and sometimes active fires are likely to be found by the rescue crews exploring ahead of fresh air; therefore, when exploring ahead of fresh air, rescue crews should make a careful examination for fires. After the fresh air has been advanced, a continual check should be made of the return air current for any signs of fire.

When a rescue crew finds a fire, they should immediately attempt to put it out with water, rock dust, or fire extinguishers before the fresh air is advanced. However, if the fire is of considerable size or is inaccessible and it cannot be extinguished by direct methods, it should be sealed promptly and effectively.

8. RESCUE OF LIVE MEN

Usually live men found after an explosion are suffering from poisonous or asphyxiating gases, burns, or injuries. Men thus found in an atmosphere containing afterdamp should have an oxygen breathing apparatus or, if sufficient oxygen is present, a gas mask or self-rescuer placed on them immediately and then carried to fresh air.

As soon as possible after live men are brought to fresh air, they should be given oxygen to breathe and artificial respiration if their breathing is slow.

When live men are found behind barricades erected to protect themselves from afterdamp, great care should be exercised to prevent poisonous or noxious gases from entering the barricade while men are being rescued. If fresh air can be advanced to the barricade in a short time, it should be done; however, if this is impossible provision should be made to admit the least possible amount of bad air behind the barricade when it is opened to rescue the men. This can be done by erecting a tight stopping, with a small opening covered with canvas, a sufficient distance outby the barricade to allow room to set a stretcher lengthwise between the stopping and the barricade. After the stopping has been erected, an opening large enough to admit an open stretcher should be made in the barricade and covered immediately with canvas.

The men found behind the barricade should be provided with the necessary protective equipment and taken to fresh air. All rescued men should be taken to a hospital for further observation and treatment.

9. HANDLINE BODIES

After an explosion, dead bodies may be found in various parts of the mine. All bodies should be wrapped in brattice cloth or canvas by the recovery crews and transported to the outside. A tag bearing the location where the body was found should be attached to each body. The location, position of the body, and the name should be marked on the mine map.

10. RETIMBERING

Since the force of an explosion will probably knock out many timbers, the roof will be weakened; therefore, it is necessary for the timber crews to replace these timbers as soon as possible in order to protect those engaged in the rescue operations that must travel along the path of the explosion.

11. CLEARING ROADWAYS

Roadways should be cleared and repairs made to the haulage tracks as soon as possible after an explosion. As previously stated transportation of material and bodies and the recovery work in general will be greatly facilitated if the haulage tracks and haulage equipment are made available for the rescue crews to use.

12. PREPARATION FOR RESUMING OPERATIONS

After the area affected by a mine explosion has been explored, the bodies removed, fires extinguished or sealed, and the inspectors and mine officials have completed their investigations, crews should be set to work building permanent stoppings, cleaning haulage roads and air courses, and making such other repairs as may be necessary to safe operation of the mine.

SECTION 7 COAL MINE ACCIDENTS

Almost all hazards that endanger the lives of workers are within human control except those resulting from the elements, such as lightning, hurricanes, and those of similar nature which are sometimes called "acts of God".

Coal mining is one of the most hazardous of the important industrial occupations; however, almost all of the hazards are controllable. The following discussion will show the causes of the most common coal mine accidents and what can be done to help prevent them.

A. FROM FALLS OF ROOF AND COAL

1. CAUSES

Removal of coal usually causes movement of the overlying strata, which results in cracks and breaks in the roof rock. Some roof material, such as shale and coal, will yield before falling; however, harder rock that does not yield, such as some sandstones and limestones, may break with little or no warning. Falls of mine roof are most common within a short time after the roof is first exposed by the mining of coal. A piece of material that falls unexpectedly from the roof, face, or rib is usually considered an accident. If a workman is struck by the unexpected fall an injury or death may result.

Workers who travel about a mine are not so likely to be struck by a loose piece of roof because they are exposed only a relatively short time to any single piece; however, a miner probably spends most of his time at work within 25 feet of the face and when a fall occurs unexpectedly he generally is in the danger zone.

Moisture from the air which is deposited on the roof is considered to be a cause of rock disintegration because it reduces the strength by its weathering action on the roof and causes the roof rock to swell, crack, and "spall off".

Another cause of accidents of this nature is a "bump", which is a sudden rupture or settling of coal pillars or of coal from an advancing entry or room face. When a bad bump occurs, coal is thrown from the face or ribs in large and small fragments; the floor is upheaved; timbers are broken, crushed, or thrown out; cars are overturned or smashed; draw slate or loose pieces of roof are thrown down; and a wind blast produces a dense cloud of dust, sometimes accompanied by gas. Bumps as a rule are not too common in coal mines; however, the term is sometimes applied to the popping noises which are heard in the roof when pillars are being mined.

A mining method that does not suit the natural conditions of the mine is often the principal cause of difficulty with the roof. The dimensions of rooms, and pillars are governed largely by the character of the coal, roof, and floor; pitch and thickness of the coal bed; and thickness and kind of overburden. The rooms should be narrow and the pillars wide enough to be safe. Where the mine roof and floor are strong, pillars that are too small to resist the overlying weight will begin to crush or squeeze. When the roof or floor are soft and the pillars are too small to support the overlying weight the pillars push into the floor or roof. The roof of haulage roads and air courses is often weakened where areas have been worked out too close to the haulageways or air courses.

2. PREVENTION

Inspection of the roof is the greatest factor in the prevention of this type of accident. A glance at the roof sometimes is all that is necessary to inform the miner that it is dangerous, but in other instances visual observation gives no indication of the condition of the roof. The roof generally is tested by striking it with a bar or some other tool. If it is solid when struck, a ringing or bell-like sound is produced. A drummy or hollow sound indicates a break in the roof.

The exposed roof in every active working place should be tested frequently, and in some places it may be necessary to test it every few minutes throughout the shift. Noises made by mining machines often prevents workmen from hearing the preliminary chipping or cracking that precedes the fall of large masses of overlying materials. The precaution of stopping machines frequently must be taken so that the roof, face, and ribs can be tested properly.

Most accidents from falls of roof and coal are due to insufficient or improper timbering; however, delay in placing timbers also account for many accidents. Ordinarily the most dangerous zones in coal mines are the regions within 25 feet of the working faces. When roof is exposed at the working face it may remain in place only a short time and the roof also may be weakened by blasting; therefore, safety posts should be set while the place is being cleaned up in preparation to setting the permanent timbers. After the permanent timbers are set the roof should be checked carefully before the safety posts are removed. The best method to insure adequate timbering is to have a systematic timbering plan which is followed even though the roof appears not to need so much timbering. A good policy to follow is: "If the roof is sound, support it and keep it good; if the roof is bad, support it to prevent it from falling".

Miners or other employees should not go under draw slate or other loose roof material until it is supported properly or taken down and the place retimbered. When taking down loose material the miner should make sure that the place under which he is standing is safe.

B. FROM HAULAGE

Haulage accidents usually result not only in injuries but also in considerable loss of production and damage to equipment. With the growth of mechanized mining there has been accompanied a demand for more and faster haulage equipment. The track and roadbed that were satisfactory for hand-loading operations often has not been improved to accommodate the extra equipment and increased haulage speeds required in the conversion from hand to mechanical loading methods.

1. CAUSES

Haulage accidents can generally be grouped into two classes, those that are due to physical defects in haulage facilities and those that are due to human failures.

In the first group there are such things as poorly maintained equipment; poorly alined, drained, cleaned, and maintained track and roadbed; obstructions such as doors on main haulage roads; poorly installed or maintained frogs, switches and switch throws; poorly alined and maintained trolley wire; poor bonding or rail welding; inadequate side and overhead clearance; inadequate timbering along haulageways; dirty, improperly spaced man holes or entire lack of them; and improper control of trips.

In the second group you have careless practices, such as jumping on and off of moving trips, coupling moving cars, operating mobile equipment at high speeds, failure to block cars properly, the wearing of loose or torn clothing, the failure to wear protective head and footwear, and the failure to obey instructions.

2. PREVENTION

The maintaining of a good roadbed and track is the foundation of a good haulage system. The roadbed must be properly graded, which includes proper drainage, and a good ballast is equally necessary. Track ties are part of the roadbed, and their proper spacing and tamping with ballast are essential to the stability of the haulage road. Mine track should be laid with rails large enough to carry safely the weight of the cars and locomotives, they should be properly alined and held in place with enough spikes, and they should be connected with well bolted plates. All frogs and switches should be properly alined and kept in good repair.

Where possible there should be a continuous clearance on one side from the mine portals to all working faces of at least 30 inches from the nearest obstruction to the farthest projection of moving equipment. This clearance should not be obstructed by loose rock, coal, switch throws, supplies, or other material.

Man holes should be provided along all haulageways where men are required to work or travel. They should be on the clearance side, suitably marked, and free from any loose rock, coal or supplies. Upon the approach of rolling stock, mine employees on a haulageway should enter the nearest shelter or man hole immediately and stay in it until they are sure that it is safe to resume working or traveling.

All haulage equipment such as locomotives and cars should be kept in good repair and well greased at all times. Lights should be provided on both the front and rear end of all trips. Locomotives should be operated at moderate speeds at all times. When rope haulage is used the end of the trip should be equipped with a safety drag to cause derailment in the event the rope breaks. The rope should be of adequate size and strength and should be replaced as soon as it shows evidence of undue wear. Rope, links, chains, and rope sockets should be examined carefully by a competent person at least once every 24 hours. Horizontal and vertical rollers should be properly alined and large enough in diameter to avoid sharp bending of the rope. Track rollers should be properly alined and, on straight track, should be so spaced as to keep the rope from dragging on the mine floor as much as possible. Rollers should be placed relatively close on curves to guide the rope properly. All rollers should be installed securely to prevent dislodgment and should be kept clean, well-oiled, and in good repair.

When there are two or more trips operating in a mine at the same time a means of control must be set up so that it is possible to tell at all times where these trips are located. This is necessary to prevent the trips from running into each other. Whenever cars are left standing in the mine they should be on a side track and the place well marked. Also, cars standing should be well blocked so that they will not start to roll at an unexpected time.

The dangerous practice of getting on and off of a moving trip should not be allowed at any time. A person can slip, trip, stumble, or fall and be injured or killed by the moving trip. Also, the coupling or uncoupling of moving cars should be prohibited as this has caused the loss of many fingers and some more serious accidents. Always be sure that cars are stopped before trying to couple or uncouple them and that a trip has completely stopped before getting on or off of it.

Where man trips are provided to haul the men to and from their working places in the mine, several precautions should be taken in order to protect the men: (1) man trips should be operated at a safe speed but not behind other trips on ascending grades or in front of trips on descending grades, (2) a suitable place should be provided at originating points where men may wait for the man trip, (3) at man trip loading and unloading points the trolley wire should be guarded adequately, (4) the man trip should come to a full stop before men load and unload, (5) when riding in a car on a trolley haulage road, men should sit inside the car on the side opposite the trolley wire and keep their hands and arms inside the car, (6) explosives should not be carried in man trips, (7) tools and supplies should be carried inside a separate car, and (8) man trips on slopes or inclines should be provided with a safety rope connected to the main rope at a point above the regular hitching and extending around or through all cars.

In low coal mines where belt conveyors have been installed, it is common practice to haul the men to and from their working place on the belts. When this is done certain precautions should be followed; (1) men and supplies should not be transported at the same time, (2) a minimum head clearance of 18 inches should be maintained between the belt and the roof or cross bars, projecting equipment, cap pieces, overhead cables, wiring, and other objects, (3) the belt speed should not exceed 250 feet a minute, (4) men riding on a belt should be at least 5 feet apart, and (5) loading and unloading stations should be well-lighted.

C. FROM ELECTRICITY

Owing to increased mechanization, electricity is assuming increasing importance in the operation of coal mines. Today few mines of any size are operated without electric power being applied in one or more phases of mine operation.

There are relatively few accidents actually attributed to electrical causes; however, many accidents that are listed under other causes are actually caused by electricity. For example, the injuries and deaths caused by a mine explosion or fire of electrical origin or the accidents caused primarily by electrical contact by which a person is thrown under or against haulage or mining equipment.

The use of electric power for coal mining operations is much more hazardous than for any other comparable industrial use. Restricted clearance, particularly overhead, is a constant source of danger in working around live, bare conductors, such as trolley lines. The relatively poor illumination in mine operations compared with that provided by most other industries increases the hazards or dangers of electric power conductors and machinery in mines.

1. CAUSES

Contact with trolley wires is the main cause of electric-shock accidents in coal mines because it is often difficult to avoid contact with these lines and perform the necessary work in the restricted space common to most mines. When a person who is not protected in some manner touches a trolley wire the electric current passes through his body and into the ground; it may cause severe shock and in numerous instances has caused death.

Electrical cables, because they are usually of a temporary nature, are usually repaired in a slipshod manner after a break occurs. These cables that are left in poor condition are very definitely a shock and fire hazard.

Another source of electric-shock accidents comes from electrical equipment. The metallic frames, casings, and coverings of motors, generators, transformers, switchboards, and other electrical equipment become "alive" through failure of insulation or by contact with live parts. Because the installation and use of electrical machinery often is of a temporary nature, it has led to slipshod methods of installation, repair, and maintenance.

Mine explosions and fires caused by electricity have been discussed in a previous section of this text and will not be discussed here.

2. PREVENTION

Trolley wires should be securely supported on insulated hangers; they should not be permitted to contact the roof, rib, cross bars, or doorframes; they should be alined properly; they should be installed on the side opposite the clearance space and man holes; they should be anchored securely and cut off and fastened with an insulated turnbuckle at the inby end. The guarding of trolley wires does not offer complete protection against personal contact, but the benefits are great enough to warrant guarding them adequately where men must pass or work under them regularly.

Temporary splices in cables should be made in a work-man-like manner and should be electrically continuous, mechanically strong, and well-insulated.

The frames, casings, or coverings of all electrical equipment should be grounded effectively.

All electrical equipment should be protected against excessive overload by fuses or equivalent protective devices of the correct type and capacity; wires or other "jumpers" that do not provide adequate protection should not be used in place of the proper fuses or circuit breakers.

All electrical equipment used in a coal mine should be of the permissible type.

D. FROM EXPLOSIVES

Injuries from explosives accidents are more likely to result fatally than from any other cause except explosions. The main reason for this is that the very nature of explosives is violence. It is important, therefore, that all explosives, including permissible explosives and charged blasting devices, be handled, stored, and used carefully, without exception.

1. BLASTING DEVICES

a. CARDOX

Cardox is not an explosive, but a blasting device. It is a strong, hollow, cylindrical, steel shell charged with liquid carbon dioxide at high pressure. A heater element, which is inserted in the steel shell before it is charged, becomes surrounded by the liquid after charging. Electric current is applied to the heater element from a permissible shot-firing device through a suitable blasting cable, whereupon the liquid carbon dioxide is heated rapidly and converted into a gas almost instantaneously. Gasification of the carbon dioxide within the steel shell produces enough pressure to shear a replaceable steel disk, allowing the gasified carbon dioxide to escape into the blast hole at high enough velocity and pressure to dislodge the coal.

The greatest hazard with cardox is the danger of a shell flying out of a bore hole when fired and expending its energy in the mine workings near the hole. Many injuries, some fatal, have been caused by flying cardox shells. Everyone should be 100 feet or more from a cardox shot and, if possible, should have two or more intervening right angles between him and the shot.

b. AIRDOX

Airdox is somewhat similar to cardox except that the pressure is released by a valve instead of through a rupture disk as with cardox. An airdox cartridge is a strong, cylindrical, steel shell charged with compressed air at an average pressure of about 11,500 pounds per square inch; the pressure is generated in a multistage air compressor usually located on the surface. The charge of compressed air reaches a shell placed in a bore hole at the face through high-pressure copper tubing connected to a two-way valve in its "admission" position the valve is thrown to its "release" position, whereupon the reduction in pressure is reflected within the airdox shell; the compressed air then escapes to the confines of the bore hole through ports in the shell. The coal is blasted by the pressure built up in the borehole. The shell is recovered after each break and can be used again and again without adjustment or renewal of parts.

The principal hazards of airdox are the dangers incident to charging and releasing high-pressure compressed air and the danger of flying shells, as with cardox. The airdox blasting device presents no gas- or dust-ignition hazards.

2. PERMISSIBLE EXPLOSIVES

Permissible explosives are essentially dynamites that have been modified so that they are relatively safe, when compared with black blasting powder and ordinary dynamites, for use in bituminous-coal mines with respect to the likelihood of gas- or coal-dust ignition. This is because the flame of a permissible explosive is smaller in volume, shorter in duration, and of a lower temperature than that of black blasting powder or dynamite. Permissible explosives are fired by detonation instead of flame, as with black blasting powder.

3. BLACK BLASTING POWDER

Black blasting powder is a more dangerous explosive to store, transport, and when fired is much more likely to ignite a surrounding atmosphere containing methane, bituminous coal dust, or both, than permissible explosives. Black blasting powder is dangerous because of the ease of ignition by flame or sparks, because of the dangers that attend the handling of metal kegs (the practice of making a hole in a black-blasting powder keg with a pick, bar, or other metal tool has caused fatal accidents), because of the toxic gases resulting from firing, and because of the long duration-large volume-high temperature of the flame when fired.

If black blasting powder has to be used, it must be handled with great care. The metal clips on the powder keg should be pried up with a wooden stick and pressed back with the fingers; the metal cap and underlying paper washers then should be lifted out with the fingers; keep open lights and electrical conductors away from both loose black powder and full powder kegs; be absolutely sure that the atmosphere around where the black powder is being used is free from methane and coal dust; always use a wooden tamping bar; and be sure, before the fuse is lit, that there isn't any loose black powder in the hole that will catch fire and set off the charge prematurely. At best black blasting powder is dangerous and if handled carelessly will surely result in an accident.

4. ACCESSORIES

Fuses, whether used alone for firing black blasting powder or with a blasting cap to fire dynamite or permissible explosives, are hazardous because they require an open flame for igniting; also, miners have been killed by premature firing of shots because the victims believed that fuse burns at the rate of 1 foot a minute instead of burning at the rate of a foot in 30 to 40 seconds. When using a fuse to set off a charge, whether black blasting powder, dynamite, or permissible explosives, always be sure that the place is free from gas and coal dust; that the fuse is long enough to give everyone time to get out of the way; and that only one charge at a time is fired.

Stemming material such as coal dust, wads of paper, or any other combustible material should never be used. If this material is used there is a very good chance that the explosive charge will ignite the stemming material which in turn might initiate an explosion or fire. A sufficient amount of stemming material should be used to prevent a "blown-out" shot which also might initiate an explosion; however, no amount of stemming material will prevent a "blown-out" shot if the hole is improperly placed or the explosive charge is too heavy.

Tamping bars should be entirely of wood without metal attachments and the ends of the bar should be smooth and kept free of foreign material. Particles of rock or sand on the end of a tamping bar may cause a spark by friction during the tamping operation and if any explosive is spilled along the bore hole it may be ignited.

Permissible explosives in coal mines should be fired electrically with detonators. A detonator contains a detonating compound consisting of a pressed primer load, a loose ignition charge, and an electrical firing element. The leg wires of electrical firing element are usually made of iron covered with white, wax-impregnated, cotton insulating material. The ends of the leg wires are shunted or twisted together and this shunt should not be removed until immediately before connecting to the shot-firing circuit.

Shot-firing cables for use in bituminous coal mines should be rubber insulated, sturdy, flexible, at least a 100 feet long, kept shunted at the battery end until ready to be attached to the blasting unit, staggered as to length at the detonator end to prevent accidental short-circuiting, wound up after each shot, and kept away from track, power wires, pipe lines, and other possible sources of active or stray currents.

The blasting units should not be capable of igniting methane-air mixtures, they should have enough electrical energy to fire the shot, they should be mechanically strong, and the live terminals should be protected so as to prevent accidental contact. There are four general types of blasting units in use today. (1) dry-cell, (2) wet-cell (usually the battery for the electric cap lamp is used), (3) magneto, and (4) generator.

5. PROCEDURE FOR FIRING

Numerous accidents occur while primers are being prepared and when the explosive is being loaded into the hole. Carelessness in preparing and placing the primer increases the possibility of misfires, hangfires, or burning of the charge in the holes. In making primers it is important that the electric detonator be secured in the primer so that it cannot be pulled out.

Before loading the explosive charge, the hole should be cleaned out so as to prevent the cuttings from getting between the cartridges of explosives. The entire charge, including the primer, should be loaded in the hole with the cartridges placed end to end and pushed back gently toward the bottom of the hole until seated. The primer cartridge should be placed with the detonator pointing toward the bulk of the charge. The remaining space in the hole then should be filled with incombustible stemming material. The first two cartridges of stemming material should be pushed gently against the explosive charge, but the remaining stemming material should be tamped firmly in place.

After the charge is securely placed in the hole, the shunt on the leg wires is removed and the wires connected to the shot-firing cable. However before connecting these wires, the shot-firer should be sure that the other end of the shot-firing cable is shunted and the cable is rolled up so that there isn't any possibility of a stray electric current getting to the shot-fire cable and prematurely setting off the charge. The shot-firer should be very careful where he unrolls the cable so that it will not cross anything that might introduce an electric current.

When ready to fire the shot-firer should give warning by shouting "fire" three times at 2 second intervals before firing the shot. Only one shot at a time should be fired. After the shot is fired the shot-firing cable should be immediately disconnected and the ends shunted.

In the event of a misfire, a period of at least 10 minutes should elapse before anyone goes into the face. Then, if by a visual check no apparent reason can be seen why the shot did not go off, a new hole is drilled 2 feet away and parallel to the misfired hole. This new hole is then fired. Under no circumstances should a misfired hole be drilled out.

SECTION 8 FIRST AID

No text on safety would be complete unless first aid is included. However, in-as-much as first aid is a complete subject of its own, only a brief description of it will be given here. The publication by the United States Bureau of Mines, "First Aid, A Bureau of Mines Instruction Manual," should be referred to for more complete and detailed information.

A. OBJECT OF FIRST AID

First aid is an emergency treatment of a person who is injured or ill to protect him until medical or surgical aid can be obtained. The first thing to do after an accident is to send for medical aid.

The objects of first aid are:

(1) Prevention of further injury.
(2) Checking conditions known to be endangering life.
(3) Protecting injuries from infections and complications.
(4) Making the patient as comfortable as possible to conserve his strength.
(5) Transporting the patient to medical assistance, where required, in such a manner as not to complicate the injury or subject the patient to any more discomfort than is absolutely necessary.

B. WHAT A FIRST AID MAN SHOULD DO

1. Send for medical aid in all serious injuries.

If you believe that the patient is in a place safe from further injury and medical aid can be obtained promptly, it is usually best not to attempt to move him but to employ such emergency care as is possible until a doctor arrives.

2. Have the patient checked in all cases of injury.

If the injury appears to be only a minor one, have the patient checked by a doctor to be sure that the injury is not serious and to be sure that the minor injury has been treated properly.

3. Take command and give orders.

When an accident occurs and an injury results, a trained first aid man should take charge. He should be calm and give orders to other who are present. He should send for a doctor at once.

4. Locate the injury.

The person in charge should make a careful, but quick, examination to determine the nature of the injuries. Find out whether breathing is normal, look for hemorrhage or serious bleeding, shock, open wounds, burns, fractures or broken bones, dislocations, and any other injuries.

In examining an injured person, do not remove his clothes in the usual way, as you may cause unnecessary movement and suffering and may make the injury worse. The clothing should be cut from the body in the vicinity of the injury.

5. Know what to do, and do it.

After the nature of the injury has been determined the person taking charge should order others present how to assist him in treating the patient's injuries. Being careful at all times not to make any unnecessary movement of the patients body or limbs. The injured part of the body should be in as near a normal position as possible. Fractures and dislocations should be supported and dressed in the line of deformity.

6. If artificial respiration is indicated, start it without delay.

This is the first consideration; after it has been started then the person in charge can direct others who are assisting him to treat the patient for bleeding which also is of prime importance.

All onlookers should be kept from crowding around the patient and shutting off air for breathing.

All clothing around the neck, chest, and waist should be loosened. Remove false teeth, tobacco, snuf, gum, or any foreign matter from the mouth. See that the patient's tongue is well forward and not back over the windpipe. In many cases one of the assistants should be ordered to hold the patients tongue out.

Never attempt to give an unconscious person water or any other liquid by mouth as it may enter his windpipe and strangle him.

7. Look for bleeding and check it.

This should be done first, unless as noted above that artifical respiration is indicated in which case bleeding should be checked immediately after artifical respiration is started. The bleeding should be checked by pressing the fingers or thumbs on the skin over the blood vessel at the location of the pressure point; by a tourniquet; or, by a bandage compress and bandage applied with pressure over the wound. Also, in case the blood vessel has been completely cut into, it may be necessary to clamp the ends of the blood vessel together with the fingers.

8. Keep the patient lying down.

Sometimes an injured man will want to walk around. He says he feels alright; but, always keep him lying down until you are satisfied he does not have a serious injury.

It is frequently dangerous to let an ill or injured person sit or stand, and to permit him to walk may cause his death.

He should not only be kept lying down, but he should be covered with a blanket and should, if possible, be lying on a blanket.

9. Treat for physical shock.

Try to make the patient as comfortable as possible by doing whatever is necessary. If a patient's face is flushed, put something under his head to raise it. If his face is pale keep his head level with his body. If he vomits, turn his head to the side so that the vomited matter will flow from the mouth and not get into his windpipe and choke him. If the patient is conscious, give him all the water he wants, but give it slowly and in sips.

Heated objects such as bricks, rocks, etc., should be wrapped and tested against your own skin on the side of the face and, if not too hot, placed next to the body of the injured person. Always encourage the patient and keep him hopeful.

10. Treat all wounds.

Cover all wounds completely with a sterile bandage compress, or sterile gauze in case of larger wounds, and then place a triangular or cravat bandage over the compress or gauze, except for wounds of the eye, nose, chin, fingers, or toes where only the compress is used. Do not allow the fingers or any other instrument which is not sterile to touch the wounds.

Remove any loose foreign objects from a wound with a piece of sterile gauze; but, never attempt to remove any object which is embedded in the wound.

In the case of a burn, exclude the air from the burned surface as quickly as possible by using picric-acid gauze or other suitable burn dressings such as foille.

11. Treatment of fractures or dislocations.

Never, unless absolutely necessary, move an injured person with a fracture or dislocation until such injury is properly supported by splints. Except for dislocations of the jaw, finger, or toe, leave the reduction of dislocations and the setting of a fracture to the doctor; however, be sure that the injured portion is properly supported and securely tied. In the case of a compound fracture a sterile compress should be placed over the wound, without undue pressure, then the splints applied.

12. Moving an injured person.

After an injured person has had the proper first-aid treatment, all fractures and dislocations firmly supported, and it is necessary to move the patient to a doctor, he may be moved on a stretcher. Place the patient carefully on the stretcher, avoiding any jerky movements, and carry him to safety. Always test a stretcher before placing an injured man on it.

Remember, all your first-aid to the injured man may be ruined by rough handling in moving him to safety; therefore, use extreme care when placing a person on a stretcher and in carrying him to safety.

C. PHASES OF FIRST AID

In the study of first aid there are several different phases, each one important within itself. Which one is most important can not be determined; therefore, they are assumed to be equally important and all phases should be thoroughly studied.

1. ANATOMY OF THE HUMAN BODY

To understand the reasons for many first aid procedures and to render intelligent and efficient first aid, it is necessary to know something about the anatomy (structure) and physiology (work) of the human body and its more important organs. The body is composed of solids (bones and tissues) and fluids (blood and secretions of various organs and membranes).

a. THE HEAD

The head is made up of the skull (a bony case that encloses and protects the brain) and the face. The head is composed of 22 bones.

b. THE TRUNK

The trunk is the main part of the body and is divided into two parts by a muscular partition known as the diaphragm. The upper portion of the trunk is the chest, its cavity and organs. The lower portion is the abdomen, its cavity and organs. There are 54 bones in the trunk.

c. THE EXTREMITIES

The extremities are divided into two parts, the upper and lower. The upper extremity on each side consists of the shoulder joint, the arm, the forearm, the wrist, and the hand. The lower extremity on each side consists of the hip joint, the thigh, the leg, the ankle, and the foot. There are 32 bones in each of the upper extremities and 30 bones in each of the lower extremities making a total of 124 bones in the extremities.

2. FIRST AID DRESSINGS

First aid dressings are triangular bandages that can be used either open or folded into cravat bandages, as required, sterile bandage compresses, sterile gauze, picric-acid gauze, tourniquets, and splints.

a. BANDAGES

A bandage is used to cover wound and burn dressings, to make improvised tourniquets, to support fractures and dislocations, to apply splints, and to form slings.

There are two types generally used, the triangular and the cravat. The triangular is made from a piece of cloth one meter square by folding the square diagonally and cutting along the fold. The cravat (wide, medium, or narrow) is made by folding a triangular bandage to the correct size required.

The ends of all bandages are tied with a square knot.

b. BANDAGE COMPRESS

A bandage compress is a special dressing to cover open wounds. It consists of a pad made of several thicknesses of sterile gauze sewed to the middle of a strip of muslin. Three sizes are used--small, medium, and large.

c. TOURNIQUET

A tourniquet is an appliance used to check severe bleeding from an artery. An improvised tourniquet can be made by placing a well padded block of wood or other hard material over the appropriate pressure point and twisting a bandage, strap, belt, etc, around the padded block and that part of the body such as leg or arm where the pressure point is located.

d. SPLINTS

Splints are used to support and protect injured parts, such as fractures, dislocations, or suspected broken bones, and to prevent movement at the point of fracture and at the nearest joint. They are usually made out of wood or wire mesh; however, any stiff material will do.

3. ARTIFICIAL RESPIRATION

Respiration is breathing by which air is taken into the lungs during inspiration and forced out during expiration. In passing to and from the lungs the air passes through the nose, the throat, and the windpipe.

Artificial respiration is a method by which normal respiration is imitated, by manual movements, to induce breathing in persons whose respiration has stopped.

Where breathing has stopped or is very irregular and feeble, artificial respiration is usually required. The most frequent conditions under which artificial respiration is required are electric shock, gas poisoning, drowning, and suffocation from various causes.

There are several methods of giving manual artificial respiration, all effective; but, in some methods more air is forced into the lungs than others and when certain types of injuries are present some methods cannot be used.

The Holger-Nielsen (back-pressure arm lift), gives the greatest exchange of air in the lungs; however, when a victim has severely injured arms that cannot be raised, this method cannot be employed. Under such circumstances, use the Schafer method. Where a victim is injured in such a way that he cannot be placed on his belly or has severe back injuries, use the Silvester method.

4. CONTROL OF BLEEDING

In order to know where and how to stop the flow of blood from a wound and to better understand the purpose of blood in the human body a knowledge of the circulatory system is essential. The circulatory system consists of the heart, the arteries, the veins, and the capillaries by which blood is carried to and from all parts of the body.

a. BLOOD SUPPLY

7 to 8 percent of the weight of the human body is blood. A man weighing 150 pounds will have 10 to 12 pints of blood in his body.

The blood consists of a fluid called plasma and two types of cells, the red and the white. The function of the blood is to carry nourishment to all the tissues of the body, furnish heat and oxygen, and remove waste matter resulting from tissue activity to such organs of excretion as the lungs, the skin, the kidneys, and the bowels.

b. THE HEART

The heart is a hollow, muscular organ, about the size of a fist, in the lower left section of the chest cavity. By its pump action the blood is kept under pressure and in constant circulation throughout the body. In a healthy person, with the body at rest, the heart contracts about 72 times a minute.

c. BLOOD VESSELS

Blood vessels are the tubes or pipes which carry the blood through out the body; there are two types, the arteries and the veins. Pure blood is carried from the heart by a large artery. Branch arteries are given off from this large artery, and the branches in turn give off succeeding branches. These branches divide and subdivide until they become very small and terminate in thread like vessels known as capillaries, which extend into all the organs and tissues.

After the blood has furnished the necessary nourishment and oxygen to the tissues and organs of the body, it takes on waste products, particularly carbon dioxide. The blood returns to the heart by means of a different system of blood vessels known as veins. The veins join the arteries through the capillaries and by a process just the reverse of that given for the arteries build up the return circulatory system.

d. LUNGS

The function of the lungs is to purify the blood. The impure blood that has been returned to the heart from all parts of the body is pumped into the sponge-like blood vessels of the lungs, where the carbon dioxide and volatile waste products are exchanged for oxygen through the delicate walls of the air cells. The purified blood is then pumped back into the heart and is ready to be recirculated through out the body. The time taken for the blood to make one complete circulation of the body averages about one and one fourth ($1\frac{1}{4}$) minutes.

e. BLEEDING

Bleeding is a flow of blood from an artery, vein, or capillary. When blood spurts from a wound and is bright red, an artery has been cut. When dark red blood flows from a wound in a steady stream, a vein has been cut. When blood just oozes from a wound capillaries have been cut.

The loss of 2 pints of blood by an adult usually is serious, and the loss of 3 pints may be fatal. The length of time it takes for 2 or 3 pints of blood to flow from a cut artery or vein will depend on the size of the artery or vein that is cut. For instance, if the principal blood vessels in the arm or the thigh are cut, bleeding may prove fatal in 1 to 3 minutes.

f. METHODS OF CONTROL

PRESSURE

For arterial bleeding use finger pressure, and apply a tourniquet over the pressure point between the heart and the wound. Apply a sterile compress and bandage over the wound, and for additional pressure (unless otherwise indicated) tie knots over it.

For venous bleeding constrict the part below the wound away from the heart side, if necessary. Apply a sterile compress and bandage over the wound, and for additional pressure (unless otherwise indicated) tie knots over it.

For capillary bleeding apply a sterile compress and cover with a bandage; tie knots over the wound.

POSITION

Elevate the wounded part to retard the flow of blood for either arterial or venous bleeding. Exceptions: Wounds of head where shock is present and there is no fracture of the skull, sunstroke, or apoplexy.

COLD

Apply cold applications to the body in the region of the injury (not into the wound), to retard the flow of blood; this is of particular use in internal bleeding and can be used for either arterial or venous bleeding.

5. THE NERVOUS SYSTEM

The nervous system plays a very important part in physical shock, which in some degree follows most injuries. The various parts of the body and the organs controlling the body functions are kept in touch with each other by the nervous system which is divided into two parts, the cerebrospinal and the sympathetic.

The cerebrospinal system consists of the brain and the spinal cord. The brain is a collection of nerve centers, each a central station for some part of the body with trunk nerves connecting the parts of the body with their particular centers. Leaving the brain, these trunk nerves are bundled into the spinal cord, which passes down through the opening in the center of the backbone or spinal column, giving off branches to all parts and organs of the body.

The nerves entering and leaving the spinal cord are mainly of two types, sensory nerves, and motor nerves. The sensory nerves, which enter the cord, convey impressions of sensations, such as heat, cold, touch, and pain from different parts of the body to the brain. The motor nerves, which leave the spinal cord, convey impulses from the brain to the muscles causing movement.

The sympathetic system is a series of nerve centers in the chest and abdominal cavity along the spinal column. Each of these nerve centers, although interconnected with the cerebrospinal system, presides over and controls vital organs and vital functions, such as, our heart, our blood pressure, our digestion of food, our excretory organs, and our breathing.

a. PHYSICAL SHOCK

Physical shock is a state of collapse or prostration that interferes with normal action of the heart, respiration, and circulation. This condition is probably due to derangement or lack of proper balance within the sympathetic nervous system that controls these vital functions.

The state of shock may develop rapidly or may be delayed and manifest itself hours later. Shock may be caused by severe or extensive injuries, severe pain, loss of blood, surgical operations, severe burns, accidents due to electricity or gas, certain illnesses, poisons taken internally, exposure to extremes of heat or cold, seeing own injuries or injuries of others, fright, anger, and joy.

b. FAINTING

Fainting is temporary loss of consciousness caused by an inadequate supply of blood to the brain and is a mild form of physical shock. Fainting may be caused by an injury, the sight of blood, exhaustion, weakness, heat, lack of air, and the emotions, such as fright or joy. Some persons faint much more readily than others.

6. WOUNDS

a. OPEN WOUNDS

An open wound is any break in the skin. When the skin is unbroken, it affords protection from most infections, bacteria, or germs. However, when the skin is broken, no matter how slight the break, germs may enter, and an infection may develop. The chief duties of a first aid man in caring for an open wound are to check bleeding and to prevent germs from getting into it.

Open wounds are divided into four groups, Abrasions, incised wounds, lacerated wounds, and punctured wounds.

ABRASIONS

Abrasions are wounds caused by rubbing or scraping. These wounds are seldom deep, but a portion of the skin has been removed, leaving a raw, bleeding surface. The bleeding in most abrasions is capillary only. Abrasions are easily infected owing to the amount of underskin surface exposed.

INCISED WOUNDS

Wounds produced by a sharp cutting edge, such as a knife, a piece of glass or metal, or a sharp edge of coal, rock, or slate, are incised wounds. The edges of such wounds are smoothly divided without bruising or tearing. Incised wounds bleed freely and are not so liable to infection as wounds of other types.

LACERATED WOUNDS

Lacerated wounds are those with ragged edges, and have been torn or mashed by blunt instruments, machinery, or rough surfaces. These wounds, in which the blood vessels are torn or mashed, do not bleed as freely as incised wounds. However, the ragged and torn tissues, with the foreign matter that is often forced or ground into the wound, make the danger of infection greater than in incised wounds.

PUNCTURED WOUNDS

Punctured wounds are produced by pointed instruments, such as needles, splinters, nails, or pieces of wire. Such wounds usually are small but may be very deep. Most of the articles causing punctured wounds are soiled, and matter causing infection often is introduced deep in the tissues. The small openings in punctured wounds and the few blood vessels cut prevent free bleeding. The danger of infection in punctured wounds is far greater than any other type of wound.

b. CARE OF OPEN WOUNDS

Rip or cut the clothing so that the injury may be seen. If loose foreign particles are in or around the wound, wipe them away with sterile gauze. Do not attempt to remove a foreign object embedded in the wound, leave this to the doctor; also, leave the work of cleansing the wound to the doctor.

Do not touch the wound with your hand, clothing, or anything that is not sterile, and do not pour water or any drug into or on it. Place a sterile bandage compress or sterile gauze over the wound (making sure the sterile dressing is wide enough to cover completely the wound and an area on each side) and tie it in place. Protect all bandage compresses or sterile gauze dressings by an outer dressing made from a cravat or triangular bandage, except dressings for wounds of the eye, nose, chin, finger, and toes, or compound fractures of the hand and foot when splints are applied.

Where there is severe bleeding from an artery, always check it by finger pressure and then by the use of a tourniquet when necessary if a tourniquet pressure point is available.

Usually considerable shock follows wounds, especially if much blood is lost. Treat shock promptly.

c. CLOSED WOUNDS

Several types of injuries may be suffered where the skin is not broken but damage occurs to the deeper tissues; these injuries usually are classed as closed wounds.

BRUISES

Bruises are the most frequent injuries suffered. They are caused by some blunt instrument or object striking the body or by the body coming in contact with a hard object, as in a fall or a bump. Usually the skin is not broken, but the soft tissues beneath the skin are injured. Small blood vessels are ruptured, causing blood to seep into the surrounding tissues, which produces swelling.

STRAINS

A strain is the overstretching of a muscle or a tendon of a muscle. In severe strains, the fibers forming the muscle or tendon may be torn. Strains are caused by sudden movements or by violent exertion in lifting or moving heavy weights.

SPRAINS

Sprains are injuries due to stretching or tearing of the ligaments or other tissues around a joint. They are caused by a sudden twist or wrench. Sprains range from minor injuries causing pain or discomfort for only a few hours to severe cases where tearing of the tissues requires many weeks of medical care before normal use of the joint is restored.

RUPTURE

Rupture is protrusion of a portion of an internal organ, usually the bowel, through the muscular wall of the abdomen. Most ruptures occur in or just above the groin, although ruptures may occur at other places over the abdomen. Ruptures are caused by muscular strains from lifting or pushing violent coughing, sudden jars in jumping, and similar acts.

All forms of rupture should have immediate medical attention.

d. FOREIGN BODIES

Objects or material foreign to the human body can cause not only pain and discomfort, but often serious injuries are the result of foreign objects.

FOREIGN BODIES IN THE EYE

Foreign bodies, such as particles of dirt, sand, cinders, coal, emery dust, or fine pieces of metal, frequently are blown or driven into the eye and lodge there. Fortunately, through an increased flow of tears, nature dislodges many of these substances before any harm is done. In no case should the eye be rubbed, as rubbing may cause scratches of the delicate eye tissues or force a foreign particle with sharp edges into the tissues, making its removal difficult.

Gentleness in handling eye injuries is absolutely essential. Never use the point of a knife blade, a toothpick, or a sharpened matchstick to try to dislodge a foreign body in the eye. If difficulty is experienced in removing the foreign body from the eye, send the patient to a doctor at once.

FOREIGN BODIES IN THE EAR

Small insects or pieces of coal or other material may get into the ear. If these cannot be removed readily the patient should receive medical attention at once.

FOREIGN BODIES IN THE NOSE

Foreign bodies in the nose usually can be removed without difficulty but occasionally require the services of a physician.

FOREIGN BODIES IN THE THROAT OR WINDPIPE

Pins, coins, fishbones, false teeth, and particles of food often become lodged in the throat or windpipe. Although as a rule there is not complete obstruction of the air passages, more or less severe symptoms of suffocation are present. The victim's face becomes livid, and he gasps for breath, with violent fits of coughing.

In all cases, an attempt should be made at once to remove the obstruction. If this is not readily done, send for a physician at once. Meanwhile, if there is serious interference with breathing, perform artificial respiration.

FOREIGN BODIES IN THE STOMACH

Foreign bodies, such as pins, coins, nails, and other articles, sometimes are swallowed accidentally or, as in the case of small children or the insane, deliberately. They may lodge in the gullet or the tube leading to the stomach and cause difficulty in swallowing, but more often they pass directly into the stomach.

Do not attempt to dislodge foreign bodies from either the gullet or the stomach. Consult a physician immediately, and leave the treatment to him.

7. DRESSINGS FOR WOUNDS AND BLEEDING

There are probably several ways in which a wound can satisfactorily be dressed; however, for a first aid man the simpliest, effective method should be used.

For the purpose of this text only the various types of wounds and bleeding, for which dressings can be applied, will be given. For details of how to apply these dressings, please refer to the United States Bureau of Mines publication, "First Aid".

The various types of wounds and bleeding are:

Extensive wounds and bleeding of the scalp.
Wound and bleeding of scalp, temple, ear, or face.
Wound and bleeding of forehead or back of head.
Injuries of eye
Wound and bleeding of nose.
Wound and bleeding of chin.
Wound and bleeding of neck or throat.
Wound and bleeding of shoulder.
Wound and bleeding of armpit.
Arm torn from body.
Dressing for amputated arm.
Wound and bleeding of arm, forearm, and wrist.
Wound and bleeding of elbow

Wound and bleeding of palm of hand.
Wound and bleeding of back of hand.
Extensive wounds and bleeding of hand.
Wound and bleeding of finger.
Wound of end of finger.
Wound and bleeding of back between shoulders.
Wound and bleeding of chest between shoulders.
Wound and bleeding of back, chest, abdomen, or side.
Wound and bleeding of lower part of abdomen, lower part of back, of buttocks.
Wound and bleeding of groin.
Wound and bleeding of crotch.
Wound and bleeding of hip.
Wound and bleeding of thigh.
Dressing for amputated thigh or leg.
Wound and bleeding of knee.
Wound and bleeding of leg.
Bleeding from varicose veins in leg.
Wound and bleeding of ankle.
Wound and bleeding of foot.
Extensive wounds and bleeding of foot.
Wound and bleeding of toe.
Wound of end of toe.

8. BURNS AND SCALDS

Burns are usually injuries that result from contact with dry heat (fire or heated objects), electricity (either by current passing through the body or by electric flashes), friction, and chemicals (strong acids or strong alkalis). Injuries that result from contact with hot solutions, hot vapors, or steam are usually considered as scalds.

The seriousness of a burn or scald is influenced by the extent of the body surface involved, as well as by the depth to which the tissues are penetrated. It is generally assumed that, where one-third of the surface of the body is injured by a second-degree burn or scald, death usually follows, but a much smaller area injured by a third-degree burn often endangers life.

Shock is very severe when burns are extensive and may cause death in a few hours. Shock is chiefly responsible for deaths that occur during the first day or two after burns.

a. CLASSIFICATION OF BURNS

Burns are classified as to the degree of injury to the body tissues.

FIRST DEGREE

The outer skin is reddened and there is slight swelling.

SECOND DEGREE

The underskin is affected, and blisters are formed.

THIRD DEGREE

The skin is destroyed, and some tissues underneath are damaged. In severe cases, muscles, nerves, and blood vessels may be destroyed and the whole area charred.

b. TREATMENT

Emergency or first aid care of burns or scalds should primarily be exclusion of air from the burned area; relief of the pain that immediately follows burns; prevention of or minimizing the onset of shock; and prevention of infection.

Remove all clothing from the injured area; but cut around any that adheres to the skin, and leave it in place. As soon as the burned or scalded area has been exposed, cover it by a protective dressing. Picric-acid gauze is one of the most popular burn dressings. It consists of sterile gauze impregnated with a ½ to 1 percent solution of picric acid, dried, and folded to fit into convenient sealed packages. To use it, remove the gauze from the package, moisten it with clean water, place it over the injured area, and hold it in place by a loosely applied bandage. To keep the gauze from drying, the cover bandage may also be kept moist.

First aid dressings for burns or scalds should be free from grease or oil.

When a person has been burned by a chemical, wash the area thoroughly with clean water to dilute the chemical, and then dress it as for a burn.

Frequently chemical substances get into the eye. The treatment is to wash the eye freely with cold water. After the eye has been washed, apply the dressing for injury of the eye. Chemical burns of the eye should receive the attention of an eye specialist as early as possible.

9. FRACTURES

The framework on which the human body is built consists of bones of various sizes and shapes that form the skeleton. A broken bone is called a fracture. There are many types of fractures, but in first aid they are divided into two groups, simple and compound.

In simple fractures the bone is broken, but no wound extends from the broken ends of the bone out through the skin. Usually in simple fractures there is no considerable displacement of the ends of the broken bone; however, by careless or improper handling a simple fracture can be converted into a compound fracture, or by damage to surrounding blood vessels or nerves the injury can be made much more serious.

In compound fractures the bone is broken, and a wound extends from the bone out through the skin. The wound in a compound fracture may be caused by one or both ends of the broken bone being forced out through the tissues and skin or by some object piercing the skin and tissues to the bone and breaking it.

When giving first aid to a patient with a fracture of the extremities, cautiously place the limb in as nearly a natural position as possible by grasping its lower part well below the fracture but not pulling on the limb, while an assistant supports the under part of the limb on either side of the break. Then apply appropriate padded splints, being sure to place extra padding under all hollow spaces, such as knee, ankle, wrist, etc.

Support all fractures except those of the skull, nose, upper and lower jaw, cheekbone, shoulder blade, and ribs until dressing has been completed.

a. LOCATION OF FRACTURES

The location of the various fractures that can be treated by a first aid man are:

Fracture of the skull.
Fracture of the nose.
Fracture of the upper jaw or cheekbone.
Fracture of the lower jaw.
Fracture of the collarbone.
Fracture of the shoulder blade.
Fracture of the upper third of the arm.
Fracture of the lower two-thirds of the arm.
Fracture of the elbow, forearm, or wrist.
Fracture or crushing of the bones of the hand.
Fracture of the fingers.
Fracture of the ribs.
Fracture of the spine.
Broken neck.
Broken back.
Fracture of the pelvis or hip.
Fracture of the thigh, knee, or ankle.
Fracture of the kneecap.
Fracture of the leg
Fracture or crushing of the bones of the boot or toes.

10. DISLOCATIONS

Where two or more bones come together and there is no bony union between them, they form a joint. The several bones forming a joint are held in place by bands of strong, fibrous tissues known as ligaments. There are three varieties of joints: Immovable joints, joints with limited motion, and freely movable joints. In first aid, we are concerned more particularly with the principal free movable joints; the lower jaw, the shoulder, the elbow, the wrist, the fingers, the hips, the knee, the ankle, and the toes. These are the joints most commonly dislocated.

A dislocation is the slipping out of normal position of one or more of the bones forming a joint. The ligaments holding the bones in proper position are stretched and sometimes torn loose. Dislocations result from force applied at or near the joints, from sudden muscular contractions, from twisting strains on joint ligaments, or from falls where the force of landing is transferred to a joint.

Treat all dislocations by applying dressings and splints so that the parts are immoblilized in the line of deformity in which they are found, and obtain medical treatment. Support dislocations, except those of the lower jaw, fingers, and toes. If medical aid is not readily available the first aid man can usually reduce dislocations of the lower jaw, fingers, and toes.

As shock frequently is present in dislocations, treat for it.

11. HANDLING AND TRANSPORTATION OF THE INJURED

After receiving first aid care a seriously injured person often requires transportation to a hospital, to a physician's office, or to his home. No matter how expert the first aid care that has been given, improper handling and careless transportation often add to the severity of the original injuries, increase shock, and frequently endanger life.

Never move a patient until a thorough examination has been made and all injuries are protected by proper dressings. Seriously injured patients should be moved only in lying position. If means for proper transportation of an injured person are not immediately at hand, continue care of the patient to conserve his strength until adequate means of transportation can be procured.

Various carries can be used in emergencies, but the stretcher is the preferred transportation method. Carrying in the arms, carrying astride the back, and the two-man carry should be used only when it is positively known that no injury will be aggravated by such handling of the patient.

12. SUNSTROKE

Sunstroke is a sudden attack of illness from prolonged exposure to the direct rays of the sun or to other high temperatures without exposure to the sun. Those engaged in hard labor in confined quarters are particularly likely to be affected.

a. SYMPTOMS

The attack is sudden, and the patient becomes unconscious rapidly. Unconsciousness may be preceded by intense headache and dizziness. The face is red and flushed. The skin is hot and dry, with no perspiration. The pulse is strong and rapid or even may be bounding in character. Breathing is labored and of a snoring type. The pupils of the eyes are enlarged but of equal size.

b. TREATMENT

Because the body temperature is excessively high, treatment centers around reducing it as quickly as possible. Remove the patient to a cool place, and lay him down with the head raised. Take off as much clothing as necessary, and apply cold applications to the body and the head. Rubbing the patient's limbs toward the heart aids circulation and is important. When the patient is conscious, give him all the cool water he desires. Give no stimulant.

13. HEAT EXHAUSTION

Heat exhaustion is collapse from the effect of heat, either from the sun or any other source. It occurs more frequently when the humidity is high. Heat exhaustion is a serious condition, and proper treatment should be given at once.

a. SYMPTOMS

The patient is seldom unconscious but may complain of feeling very weak. His face is pale and anxious looking and covered with cold perspiration. Frequently he vomits. He may complain of feeling chilly. His pulse is rapid and weak, and his breathing is shallow, with little chest expansion.

b. TREATMENT

The treatment for heat exhaustion is the same as that for physical shock, namely, the patient should be lying down with the head low. Cleanse his mouth, wrap his body in coverings, apply hot applications, use stimulants, rub the extremities, and obtain the services of a physician.

14. HEAT CRAMPS

The loss of the body's salt content (through sweating) from the body fluids excites irritation of the muscles, causing spasmodic or heat cramps.

a. SYMPTOMS

Heat cramps are painful spasms of muscles, especially those of the abdomen and limbs, after prolonged exposure to high temperatures while engaged in strenuous labor. The spasmodic cramps experienced may be simply a slight cramp in the abdomen or muscles of an extremity or so severe as to cause convulsions.

b. TREATMENT

The treatment for mild heat cramps is increased salt intake, warm baths, and rest. If the cramps are severe and persistent, medical care is necessary.

15. FROSTBITE

Frostbite results from exposure to severe cold. The nose, cheeks, ears, toes, and fingers are the parts most frequently frostbitten.

a. SYMPTOMS

Frostbite is more likely to occur when a high wind is blowing, which takes heat from the body rapidly. Usually frostbite is not associated with pain but rather with a feeling of intense coldness and numbness. The victim may not be aware of frostbite of the cheeks, ears, or nose until he removes his gloves or shoes. The frostbitten area is dead white.

b. TREATMENT

Do not rub the part frostbitten nor expose it to high temperatures immediately. As soon as possible the patient should be brought into a warm room. In the meantime the frostbitten part should be covered with woolen cloth and the patient made warm.

After getting the patient in the room the frostbitten part should be rewarmed as rapidly as possible by immersing it in luke warm water. Never hot water. Hot-water bottles or heat lamps should never be used, nor should the affected part be placed near a hot stove.

16. APOPLEXY

Apoplexy, cerebral hemorrhage, or stroke is spontaneous rupture of a blood vessel within the skull, causing a hemorrhage into the brain tissues. It usually occurs in elderly persons.

Besides spontaneous rupture of a blood vessel within the brain, blows to the head may cause cerebral hemorrhage. In all head injuries, symptoms of cerebral hemorrhage should be looked for, and if present the treatment for apoplexy should be administered.

a. SYMPTOMS

The patient usually is unconscious. The face is flushed and warm but sometimes may appear ashen gray. The pulse at first is slow and strong but later becomes rapid and weak. Respiration is slow and snoring in type, the lips and cheeks puffing out at each expiration. The pupils of the eyes are unequal in size, and often one eyelid droops. Frequently the mouth is drawn to one side, and if the patient tries to talk he mumbles out of one side of the mouth. Usually only one side of the body is paralyzed.

b. TREATMENT

Have the patient lying down with the head well-raised. Allow plenty of fresh air, but keep the patient warm with covers. Apply cold applications or an ice bag to the head. Give no stimulants. Keep the patient absolutely quiet, and do not move him unless necessary. Obtain medical care as soon as possible.

17. POISONS

Many substances are poisonous to the human body and gain entrance into it in several ways. A first aid man should be able to care for the commoner poisons and to render general first aid to all cases.

Only the different types of poisons will be given here. Refer to the previous mentioned publication, "First Aid" for symptoms and treatment of the various poisons.

a. POISONING BY MOUTH

For the purpose of first aid, the poisons entering the human body by mouth are divided into three general groups, according to their action: Corrosive poisons, irritant poisons, and systemic poisons.

CORROSIVE POISONS

Corrosive poisons corrode, burn, or eat into the tissues when they come in contact with the mucous membrane of the lips, mouth, throat, gullet, and stomach. Besides the immediate corroding action on the tissues they touch, they excite an inflammatory condition of the deeper tissues and in some instances through absorption exert harmful effects on the entire system.

The more common corrosive poisons are the strong acids (hydrochloric, sulfuric, nitric, oxalic, carbolic, and lysol) and the strong alkalies (potash, soda, lye, unslaked lime, and strong ammonia water).

IRRITANT POISONS

Irritant poisons are substances that, when swallowed, set up irritation within the stomach, manifested by distress, nausea, vomiting, and severe pain. With most of the irritant poisons, these symptoms are caused by direct irritation of the membrane lining the stomach, but with others there is a secondary action through absorption.

The more common irritant poisons are mainly the metals or salts of metals: Antimony, arsenic, copper, iodine, lead, mercury, phosphorus, zinc, and silver nitrate.

SYSTEMIC POISONS

The systemic poisons affect the body as a whole through their action on various systems, organs, or tissues. The systemic poisons are divided into two general groups: The depressant poisons, whose general action is that of a narcotic with progressive lowering of the vital functions of the circulation and respiration, and the convulsant poisons, whose general action produces spasms or convulsions with rapid paralysis of the vital functions of circulation or respiration, or both.

The depressant poisons usually are medicines or drugs that are given to relieve pain or induce sleep but when taken in excess act as poisons.

The more common are opium, morphine, laudanum, and paregoric; also, sleep-producing preparations, such as sleeping powders.

The more common convulsant poisons are nitroglycerin, hydrocyanic acid and the cyanides, and strychnine.

b. POISONS INJECTED WITHIN THE SKIN

Many substances or poisons may enter the body through breaks in the skin, such as infected wounds, drugs injected hypodermically, or bites of rabid animals, poisonous snakes, and poisonous insects. The last three are the only ones discussed here.

BITES OF RABID ANIMALS

Any animal may suffer from rabies. If a person is bitten by an animal, always suspect the animal to be rabid until it is proven otherwise. The saliva from a rabid animal enters the wound caused by the bite and the disease is transmitted to the person bitten. A person bitten by an animal should receive medical attention.

BITES OF POISONOUS SNAKES

Any person bitten by a poisonous snake should have immediate medical attention. The poison from the snake enters the skin through the bite of the snake. This poison is then circulated through the body by the venous circulation system.

The poisonous snakes usually found are the coral snake, the copperhead, the rattlesnake, and the water moccasin.

The effect of a bite of this nature is stinging pain with gradual swelling and discoloration. After the poison has started to circulate, the patient becomes very weak with nausea; has rapid and weak pulse; and a profuse flow of saliva.

BITES AND STINGS OF INSECTS

Many insects bite or sting, but few are poisonous in the sense that their bite or sting can cause serious symptoms of itself. However, there are insects that do transmit disease where the insects act as hosts to an organism or virus of those diseases. As an example, certain types of mosquitoes transmit malaria, yellow fever, and other diseases. Also, certain types of ticks transmit spotted or Rocky Mountain fever. Then there are certain types of biting flies that the bite transmits tularemia or rabbit fever.

BITES AND STINGS OF SPIDERS, CENTIPEDES, TARANTULAS, AND SCORPIONS

The effects of stings and bites from these are much more severe than those of the insects previously mentioned. They may cause alarming symptoms; but, except for bites of tarantulas and black-widow spiders, seldom prove fatal.

The black-widow is a moderately large, glossy, black spider with very fine hairs over the body, giving it a silky appearance. On the underside of the abdomen is a characteristic red or crimson marking in the form of an hour glass. The female only is poisonous; the male, which is much smaller, is harmless.

c. POISONS BY CONTACT WITH SKIN

GASES, FUMES, MISTS, LIQUIDS, AND DUSTS

Many inorganic and organic substances, in the form of gases, fumes, mists, liquids, and dusts, cause poisoning or dermatoses when they come in contact with the skin. Dermatoses are diseases of the skin and its appendages and are characterized by alterations in the normal structure, irritation, and inflammation.

Except in few instances, dermatoses do not progress rapidly but manifest themselves gradually after contined exposure to the agents causing them. Persons who note changes in the normal texture of their skin or continued irritation or inflammation of the skin should seek medical advice before a chronic dermatosis develops.

POISONOUS PLANTS

The most common of these are poison-ivy, poison-oak, and poison-sumac. These poisonous plants grow as vines or, in locations providing favorable soil and moisture, as shrubs, waist to shoulder high. So called poison-ivy and poison-oak are neither ivy nor oak but species of sumac. The poison emanates principally from their leaves but also may be given off from bruising their roots, stems, and berries. The smoke from burning brush containing the plants has been known to carry the poisonous principle some distance.

SECTION 9 QUESTIONS AND ANSWERS

A. FIRE BOSS

1. Q. What, in general, is the responsibility of the fire boss?
   A. To make sure that all working places are safe and that no part of the mine contains noxious or explosive gases, fire hazards, or any other unsafe conditions.

2. Q. Who can qualify as a fire boss in Afghanistan?
   A. A responsible person with 3 years of coal mining experience who has a practical knowledge of mine ventilation, mine gases, mine fires, and mine explosions; and, he must be able to use correctly a flame safety lamp, carbon monoxide detector, and an anemometer.

3. Q. What days should a fire boss examine the mine?
   A. Every day of the year whether the mine is working or not.

4. Q. When should a fire boss examine the mine?
   A. Not more than 3 hours before each shift on working days and every 8 hours on idle days.

5. Q. How should the fire boss mark the entrance to the mine before an examination has been made?
   A. By a red danger sign.

6. Q. When should the danger sign at the entrance of the mine be removed?
   A. When the mine is reported safe by the fire boss.

7. Q. When should the men be permitted to enter the mine?
   A. After the red danger sign has been removed.

8. Q. Who should be permitted to enter the mine before the red danger sign has been removed?
   A. The mine manager, but only in case of necessity.

9. Q. Under what conditions should men be permitted to enter a mine before it has been reported safe by the fire boss?
   A. To help the fire boss make the mine safe, but even then only under the direct supervision of the mine manager.

10. Q. What should a fire boss look for in examining a mine?
    A. Anything which would make the mine unsafe such as roof conditions, mine gases, ventilation, mine temperatures, and fire and explosion hazards.

11. Q. What should the fire boss do if he finds an unsafe condition during his examination?
A. He should do or cause to be done whatever may be necessary to remove or correct the dangerous condition which he found.

12. Q. How can the management be sure that the fire boss has examined the entire mine?
A. The fire boss shall leave evidence, including date, of every place he examined.

13. Q. How many fire bosses are required?
A. At least one for every operating mine.

14. Q. What instrument should be carried by a fire boss at all times?
A. A flame safety lamp.

1. FLAME SAFETY LAMP

15. Q. Who should carry a flame safety lamp at all times?
A. The mine manager, the mine foreman, the section foreman, the fire boss, the shot firer, the engineer, and any person that enters the mine who is not accompanied or preceeded by a person carrying a flame safety lamp.

16. Q. What is the operational principle of the flame safety lamp?
A. The behavior of the flame.

17. Q. What type of a lock should be used on a flame safety lamp?
A. A magnetic lock.

18. Q. What is the best fuel to use in the flame safety lamp?
A. Hydrocarbons high in hydrogen such as Naphtha or Heptane.

19. Q. What should be done with flame safety lamps before they are used?
A. They should be cleaned, filled, examined, locked, and tested by a competent person.

20. Q. When can you be sure a flame safety lamp will not cause an explosion?
A. When it is properly designed, properly assembled, and properly used.

21. Q. When should a flame safety lamp be opened inside of a mine?
A. Never.

22. Q. If a flame safety lamp becomes extinguished, what procedure should be followed in relighting it?
A. The lamp should be taken to fresh air and relighted with the internal igniter.

23. Q. What is the lowest percentage of methane that can usually be detected with a flame safety lamp?
A. 1 percent.

24. Q. How can you estimate the percentage of methane in the mine air when using a flame safety lamp?
A. By the height of the "gas cap" or the elongation of the flame.

25. Q. What percentage of oxygen must be present in the mine air for a flame safety lamp to be reliable in the detection of methane?
A. At least 20 percent.

26. Q. What percentage of oxygen must be present in the mine air to keep the flame of a flame safety lamp burning?
A. At least 16 percent if the atmosphere is free of methane or other combustible gases, or at least 13 percent regardless of the amount of combustible gases in the atmosphere.

27. Q. How should a flame safety lamp be handled during tests?
A. It should be raised slowly so as to explore the atmosphere from the bottom upwards.

28. Q. What should be done with the flame safety lamp if methane is detected during testing?
A. The lamp should be slowly withdrawn from the gaseous atmosphere.

29. Q. When testing for methane with a flame safety lamp, which is the most reliable, the normal flame or the cap flame?
A. The cap flame.

30. Q. What influence does different fuels burned in a flame safety lamp have upon the height of the "gas cap" in the same percentage of methane?
A. The height of the "gas cap" depends upon the temperature of the flame; the temperature of the flame depends upon the type of fuel used.

2. ANEMOMETER

31. Q. What is an anemometer?
A. It is an instrument used to measure the velocity of an air current in mine airways.

32. Q. What length of time is a reading usually taken?
A. 1 minute.

33. Q. What does the number of revolutions as recorded on the face of the dial tell you?
A. Each revolution corresponds to one lineal foot of air travel; therefore, the number of revolutions recorded in a minute tells you the velocity of the air in feet per minute.

34. Q. From this reading of feet per minute, how do you determine the quantity of air traveling through the airways?
A. By taking the reading of the anemometer times the cross sectional area, in square feet, of the airway at the place where the reading was taken gives the quantity of air passing in cubic feet per minute.

3. CARBON MONOXIDE DETECTOR

35. Q. What is a carbon monoxide detector used for?
A. To detect the presence of carbon monoxide gas in the air.

36. Q. What chemicals make up what is known as Hoolamite?
A. Hoolamite is a mixture of iodine pentoxide and sulphuric acid on granular pumice stone.

37. Q. What color is hoolamite?
A. White

38. Q. How do you tell whether or not there is any carbon monoxide in the air?
A. When carbon monoxide comes into contact with hoolamite, iodine is liberated changing the white granulars to bluish green of increasing depths.

39. Q. How do you determine the percentage of carbon monoxide in the air?
A. After squeezing the bulb the required number of times (usually 10), compare the resulting color of the granulars of hoolamite with the permanent colors in the color tube and note the corresponding percentage of carbon monoxide.

40. Q. Is the hoolamite carbon monoxide detector a continuous carbon monoxide detector?
A. No, the detector must be operated by squeezing the bulb the required number of times each time a test is desired.

B. VENTILATION

1. Q. What is the best defense against coal mine fires and explosions?
   A. Adequate and proper ventilation.

2. Q. What is one way of telling when a ventilating system is adequate?
   A. When there is sufficient air at the working face for the number of men working at the face.

3. Q. How much fresh air does a working man require?
   A. Between 30 and 40 cubic feet per minute.

4. Q. Is this amount sufficient for a working man underground in a coal mine.
   A. No, because oxygen is absorbed by the coal, by the oxidation of the timbers, and a sufficient amount of air is needed to sweep away gases which may be found in his working place.

5. Q. How much air should be supplied for each and every man working underground in a coal mine?
   A. On an average, 150 cubic feet of air per minute per man at the working face.

6. Q. How much air should be passing through the last cross cut in a well ventilated mine?
   A. 6000 cubic feet of air per minute.

7. Q. Approximately how much of the air entering a mine should reach the working face?
   A. At least 50 percent.

8. Q. What instrument is used to measure the amount of air traveling in a mine?
   A. A standard anemometer.

9. Q. Where should the air in a mine be measured each day by the mine foreman?
   A. At the last cross cut or break-thru nearest the working face of each split of air.

10. Q. When picking the exact spot to take an air reading, what should a person look for?
    A. He should be sure the place selected has smooth walls, easy to get to, and easy to measure the cross-sectional area.

11. Q. When measuring the air flow, should the anemometer be held in the center of the entry?
    A. No, the anemometer should be moved around the entire cross-sectional area to be sure of getting a good average.

12. Q. When measuring the air with an anemometer is one reading sufficient?
A. No, 3 readings should be taken and averaged.

13. Q. What does the reading of an anemometer tell you?
A. The velocity of the air in feet per minute.

14. Q. What unit of measure should be used when determining the cross-sectional area at the place where the reading with the anemometer was taken?
A. Square feet.

15. Q. How do you determine the quantity of air flowing in cubic feet per minute?
A. Multiply the velocity of the air (feet per minute) by the cross-sectional area (square feet).

1. VENTILATING SYSTEM

16. Q. How many openings into a mine must there be to have a ventilating system?
A. At least two.

17. Q. How far apart should these two openings be?
A. At least 50 feet.

18. Q. What is the object of a ventilating system?
A. To have an adequate quantity of air delivered to, and then removed from, the working face.

19. Q. What are the two types of ventilating systems?
A. The split system and the continuous current system.

20. Q. What 3 basic considerations should be taken into account when establishing a ventilation system?
A. (1) the length and condition of the airways, (2) leakage of air between the intake and return, and (3) distribution of the air to the various working places by splitting the air current.

21. Q. When should a mine be ventilated by one continuous current of air?
A. Only when the mine is very small.

22. Q. What advantages does a split system of ventilation have over a continuous current system of ventilation?
A. (1) a much larger volume of air can be circulated without increasing the power, (2) the different sections of the mine can be isolated, (3) the effects of fires and explosions are more likely to be localized, (4) interruptions to air flow in one split will not seriously affect other splits, (5) efficiency of the entire ventilating system will be improved, and (6) the system is very flexible and can be controlled easier.

23. Q. What is ventilating pressure?
A. It is the difference between the intake pressure and the discharge pressure.

24. Q. What purpose does this ventilating pressure have in the ventilating system?
A. It is the force which circulates the air current around the various parts of a mine.

25. Q. What are the two methods used today to create this ventilating pressure?
A. The blowing and the exhaust systems.

26. Q. What, in general, is the principal of the blowing system?
A. The fan creates a pressure above that of the atmosphere and the air is blown through the airway by the pressure created.

27. Q. What, in general, is the principal of the exhaust system?
A. The fan reduces the pressure below that of the atmosphere and the air flows through the airways toward the fan.

28. Q. How is this ventilating pressure measured?
A. By an instrument known as a water gage.

29. Q. What, in general, is the principal of the water gage?
A. The water gage consists of a "U" tube half filled with water. One side of the "U" is exposed to the air on the intake airway of the ventilating system and the other side of the "U" is exposed to the return airway; the difference between the water level of one side of the "U" and that of the other side, in inches, is the water gage reading. This difference then is the ventilating pressure.

30. Q. Where will the water gage reading be the greatest, between the intake and the return airway near the entrance to the mine or between the intake and the return airway near the working face?
A. Near the mine entrance.

31. Q. Exactly what does this difference in water gage reading mean in relation to the ventilating system?
A. A high water gage reading means that it will take more pressure to push the air through the mine than a low water gage reading.

32. Q. What is mine resistance?
A. It is the resistance to the flow of air offered by an airway.

33. Q. What are the two kinds of mine resistance?
A. Natural resistance and artificial resistance.

34. Q. What is natural resistance?
A. It is the friction caused by the rubbing of the air on the inner surface of the airway.

35. Q. What is artificial resistance?
A. It is the resistance caused by the air current striking against obstructions such as timbers, roof falls, constrictions in the airway, etc.

36. Q. What effect does mine resistance have on the ventilating system?
A. The more the resistance the higher the water gage reading or the ventilating pressure.

37. Q. How is the direction and quantity of air flow controlled in a mine?
A. It is carried out by the use of stoppings, doors, overcasts, undercasts, line brattices, seals, regulators, and check curtains.

38. Q. What is a stopping used for?
A. A stopping is a wall or barrier placed in an opening to prevent the flow of air through that opening; thereby, conducting the air along the proper airway.

39. Q. When is a door used?
A. A door is used in place of a stopping when the mining operation requires travel through the entry where a stopping would ordinarily be placed.

40. Q. What are overcasts used for?
A. An overcast is used to carry one current of air over another, usually return air over intake air.

41. Q. What are undercasts used for?
A. An undercast is used to carry one current of air under another, usually return air under intake air.

42. Q. How big should an overcast or an undercast be?
A. They should have a cross-sectional area equal to or greater than the cross-sectional area of the entry approaching and leaving the overcast or undercast.

43. Q. What is a line brattice used for?
A. It is used to direct the flow of air from the last cross cut to the working face.

44. Q. What are seals used for?
A. Their use is mainly to seal off old and abandoned areas to keep the bad air from these areas from mixing with the regular ventilating current. They are also used to isolate fire and explosion areas.

45. Q. What are regulators?
A. They are usually small sliding doors placed in a stopping.

46. Q. What are regulators used for?
A. They are used to control the amount of air so that each split will have sufficient air for its needs.

47. Q. Where are regulators usually placed?
A. In the return airway of a split as near to the main return airway as possible.

48. Q. What are check curtains used for?
A. They usually consist of one or more layers of brattice cloth and are often used in place of a temporary door or stopping.

2. SPLITTING THE AIR

49. Q. What does splitting the air mean?
A. It is the dividing of the main air current into two or more separate ventilating currents, each separate current ventilating a different district or section of the mine.

50. Q. Does each separate ventilating current or split have the same quantity of air?
A. No, each split is supplied with the correct amount of air that is needed on that particular district or section. This is done by the use of regulators.

51. Q. Are smokes and gases given off in one district of a mine carried to other districts by the air current in a split system of ventilation?
A. No, they go directly to the main return and thence to the outside.

52. Q. What is required in order to split an air current?
A. All that is required is to have two or more separate routes for the air to follow.

53. Q. What is natural splitting?
A. When all airways or routes are open for the free passage of air. The portion for each route being determined by the amount of mine resistance in that route.

54. Q. What is controlled splitting?
A. When regulators are placed in the various splits to control the amount of air passing through these splits.

55. Q. How do regulators control the amount of air passing through the various splits?
A. Regulators create more resistance; thereby, letting more air go through another split. This amount of resistance is varied until the right amount of air is passing through all splits.

56. Q. What is a free split?
A. The split which does not have a regulator.

57. Q. What is primary splitting?
A. When two or more splits are taken off of the main air current.

58. Q. What is secondary splitting?
A. When two or more splits are taken off of a primary split.

3. MINE FANS

59. Q. What is the most important factor in a ventilating system?
A. The fan.

60. Q. Can a mine be satisfactorily ventilated without a fan?
A. No.

61. Q. Can a mine be satisfactorily ventilated with a fan that operates only part time?
A. No.

62. Q. What are the two different types of fans?
A. Centrifugal and axial-flow.

63. Q. What is a centrifugal fan?
A. It is a fan that has its blades set at right angles to the plane of revolution.

64. Q. What type of blades does the centrifugal fan have?
A. They can be either radial (paddle) blades or inclined to the radius either forward in the direction of revolution, or backward.

65. Q. Can centrifugal fans be either exhaust or blowing?
A. Yes.

66. Q. What is an axial-flow fan?
A. It is a fan in which the path of the air flow is parallel to the axis of the fan rotor.

67. Q. What type of fans are the disk and the propeller?
A. Axial-flow fans.

68. Q. What is the latest type of axial-flow fan?
A. The propeller type.

69. Q. What advantages does this type of fan have?
A. (1) high efficiency, (2) ease of reversing, (3) low initial cost, (4) adjustable blades, and (5) suitable for direct drive.

70. Q. Does the location of the fan have any influence on the mechanical efficiency of the fan?
A. No, because the mechanical efficiency is based on the size of the fan and the mine resistance.

71. Q. Is the location of the main mine fan important with respect to the mine openings?
A. Yes, for two very definite reasons; (1) the fan must be offset from the mine opening by at least 15 feet and (2) the fan must be located so that the return air cannot be drawn into the intake openings.

72. Q. Why should the main mine fan be offset at least 15 feet?
A. Because if the fan was placed in a direct line with the mine openings it may be damaged in the event of a mine explosion.

73. Q. What are explosion doors?
A. They are doors placed in a direct line with the mine opening in which the fan is located. These doors would open and relieve much of the force of a mine explosion; thereby, giving more protection to the mine fan.

74. Q. Should fans be run continuously or only when men are in the mine?
A. They should always be run continuously because intermittent operation of a fan is often responsible for accumulations of explosive atmospheres or the overheating of a portion of the mine.

75. Q. If the mine fan stops, what should be done with the men working in the mine?
A. They should be withdrawn from the mine and not allowed to re-enter until ventilation has been restored and the mine pronounced safe by a fire boss.

76. Q. What is a booster fan?
A. A fan which raises the pressure, either positive or negative, of the air current at the point where the pressure imparted by the main fan is insufficient to force the air current into distant parts of the mine.

77. Q. Where should a booster fan be placed?
A. On the intake airway.

78. Q. What is an auxiliary fan?
A. Small portable fans, usually electrical, with canvas tubes or metal pipes attached.

79. Q. Where are auxiliary fans used?
A. They are used to ventilate headings or narrow workings that are without cross cuts.

80. Q. Are booster and auxiliary fans used in a properly planned ventilation system?
A. No, they should never be part of the standard ventilation system; however, they can be used for emergencies or under exceptional conditions.

C. COAL MINE GASES

1. AIR

1. Q. In a mine where gas has never been detected, can you assume that gas will never be found?
A. No, because there is always the possibility that gas will occur.

2. Q. Is the composition of pure dry air the same in Washington, D. C., U.S.A., as it is in Kabul, Afghanistan?
A. Yes, providing the air is free from smokes, fumes or products of breathing in a closed room.

3. Q. For all practical purposes, what are the two gases which air is composed of?
A. Oxygen and nitrogen.

4. Q. Is air a chemical or mechanical mixture of gases?
A. A mechanical mixture.

5. Q. What is the most important gas known?
A. Oxygen, because without it life cannot exist.

6. Q. What is the composition of the air exhaled from the human body?
A. About 16.3 percent oxygen, 79.3 percent nitrogen, and 4.4 percent carbon dioxide.

7. Q. Is the composition of the air that leaves a mine the same as that which enters the mine?
A. No, the air loses some of its oxygen and gains carbon dioxide and any other gas that might be present in the mine.

8. Q. How does the air lose some of its oxygen?
A. By the breathing of men and animals, by the coal and timbers absorbing some, and by oxidation of fine particles of sulphur which is included in some coal seams.

9. Q. What is the lost oxygen largely replaced by?
A. Carbon dioxide gas.

10. Q. Where does the carbon dioxide come from that is found in mine air?
A. From the exhaled air of men and animals, from the coal, and from decaying timbers.

11. Q. What other gases besides carbon dioxide are liable to be found in the mine air which leaves a mine?
A. Methane, carbon monoxide, and hydrogen sulphide.

12. Q. Where does the carbon monoxide come from that is found in the mine air?
A. During normal operation it comes from the gases given off when blasting, and from any internal combustion engines that may be running in the mine. Also, during a fire or an explosion, large amounts of carbon monoxide are liberated.

13. Q. Where does the methane come from that is found in the mine air?
A. It is liberated from the coal seam.

14. Q. Where does the hydrogen sulphide come from that is found in mine air?
A. From stagnant water or by emission from the strata.

15. Q. What is the moisture in the air called?
A. Water vapor.

16. Q. Is the proportion of water vapor always the same in mine air?
A. No, it varies with temperature and pressure.

17. Q. Which air carries the most water vapor, hot or cold?
A. Hot.

18. Q. Is the mine drier in the summer or the winter?
A. Winter, because the cold air entering the mine takes up moisture as it is warmed by the floor, roof, and ribs of the mine.

2. PHYSICAL PROPERTIES OF GASES

19. Q. What is specific gravity?
A. It is the relative weight of a substance as compared to some standard.

20. Q. What is the standard for liquids and solids?
A. Water

21. Q. What is the standard for gases?
A. Air.

22. Q. How much does a cubic foot of water weigh?
A. Approximately 62.5 pounds.

23. Q. If a certain coal has a specific gravity of 1.5, how much will a cubic foot of this coal weigh?
A. 1.5 x 62.5 = 93.75 pounds.

24. Q. How many pounds in a short ton?
A. 2000.

25. Q. How many cubic feet will a ton of coal with a specific gravity of 1.5 occupy?
A. 2000 ÷ (1.5 x 62.5) = 2000 ÷ 93.75 = 21.3 cubic feet.

26. Q. What is meant when we say that carbon dioxide has a specific gravity of 1.53?
A. It means that a given volume of carbon dioxide will be 1.53 times as heavy as the same volume of air at the same temperature and pressure.

27. Q. Is it important that the temperature and pressure of the gas and the air be the same when considering specific gravity?
A. Yes, because gases expand when heated; therefore, it is possible that a gas which is heavier than air under the same conditions of temperature and pressure may be lighter than air if heated sufficiently.

28. Q. What is diffusion of gases?
A. It is the gradual mixing of two or more gases which are in contact with each other.

29. Q. Is the diffusion of gases dependent on the specific gravity of the gases?
A. No, a heavy and a light gas will diffuse just the same as two gases with the same specific gravity.

30. Q. After gases have become mixed by diffusion, will they separate?
A. No.

31. Q. Why does this property of diffusion make it possible to remove gases from a mine?
A. Because all gases will diffuse with the mine air and be carried to the outside by the air current.

32. Q. What is meant by occlusion of gases?
A. It is the absorption of gases by solids.

33. Q. What is the significance of occlusion to the coal miner?
A. Coal, a solid, occludes gas, mainly methane.

34. Q. How much gas can coal occlude?
A. It has been found that the volume of gas occluded in the coal may be two times the volume of the coal itself.

3. MINE GASES

a. OXYGEN

35. Q. What is the chemical symbol for oxygen?
A. O.

36. Q. What is the specific gravity of oxygen?
A. 1.105.

37. Q. Is oxygen combustible?
A. No.

38. Q. Will oxygen support combustion?
A. Yes.

39. Q. Will oxygen support life?
A. Yes.

40. Q. Is oxygen poisonous?
A. No.

41. Q. Does oxygen have any color?
A. No.

42. Q. Does oxygen have any odor?
A. No.

43. Q. Does oxygen have any taste?
A. No.

44. Q. If the percentage of oxygen in the air is reduced to 15 percent, what effect does it have on a man?
A. Practically none.

45. Q. If the percentage of oxygen in the air is reduced below 15 percent, what effect does it have on a man?
A. At first his breathing becomes deeper and more frequent, his pulse faster, and his face becomes somewhat dusky; however, as the percentage continues to decrease his life becomes in danger.

46. Q. What happens to the flame of a candle or a wick-fed flame when the percentage of oxygen is decreased to 15 percent?
A. The flame will be extinguished if the air is free of any combustible gas.

47. Q. Does a small reduction in the percentage of oxygen have any effect on the flame of a flame safety lamp?
A. Yes, at 19 percent oxygen the light given by the safety lamp is only about one-third of the amount emitted at 20.94 percent oxygen.

b. NITROGEN

48. Q. What is the chemical symbol of nitrogen?
A. N.

49. Q. What is the specific gravity of nitrogen?
A. 0.967.

50. Q. Is nitrogen combustible?
A. No.

51. Q. Will nitrogen support combustion?
A. No.

52. Q. Will nitrogen support life?
A. No.

53. Q. Is nitrogen poisonous?
A. No.

54. Q. Does nitrogen have any color?
A. No.

55. Q. Does nitrogen have any odor?
A. No.

56. Q. Does nitrogen have any taste?
A. No.

57. Q. What is the main function of nitrogen in air?
A. To dilute the oxygen of the air so combustion will not take place so rapidly and so that people will not be injured by breathing pure oxygen continuously.

58. Q. Can you detect nitrogen with a flame safety lamp?
A. No, only the lack of oxygen or the presence of methane.

59. Q. For all practical purposes, can we assume the air usually contains at least 79 percent nitrogen?
A. Yes.

c. METHANE

60. Q. What is the chemical symbol for methane?
A. CH_4

61. Q. What is the specific gravity of methane?
A. 0.555.

62. Q. Is methane combustible?
A. Yes.

63. Q. Will methane support combustion?
A. No.

64. Q. Will methane support life?
A. No.

65. Q. Is methane poisonous?
A. No.

66. Q. Does methane have any color?
A. No.

67. Q. Does methane have any odor?
A. No.

68. Q. Does methane have any taste?
A. No.

69. Q. By what other names is methane known?
A. Marsh gas, gas, fire damp, and light carburetted hydrogen.

70. Q. Is methane a chemical mixture or a chemical compound?
A. It is a chemical compound made up of one atom of carbon combined with four atoms of hydrogen -- (CH_4).

71. Q. Why is methane found in almost all coal seams?
A. Coal represents the remains of plants that grew many years ago and methane is formed by the decomposition of vegetable matter under water; therefore, as coal was being formed, methane was also being formed.

72. Q. How does methane escape from the coal seam?
A. By coming through the pores of the coal and through small fissures or cracks in the coal.

73. Q. Why does methane tend to be found in holes or cavities in the roof of a coal mine?
A. Because it is about half as heavy as air and tends to rise to the top --specific gravity of methane is 0.555.

74. Q. Even though methane is light and tends to rise, it will nevertheless diffuse with the mine air; however, what will help and speed up this diffusion?
A. A good ventilating air current.

75. Q. What is an explosion?
A. Very rapid combustion.

76. Q. When will methane explode?
A. When the mixture of methane and air is in the proper proportions, the mixture will burn very rapidly or explode.

77. Q. What is the explosive range of a methane-air mixture?
A. Between 5 and 15 percent methane and at least 12.1 percent oxygen.

78. Q. At what percent methane will the explosion be the most violent?
A. At 9 percent.

79. Q. Why is the explosion of a methane-air mixture the most violent at 9 percent methane?
A. Because the mixture has just enough oxygen to burn all of the methane almost instantaneously.

80. Q. At approximately what temperature will methane be ignited?
A. About 1000 degrees Fahrenheit.

81. Q. In a methane-air mixture where the percentage of methane is less than 5, will it explode?
A. No, however it will greatly increase the chances of a dust explosion if fine coal dust is in suspension in the mine air.

82. Q. How is the most practical way to detect methane in mine air?
A. With a flame safety lamp.

d. CARBON DIOXIDE

83. Q. What is the chemical symbol for carbon dioxide?
A. CO_2.

84. Q. What is the specific gravity of carbon dioxide?
A. 1.529.

85. Q. Is carbon dioxide combustible?
A. No.

86. Q. Will carbon dioxide support combustion?
A. No.

87. Q. Will carbon dioxide support life?
A. No.

88. Q. Is carbon dioxide poisonous?
A. No.

89. Q. Does carbon dioxide have any color?
A. No.

90. Q. Does carbon dioxide have any odor?
A. No.

91. Q. Does carbon dioxide have any taste?
A. Yes, an acid taste when moist and present in considerable quantity.

92. Q. In a coal mine where are the 6 places where carbon dioxide comes from?
A. (1) it is given off by the coal, (2) it comes from the breathing of men and animals, (3) it comes from fumes of explosives, (4) it comes from decaying timbers, (5) it comes from the action of oxygen on the carbon of the coal, and (6) it is always a product of combustion, therefore, always present after a mine fire or an explosion.

93. Q. Why is carbon dioxide said to be the regulator of our breathing?
A. Because an increase in the amount of carbon dioxide breathed results in an increase of breathing.

94. Q. At what percentage of carbon dioxide will a person first notice a deeper and more frequent breathing?
A. At approximately 3 percent.

95. Q. At what percentage of carbon dioxide will a person notice a marked panting and a rapid pulse?
A. Between 5 and 6 percent.

96. Q. At what percent of carbon dioxide will a person notice a violent panting, throbbing, and flushing of the face?
A. At approximately 10 percent.

97. Q. If a person breaths air containing 12 to 15 percent carbon dioxide, What effect will it have on him?
A. The person will soon become unconscious.

98. Q. Is a flame safety lamp an indicator of carbon dioxide?
A. No, it only indicates a lack of oxygen.

99. Q. What name do miners commonly attach to carbon dioxide?
A. Black damp; however, black damp is actually a mixture of carbon dioxide and nitrogen.

100. Q. Approximately what are the percentages of carbon dioxide and nitrogen in average black damp?
A. Between 10 and 15 percent carbon dioxide and 85 to 90 percent nitrogen.

101. Q. What is choke damp?
A. Approximately the same as black damp except it probably contains a higher percentage of carbon dioxide.

e. CARBON MONOXIDE

102. Q. What is the chemical symbol for carbon monoxide?
A. CO.

103. Q. What is the specific gravity of carbon monoxide?
A. 0.967.

104. Q. Is carbon monoxide combustible?
A. Yes.

105. Q. Will carbon monoxide support combustion?
A. No.

106. Q. Will carbon monoxide support life?
A. No.

107. Q. Is carbon monoxide poisonous?
A. Yes, extremely so.

108. Q. Does carbon monoxide have any color?
A. No.

109. Q. Does carbon monoxide have any odor?
A. No.

110. Q. Does carbon monoxide have any taste?
A. No.

111. Q. What other names is carbon monoxide known by?
A. White damp and carbonic oxide gas.

112. Q. How is carbon monoxide formed?
A. It is always a product of incomplete combustion.

113. Q. What is incomplete combustion?
A. Where there isn't sufficient oxygen present to completely burn all the carbon.

114. Q. Where in a coal mine would you have incomplete combustion?
A. Mine fires and explosions; the explosion of black blasting powder, permissible powder, and dynamite; and, the exhaust gases from gasoline engines.

115. Q. Why is carbon monoxide combustible?
A. Because carbon monoxide is a product of incomplete combustion, it can still take up more oxygen and burn to carbon dioxide.

116. Q. Will carbon monoxide explode?
A. Yes, under certain conditions.

117. Q. Under what conditions will carbon monoxide explode?
A. In mixtures of air and carbon monoxide where the carbon monoxide is between 15 and 73 percent.

118. Q. Why are explosions caused by carbon monoxide uncommon in coal mines?
A. Because carbon monoxide is very seldom found in any considerable quantity.

119. Q. Are minute percentages of carbon monoxide harmful to a person?
A. Yes, if breathed for a few hours.

120. Q. What effect would breathing 0.1 percent carbon monoxide have on a person?
A. He would be unable to walk in about 2 to $2\frac{1}{4}$ hours if at rest; but, if walking instead of resting his legs would give way in about an hour.

121. Q. Does carbon monoxide poisoning give any warning to a person?
A. No, a person usually just goes into unconsciousness, then death.

122. Q. In an atmosphere containing 0.5 percent carbon monoxide, how long would it take a person to become unconscious?
A. After a few breaths had been taken.

123. Q. What color flame does carbon monoxide burn with?
A. A pale blue flame.

124. Q. Can carbon monoxide be safely detected by using a flame safety lamp?
A. No, because no gas cap could be seen unless at least 1 percent carbon monoxide was present.

125. Q. What is the most practical working test for carbon monoxide?
A. The use of small birds such as canaries, if modern CO detectors are not available.

126. Q. Will a small bird such as a canary be affected by carbon monoxide before a human?
A. Yes, usually a canary or small bird will fall from its perch before sufficient carbon monoxide is present to effect a man.

127. Q. Are there any other methods for detecting carbon monoxide?
A. Yes, several mechanical detectors have been developed.

128. Q. What is afterdamp?
A. It is a mixture of gases resulting from a mine fire or explosion.

f. HYDROGEN SULPHIDE

129. Q. What is the chemical symbol for hydrogen sulphide?
A. H_2S

130. Q. What is the specific gravity of hydrogen sulphide?
A. 1.191

131. Q. Is hydrogen sulphide combustible?
A. Yes.

132. Q. Will hydrogen sulphide support combustion?
A. No.

133. Q. Will hydrogen sulphide support life?
A. No.

134. Q. Is hydrogen sulphide poisonous?
A. Yes.

135. Q. Does hydrogen sulphide have any color?
A. No.

136. Q. Does hydrogen sulphide have any odor?
A. Yes, that of rotten eggs.

137. Q. Does hydrogen sulphide have any taste?
A. Yes, a slightly sweetish.

138. Q. By what name do the miners usually call hydrogen sulphide?
A. Stink damp.

139. Q. Can minute quantities of hydrogen sulphide be detected easily?
A. Yes, by the sense of smell.

140. Q. Where, in general, is hydrogen sulphide found around a coal mine?
A. It is sometimes given off by stagnant water, it is sometimes detected in afterdamp, and it is sometimes found in water which seeps into a mine.

141. Q. At approximately what temperature does hydrogen sulphide ignite?
A. At about 500 degrees Fahrenheit.

142. Q. Is hydrogen sulphide usually found in large quantities in coal mines?
A. No, it is very seldom found in dangerous quantities.

143. Q. Is air containing 0.05 percent hydrogen sulphide dangerous?
A. Yes, at this percentage such things as giddiness and vomiting will occur.

144. Q. What percentage of hydrogen sulphide in air would cause death in about an hour?
A. About 0.07 percent hydrogen sulphide.

g. ACETYLENE OR CARBIDE GAS

145. Q. What is the chemical symbol for acetylene or carbide gas?
A. C_2H_2

146. Q. What is the specific gravity of carbide gas?
A. 0.906.

147. Q. Is carbide gas combustible?
A. Yes.

148. Q. Will carbide gas support combustion?
A. No.

149. Q. Will carbide gas support life?
A. No.

150. Q. Does carbide gas have any color?
A. No.

151. Q. Does carbide gas have any odor?
A. Yes, peculiar and characteristic.

152. Q. Does carbide gas have any taste?
A. No.

153. Q. Is carbide gas poisonous?
A. No, but if breathed in large quantities would cause suffocation.

154. Q. Is acetylene or carbide gas ever found naturally in a coal mine?
A. No.

155. Q. Does a miner ever come into contact with carbide gas in a coal mine?
A. Yes, the gas which comes from the carbide lamps used by miners is carbide gas.

156. Q. What is the chemical formula for what most miners simply call "carbide"?
A. CaC_2 or calcium carbide.

157. Q. What is the principle of a carbide lamp?
A. Water (H_2O) comes into contact with calcium carbide (CaC_2) and the chemical product is carbide gas (C_2H_2) and slaked lime (CaO).

158. Q. At what temperature will carbide gas ignite?
A. Approximately 650 degrees Fahrenheit.

159. Q. Is acetylene or carbide gas explosive?
A. Yes.

160. Q. What is the explosive range of carbide gas?
A. From 3 to 73 percent acetylene or carbide gas.

161. Q. What is the best way to insure against an explosion caused by carbide gas?
A. Keep all calcium carbide stored outside of the mine.

h. HYDROGEN

162. Q. What is the chemical symbol for hydrogen?
A. H.

163. Q. What is the specific gravity of hydrogen?
A. 0.070.

164. Q. Is hydrogen combustible?
A. Yes.

165. Q. Will hydrogen support combustion?
A. No.

166. Q. Will hydrogen support life?
A. No.

167. Q. Is hydrogen poisonous?
A. No, but if breathed in its pure state would cause suffocation.

168. Q. Does hydrogen have any color?
A. No.

169. Q. Does hydrogen have any odor?
A. No.

170. Q. Does hydrogen have any taste?
A. No.

171. Q. Where might hydrogen be encountered in a mine?
A. Small quantities occassionally are produced by explosives and by explosions; however, the most important source is the charging of storage battery locomotives where the electric current breaks down water into hydrogen and oxygen.

172. Q. What color is the flame of burning hydrogen?
A. Almost colorless.

173. Q. Is a mixture of air and hydrogen explosive?
A. Yes.

174. Q. What is the explosive range of hydrogen?
A. Between 10 and 66 percent hydrogen.

175. Q. Is there any simple or practical test for hydrogen?
A. No.

i. OXIDES OF NITROGEN

176. Q. What is the most irritating oxide of nitrogen?
A. Nitrogen peroxide.

177. Q. What is the chemical symbol for nitrogen peroxide?
A. NO_2.

178. Q. What is the specific gravity of nitrogen peroxide?
A. 1.589.

179. Q. What is the color of nitrogen peroxide?
A. Reddish.

180. Q. What is the odor associated with nitrogen peroxide?
A. A burned-powder odor.

181. Q. Where do the oxides of nitrogen come from in a mine?
A. From the burning, afterburning, and, under certain conditions, the detonation of high explosives.

182. Q. What effect on man does the breathing of oxides of nitrogen ha[illegible]
A. They corrode the respiratory passage, and the breathing of rel-
atively small amounts may cause death.

183. Q. What percent of nitrogen peroxide is fatal if breathed for about a half hour?
A. 0.07 percent.

184. Q. What are "shucked" explosives?
A. Those with the wrapper removed from the cartridge.

185. Q. Why should "shucked" explosives never be used?
A. Because they usually produce harmful percentages of oxides of nitrogen even when detonated properly.

j. SULPHUR DIOXIDE

186. Q. What is the chemical symbol for sulphur dioxide?
A. SO_2.

187. Q. What is the specific gravity of sulphur dioxide?
A. 2.264.

188. Q. Does sulphur dioxide have any color?
A. No.

189. Q. Is sulphur dioxide a suffocating gas?
A. Yes.

190. Q. Does sulphur dioxide have a smell?
A. Yes, a strong pungent, sulphurous smell.

191. Q. Where in a mine is sulphur dioxide liable to be noticed?
A. It may be given off by explosives or it may be present in gob fires in which iron pyrite is burning.

192. Q. Is sulphur dioxide poisonous?
A. Yes.

193. Q. Can you usually detect sulphur dioxide before it reaches concentrations that are dangerous?
A. Yes, it is so irritating to the eyes and the respiratory passages that it is very noticeable before it reaches dangerous concentrations.

4. DETECTION OF MINE GASES

194. Q. What is the most common detector used for detecting the presence of methane in the mine air?
A. The flame safety lamp.

195. Q. Name the 3 most common types of electrical methane detectors.
A. M.S.A. methane detector (AP-6), M.S.A. methane detector type W-8, and M.S.A. methane detector type E-2.

196. Q. What, in general, is the principal of operation of the M.S.A. methane detectors?
A. The detectors have a balanced electrical bridge with the filament made of activated platinum. This filament is heated by an electric current which burns any methane which comes into contact with it. The burning of the methane increases the temperature and electrical resistance of the filament; this change of resistance unbalances the electrical circuit of the instrument. The amount of unbalance is proportional to the amount of methane present and is so indicated on a graduated scale.

197. Q. What supplies the electric current to the methane detectors?
A. A standard electric cap lamp battery.

198. Q. What percentage range of methane can be detected with these 3 M.S.A. detectors?
A. From 0 to 5 percent.

199. Q. What is the M.S.A. methane alarm?
A. An electrical instrument which samples the mine air continuously and gives warning when a dangerous concentration of methane is present in the mine air.

200. Q. What bird or animal is the best live detector for carbon monoxide gas?
A. The canary bird.

201. Q. Once a canary has been used to detect carbon monoxide, can the same bird be used again?
A. Yes, tests have shown that a canary does not lose its susceptibility to carbon monoxide after repeated exposures.

202. Q. How are canaries used to detect carbon monoxide gas?
A. A canary will show symptoms of distress and usually fall from its perch before the concentrations of carbon monoxide is dangerous to man.

203. Q. What mechanical carbon monoxide detectors are in common use?
A. The Iodine Pentoxide or Hoolamite detector, the M.S.A. colorimetric carbon monoxide detector, and the M.S.A. hand-operated carbon monoxide indicator.

204. Q. What is the difference between the detector tubes of the hoolamite and the colorimetric carbon monoxide detectors?

A. In the hoolamite the tube contains white granular impregnated pumice stone and in the colorimetric the tube contains a yellow silica gel.

205. Q. What, in general, is the operating principal of the hoolamite and the colorimetric carbon monoxide detectors?

A. When air containing carbon monoxide is passed through the detector tubes, the material in the tubes changes color. This color change then is the basis for determining the percentage of carbon monoxide present in the air.

206. Q. What, in general, is the operating principal of the M.S.A. hand-operated carbon monoxide indicator?

A. An air sample is first dehydrated and then brought into contact with the chemical "hopcalite" which changes any carbon monoxide into carbon dioxide. The heat generated by this chemical reaction is directly proportional to the amount of carbon monoxide present in the air sample and is measured by differential thermocouples.

207. Q. What is one instrument used to detect hydrogen sulphide?

A. The M.S.A. hydrogen sulphide detector.

208. Q. What, in general, is the operating principal of the M.S.A. hydrogen sulphide detector?

A. A sample of air is passed through a detector tube containing silver cyanide ($AgCN_3$) on activated alumina (Al_2O_3), if there is any hydrogen sulphide present in the air it will react with the silver cyanide and turn the white granules to a dark gray. The percentage is then determined by comparing the resulting gray to a standard color chart.

209. Q. How can the percentage of oxygen be determined accurately?

A. The only accurate way is to collect and analyze air samples.

210. Q. Is there any quick test for determining the rough percentage of oxygen in mine air?

A. Yes, in the hands of an experienced user, the action, color, and illuminating power of the flame of a flame safety lamp indicates roughly the amount of oxygen within a range of 20.94 to 16 percent.

211. Q. How can the percentage of carbon dioxide be determined accurately?

A. Only by collecting and analyzing a sample of air.

212. Q. What, in general, is the operating principal of the M.S.A. sulphur dioxide detector?

A. A sample of air is pulled through a detector tube containing reagent granules which are turned white if any sulphur dioxide is present in the air. The length of travel of the discoloration is proportional to the concentration of sulphur dioxide.

5. PROTECTION AGAINST MINE GASES

213. Q. What is the best method of protection against mine gases during the normal operation of a mine?
A. By adequate ventilation.

214. Q. What are the four methods used for protection against carbon monoxide gas?
A. (1) erection of baricades, (2) self-rescuer, (3) self-contained oxygen breathing apparatus, and (4) gas masks.

215. Q. Can all four of these methods be used in an atmosphere deficient in oxygen?
A. No, only the self-contained oxygen breathing apparatus.

D. COAL MINE EXPLOSIONS

1. Q. Can explosions be completely eliminated in coal mines?
A. No, because of the inherent dangers which exist in the mining of coal.

2. Q. What are the three usual classificiations of coal mine explosions?
A. (1) gas explosions, (2) coal-dust explosions, and (3) a combination of gas and coal-dust explosions.

1. GAS (Methane) EXPLOSIONS

3. Q. What three factors are necessary to produce a gas explosion?
A. (1) sufficient oxygen in the air, (2) between 5 and 15 percent methane in the air, and (3) a source of ignition.

4. Q. If a variation occurs in any one of the three factors necessary to produce a gas explosion, will an explosion still take place?
A. No, at least it is very unlikely even though the other two factors are "right" for an explosion.

5. Q. What are usually given as the explosive limits of a methane-air mixture?
A. From 5 to 15 percent methane.

6. Q. Are these explosive limits of a methane-air mixture always the same?
A. No, certain factors change the limits to an extent.

7. Q. What factors can change the explosive limits of a methane-air mixture?

A. The atmospheric pressure of the mixture, the temperature of the mixture, the presence of carbon dioxide in the mixture, and a decrease in the oxygen content of the mixture.

8. Q. What is the source of ignition of a gas explosion?

A. Heat.

9. Q. What type of heat must be present to ignite a gas explosion?

A. An open flame such as a match, an electrical arc, or a spark.

10. Q. Will any open flame ignite a gas explosion?

A. No, the flame must be hot enough and last long enough.

11. Q. How hot must the flame be to be the source of ignition of a gas explosion?

A. At least 1000 degrees Fahrenheit.

2. COAL DUST EXPLOSIONS

12. Q. Will coal dust explode by itself?

A. Yes, providing it comes into contact with a source of ignition and is dense enough.

13. Q. What happens if there is methane in the mine air in relation to a coal dust explosion?

A. It increases the possibility of a dust explosion and also makes a dust explosion more violent when it does occur.

14. Q. Is coal dust always explosive?

A. No, only when it is raised in a dense cloud.

15. Q. Must the dense cloud of coal dust be large to be explosive?

A. No, only dense surrounding the source of ignition.

16. Q. Once a dust explosion occurs, does it require a dense cloud to spread it through out the mine?

A. No, because the pressure produced by the explosion raises additional dust in advance of the flame and thus carries along or propagates the explosion.

17. Q. What are the seven factors that usually influence dust explosions?

A. (1) size of the coal dust particles, (2) composition of the coal dust, (3) amount of methane in the mine air, (4) quantity and concentration of the coal dust, (5) distribution of the coal dusts, (6) source and type of ignition, and (7) the surrounding conditions.

18. Q. What size of coal dust particles are the most explosive?
A. The finer the coal dust, the more explosive.

19. Q. Generally speaking, what size of bituminous coal dust particles are explosive?
A. Those that are finer then 20-mesh (0.025 inch openings).

20. Q. What is in the composition of a coal dust mixture that influences its explosibility?
A. Incombustible material and volatile matter.

21. Q. What effect on the explosibility of a coal dust mixture does incombustible material have?
A. The higher the percentage of incombustible material the less explosive the mixture until at 65 percent incombustible material the mixture will not explode.

22. Q. What is volatile matter in relation to coal?
A. It is the gassy matter given off by coal when heat is applied.

23. Q. What effect on the explosibility of a coal dust mixture does volatile matter have?
A. The higher the percentage of volatile matter in the combustible part of the coal dust the more explosive the mixture.

24. Q. What percentage of volatile matter in the combustible part of a coal dust mixture is needed to make the mixture explosive?
A. Over 12 percent.

25. Q. What effect on the explosibility of a coal dust mixture does the presence of methane in the mine air have?
A. The presence of a small percentage of methane will increase the explosibility. The higher the percentage, the more explosive.

26. Q. On an average, how much coal dust must be present in the dense dust cloud immediately surrounding the source of ignition to cause a coal-dust explosion?
A. More than 0.05 ounces of coal dust per cubic foot of air space.

27. Q. What effect on a coal dust explosion would a larger concentration of coal dust have?
A. The larger the concentration the more violent the explosion.

28. Q. Why is the coal dust that is distributed on the ribs, overhead timbers, cribbing, and lagging more dangerous than dust found on the bottom?
A. Because it is much finer and because the dust on the bottom is usually mixed with shale, sand, and other incombustible material.

29. Q. What source and type of ignition can propagate a coal dust explosion?
A. The source can be the agency that raises the dust from its resting place, such as a local gas explosion or certain blasting powders; also, such things as a match, open light, electrical arc, or a spark. Regardless of the source, the heat to ignite or propagate an explosion must be an open flame.

30. Q. What effect does the surrounding conditions have on a coal dust explosion?
A. The surfaces of the entries may be coal or rock, hard or friable, wet or dry, rough or smooth, or timber lined; these conditions will add inert dust, add more fuel, or change the rate at which the heat is absorbed from the moving flame of the explosion.

3. PREVENTION OF COAL MINE EXPLOSIONS

31. Q. How can coal mine explosions be reduced?
A. By eliminating as nearly as possible all gas, coal dust, and sources of ignition.

32. Q. What generally can be done to help eliminate gas, coal dust and sources of ignition?
A. Adequate ventilation, use of water, use of rock dust, eliminate use of open lights, use of permissible explosives, and safe use of electrical equipment.

33. Q. How does adequate ventilation help to reduce coal mine explosion hazards?
A. By diluting and making harmless any methane that may be given off and by carrying away coal dust so as to prevent it from reaching dangerous concentrations.

34. Q. How does the use of water help eliminate coal mine explosion hazards?
A. Coal dust that is wet will cling together making the formation of a dense dust cloud difficult.

35. Q. Where should water be sprayed on the coal?
A. At the working face and at loading points because it is here that most of the coal dust is formed.

36. Q. Will wet coal dust explode?
A. Yes, if it comes into contact with a source of ignition and is in a dense cloud; therefore, water prevents coal dust explosions only when it wets the dust enough to prevent a dust cloud.

37. Q. What is rock dust?
A. Limestone or gypsum ground very fine so that all of it will pass through a screen having 20 openings per lineal inch and 60 percent of it will pass through a screen having 200 openings per lineal inch.

38. Q. How does the use of rock dust help eliminate a coal mine explosion?
A. Rock dust is incombustible and a coal dust mixture containing 65 percent incombustible material will not explode.

39. Q. If methane is present in the mine air, will 65 percent incombustible material still prevent an explosion?
A. No, for every 0.1 percent methane in the mine air 1 percent incombustible material should be added to the 65 percent.

40. Q. What should be done to a mine before it is rock dusted?
A. All accumulations of fine coal should be loaded out and the passageways sprayed with water.

41. Q. How much of the mine should be rock dusted?
A. All of it up to within 40 feet of the working face.

42. Q. What portion of the passageways should be rock dusted?
A. The top, bottom, and ribs.

43. Q. Once a mine is rock dusted, does it ever have to be rock dusted again?
A. Yes, all rock dusted areas should be maintained so as to have at least 65 percent incombustible material in a sample of a coal dust mixture taken from the roof, bottom, or ribs.

44. Q. How often should a mine be rock dusted to maintain 65 percent incombustible material?
A. Every 3 months to a year depending on the amount of coal dust present in the mine.

45. Q. How is rock dust applied to the roof, bottom, and ribs of a coal mine?
A. It can be applied by hand or by air pressure machines that blow the rock dust through tubing which can be directed on the roof, bottom, and ribs.

46. Q. Should men applying rock dust wear any type of respirator?
A. Yes, they should wear a dust respirator to prevent the fine rock dust from getting into their lungs.

47. Q. How much rock dust is needed to be sure there is 65 percent incombustible material in a coal dust mixture?
A. As a general rule about 3 to 4 pounds of rock dust per lineal foot; however, the only sure way is to take a sample after rock dusting to be sure of the 65 percent.

48. Q. What is one way in which some of the sources of ignition can be eliminated?
A. By prohibiting the use of open lights in a mine (use permissible electric cap lamps), by searching the men before they go in a mine to be sure they are not carrying any matches or smoking materials, and being sure that all flame safety lamps are correctly assembled and in the hands of an experienced person.

49. Q. What are permissible explosives?

A. Explosives that produce a flame that is comparatively short in length and duration and has a lower combustion temperature than regular dynamite.

50. Q. Does the use of permissible explosives eliminate the danger of an explosion caused by blasting?

A. No, but it will reduce the frequency of explosions due to blasting.

51. Q. What are some of the ways in which electricity is responsible for the ignition of explosions?

A. Arcs and sparks from the electrical parts of cutting, drilling, and loading machines; trolley wires and other power conductors caught under falls of roof or ribs; short circuits of poorly insulated electric conductors; sparks and arcs from electric trolley locomotives; etc.

52. Q. What can be done around a coal mine to help eliminate the electrical source of ignition of an explosion?

A. Use only permissible electric equipment, maintain all equipment in a permissible manner, inspect and repair all electrical conductors frequently, and permit only experienced electricians to inspect and repair electrical equipment and conductors.

4. COURSE OF ACTION AFTER AN EXPLOSION

53. Q. Do the men working in a mine need to know the entrances and exits other than those that they use every day?

A. Yes, because when an explosion occurs the regular exits may be closed and the men, if they don't know of another exit, may be trapped unnecessarily.

54. Q. If a man underground survives an explosion, what can he do?

A. He can take a chance on getting out of the mine or he can erect a barricade and remain in the mine until rescued.

55. Q. What are two main hazards that threaten a miner that has survived an explosion?

A. The asphyxiation by carbon monoxide and suffocation from lack of oxygen.

56. Q. What is a self-rescuer?

A. It is a respirator that removes the hazard of carbon monoxide for one-half hour or more.

57. Q. What is the primary purpose of the self-rescuer?

A. It is to help miners escape at times of mine fires or explosions by providing temporary protection from carbon monoxide gas.

58. Q. Can the self-rescuer be worn in atmospheres deficient in oxygen?
A. No, self-rescuers cannot and must not be worn where there is insufficient oxygen to support life.

59. Q. Generally speaking, when there is a fire or an explosion, is there sufficient oxygen to support life?
A. Yes, because a fire usually would not burn in an atmosphere deficient in oxygen.

60. Q. What is a barricade?
A. It is a sealed off refuge chamber for men trapped in a mine after an explosion.

61. Q. How large should a barricaded area be?
A. As large as possible.

62. Q. Approximately how much space, for air, does a man require in a confined space?
A. He will require about one cubic yard of air an hour.

63. Q. In a barricaded area should all men remain at rest all the time?
A. Yes, except one person should walk around occasionally to mix the air.

E. COAL MINE FIRES

1. Q. Can fires in coal mines be completely eliminated?
A. No, because of the highly combustible nature of coal, timber, explosives and other material usually abundant in coal mines.

2. Q. When bituminous coal is heated or burned, what is liberated?
A. Volatile constituents that are flammable and explosive.

3. Q. Can this volatile matter liberated during a fire make a non-gassy mine gassy?
A. Yes, a mine that under normal conditions does not liberate explosive gas may during a fire become an extremely gassy mine.

4. Q. During a mine fire, what dangers or hazards are encountered?
A. The danger of a gas explosion; the hazard of a small gas explosion setting off a large coal dust explosion; the danger that a fall of roof may throw a dense cloud of coal dust into the air which will come into contact with the flame of the fire and ignite or propagate a coal dust explosion; the danger that a roof fall will injure or kill men engaged in fighting or sealing the fire; and, the danger of men being asphyxiated by smoke, fumes, and poisonous gas.

1. CAUSES OF MINE FIRES

5. Q. What are the primary causes of mine fires?
   A. Electricity, open flames, explosions, friction, spontaneous combustion, and possibly incendiarism.

6. Q. What are the two primary electrical causes of mine fires?
   A. Electrical arcs and short circuits.

7. Q. Where in a mine are electrical arcs liable to be found?
   A. From electrical parts of cutting, drilling, and loading machines and from the trolley poles of electric locomotives.

8. Q. How can an electric arc or a short circuit start a mine fire?
   A. If the arc comes into contact with combustible material or the short circuit occurs in an electrical conductor that is in contact with combustible material.

9. Q. How is a mine fire usually started by an open flame?
   A. The open flame comes into contact with the coal, paper, wood, oily rags, or other combustible material and a fire results.

10. Q. What may happen if a weak detonator is used to set off an explosive charge?
    A. It may cause the explosive to burn instead of exploding, thus setting fire to the coal.

11. Q. How has black blasting powder caused mine fires?
    A. It has caused many a mine fire because of the long-flame which is produced when the powder is exploded; and also, black blasting powder itself is easily ignited by an open flame and for this reason can be the cause of mine fires.

12. Q. Should black blasting powder be stored inside of a mine?
    A. No, unless it is stored in a fire proof container.

13. Q. Generally speaking, how can friction start a mine fire?
    A. The heat generated by, or a spark produced from, friction has caused a fire when this heat or spark came in contact with combustible material.

14. Q. What are two ways a hoisting rope can cause friction?
    A. By the rubbing of the rope on a "frozen" roller and by the rope being improperly guided and continuously rubbing on a mine timber.

15. Q. What is spontaneous combustion of coal?
    A. It is the self-ignition of coal caused by the heat produced from a chemical change that takes place when certain coals are loose and finely divided.

16. Q. Does the composition of the coal have any bearing on whether or not spontaneous combustion will take place?
A. Yes, it has been proven that the composition of coal has much to do with its liability to heat and take fire spontaneously.

17. Q. How deep must the finely divided coal dust be before there is danger of spontaneous combustion?
A. In some coals, heating will result and fire occur when the coal dust has collected to only a small depth.

18. Q. What is incendiarism in relation to coal mine fires?
A. The starting of a mine fire intentionally.

2. PREVENTION OF MINE FIRES

19. Q. What type of electric motors should always be used inside a coal mine?
A. Permissible electric motors.

20. Q. How should permissible electric motors be maintained?
A. In a permissible condition at all times.

21. Q. Where should electric trolley locomotives not be used?
A. In any atmosphere where the arc from the trolley pole is liable to ignite a gas-air mixture.

22. Q. In an atmosphere where gas is known to be present, what type of electric locomotives should be used?
A. A permissible battery locomotive.

23. Q. When should electric conductiors or wires be replaced?
A. At the first sign of wear or at any time they are damaged during the mining operations.

24. Q. How is the best way to prevent a mine fire from being ignited by an open flame?
A. To prohibit any open flame inside the mine.

25. Q. What type of explosive should be used in a coal mine to minimize the danger of a mine fire being ignited during the blasting operation?
A. Permissible blasting powder.

26. Q. What is the maximum number of holes that should be fired at one time when blasting in a coal mine?
A. One.

27. Q. What precautions should be taken to minimize the danger of the friction caused by a hoisting rope igniting a mine fire?
A. See that all hoisting ropes are properly guided and that all rollers and guides are working properly.

28. Q. What are the three most important ways to minimize the danger of mine fires being ignited by spontaneous combustion?
A. (1) adequate ventilation to carry away any heat formed by chemical reaction, (2) not allowing any waste material such as old timbers, ties, oily rags, and papers to accumulate, and (3) not allowing any coal dust to accumulate.

3. FIGHTING MINE FIRES

29. Q. Can all mine fires be fought in the same way?
A. No, each fire has its own characteristics and must be fought accordingly.

30. Q. What are the three most common methods of controlling and fighting mine fires?
A. (1) direct attack, (2) enclosing the fire area with tight seals, and (3) flooding the fire area with water.

31. Q. What is the best method of fighting a mine fire?
A. By direct attack, if possible.

32. Q. Why is it not always possible to fight a mine fire by direct attack?
A. Because of late discovery; lack of water, materials, equipment, or essential facilities; or, improper procedure in the early stages of the fire.

33. Q. What are the common ways of fighting a mine fire by direct attack?
A. Water, fire extinguishers, and rock dust.

34. Q. How can water be made available in a mine where it is not possible to pipe it to all working faces?
A. By the use of water boxes.

35. Q. What is a water box?
A. A storage for water, they can be mounted on wheels and transported on the mine track, or they can be in the form of barrels and stored at regular intervals through out the mine.

36. Q. What other equipment should be stored with each water box?
A. Two large buckets, and if possible a hand pump with at least a 50 foot piece of flexible hose attached.

37. Q. What type of fire extinguisher should be used on a fire when it is first discovered?

A. During the first few minutes of a fire almost any fire extinguisher will put it out unless a large quantity of gas is burning.

38. Q. What are the 4 common types of portable fire extinguishers used around coal mines?

A. (1) soda-acid, (2) carbon tetrachloride, (3) foam-type, and (4) carbon dioxide.

39. Q. What, in general, is the principal of the soda-acid fire extinguisher.

A. Carbonic gas is generated by the chemical action of acid on soda, then the carbonic gas forces the water in the tank through the hose and nozzle.

40. Q. Approximately how far away from the fire is the soda-acid portable fire extinguisher effective?

A. Between 30 and 40 feet.

41. Q. Should the soda-acid fire extinguisher be used on electrical fires?

A. No, because water is an electrical conductor; therefore, there is an electrical shock hazard to the person using the extinguisher.

42. Q. Can a carbon tetrachloride fire extinguisher be used on an electrical fire?

A. Yes, because carbon tetrachloride is a non-conductor of electricity.

43. Q. Are the vapors from carbon tetrachloride dangerous?

A. Yes, because these vapors may be decomposed by the heat thus producing hydrochloric acid, chlorine, or phosgene, all of which are dangerous to the respiratory system.

44. Q. When should a carbon tetrachloride fire extinguisher not be used?

A. This type of extinguisher should not be used unless there is a sufficient ventilating current to carry away the carbon tetrachloride vapors.

45. Q. What, in general, is the principal of the foam-type fire extinguisher?

A. It produces a foam blanket containing carbon dioxide which when spread over the surface of a fire smothers it.

46. Q. What chemicals are used in the foam-type fire extinguisher?

A. An aqueous solution of sodium bicarbonate containing a foaming ingredient in the outer tank and an aqueous solution of aluminum sulfate in the inner cylinder.

47. Q. Should the foam-type fire extinguisher be used on electrical fires?

A. No, because the foam is an electrical conductor the same as water.

48. Q. Approximately how far away from the fire is the foam-type portable fire extinguisher effective?

A. Between 30 and 40 feet.

49. Q. What, in general, is the principal of the carbon dioxide fire extinguisher?

A. Liquid carbon dioxide under very high pressure is gasified, by the reduction of pressure, when it is released from the heavy-duty steel cylinder of the fire extinguisher; the resulting gas cloud and carbon dioxide snow settles over the fire and smothers it.

50. Q. Approximately how far away from the fire is the carbon dioxide portable fire extinguisher effective?

A. Between 6 and 8 feet.

51. Q. What type of portable fire extinguisher should be used on an electrical fire?

A. A fire extinguisher filled with carbon tetrachloride.

52. Q. What type of portable fire extinguisher should be used on an oil or other petroleum product fire?

A. The foam-type fire extinguisher.

53. Q. Where should fire extinguishers be stored in a mine?

A. A small portable fire extinguisher filled with carbon tetrachloride should be stored on each and every electrical machine and a soda-acid or foam-type portable fire extinguisher should be available at all working places.

54. Q. What type of fire extinguishers should be stored near a gasoline engine?

A. A foam-type fire extinguisher and a small carbon tetrachloride fire extinguisher.

55. Q. Is rock dust effective in fighting fires?

A. Yes, it is effective in fighting all fires when they first start.

56. Q. Why is rock dust effective in fighting mine fires?

A. The fine limestone rock dust covers the fire and smothers it; and, at the same time, the heated limestone dust gives off carbon dioxide which also aids in smothering the fire.

57. Q. Should rock dust, other than that used for actual rock dusting, be stored in the mine?

A. Yes, a liberal supply should be stored near each working face and at all places through out the mine where a fire might start.

58. Q. When direct fire fighting is impracticable, what is the most effective method for controlling and extinguishing a mine fire?

A. To enclose the affected region with tight seals.

59. Q. Why does sealing the affected area with tight seals extinguish the fire?

A. It excludes the air from the fire and extinguishes it through the lack of oxygen necessary to support combustion.

60. Q. When sealing a mine, why should temporary seals be built and all men removed from the mine?

A. Because behind the seals there develops a race between decreasing oxygen and increasing methane and if the methane wins an explosion may result.

61. Q. What is the greatest uncontrollable factor in fighting mine fires?

A. The amount of methane distilled from the coal by the heat of the fire.

62. Q. After the temporary seals have been built and it is sure that an explosion will not occur, where should the permanent seals be built?

A. They should be built in a place where the roof is sound and unlikely to be distrubed.

63. Q. When building the permanent seals, what provision should be made in the seals themselves?

A. Provisions for sampling gases and for taking water-gage and temperature readings behind the seals.

64. Q. What can defeat the efforts to deplete oxygen and make the fire difficult or impossible to extinguish?

A. Leaks around or through the seals, cracks or breaks in the roof from the fire area to the ventilated part of the mine; also, any breaks to the surface from the fire area.

65. Q. When should samples of the atmosphere in a sealed fire area be taken?

A. Only when the pressure is outward from the seals because if samples are collected when the pressure is inward they can be contaminated by the air outside the seals.

66. Q. How often should samples of air behind the fire seals be collected?

A. Once every 24 hours for several days after the fire.

67. Q. When the analysis of the air behind the seals shows a gradual and continual decrease of oxygen, what does this indicate?

A. It indicates that the seals are tight.

68. Q. What does the presence of carbon monoxide in the mine air behind the fire seals indicate?

A. It indicates an active or a recently active fire.

69. Q. What does the absence of carbon monoxide in the mine air behind the fire seals indicate?

A. It indicates that the flame and active combustion probably have ceased.

70. Q. Does carbon dioxide influence the explosive range of methane-air mixtures when it is found within a sealed area?

A. No, the influence of carbon dioxide on the explosive range of methane-air mixtures within a sealed area is very slight.

71. Q. What should the percentage of oxygen be reduced to within a sealed area before the area is unsealed?

A. To at least 12 percent, and preferable reduced to below 3 percent.

72. Q. What two factors must be considered before a fire can be controlled by flooding?

A. (1) the fire location must be such that water pumped into the mine will flood the affected area, and (2) there must be enough water available for flooding.

73. Q. Why should a mine fire be controlled by flooding only as a last resort after direct attack and sealing have failed?

A. Because of the uncertainty of the effectiveness of flooding and because of the damage done to the mine and equipment by flooding.

74. Q. If a fire is small when first discovered, what should the person do who discovered it?

A. He should use water, rock dust, fire extinguishers, or whatever is at hand to smother it and at the same time call for help.

75. Q. If a fire is large when first discovered, what should the person do who discovered it?

A. He should call all sections of the mine by telephone, if available, or he should run to the nearest men, telling them of the fire and have them spread the word through out the mine.

76. Q. What should the mine foreman (who should be notified immediately) do when the men notify him that the mine is on fire?

A. He should immediately notify the mine manager and notify and organize the fire fighting party.

77. Q. What men should be allowed in the mine?

A. Only those men that are actually engaged in fighting the fire should be allowed in the mine.

78. Q. If it is decided to reverse the fan, when should this be done?

A. Within 10 or 15 minutes after the fire starts as later is generally to late to accomplish anything.

79. Q. Who should authorize the reversing or stopping of the mine fan?

A. The man officially and legally in charge of the mine.

80. Q. What equipment is available for the protection of fire-fighters?

A. self-contained oxygen breathing apparatus, and all-service gas masks.

81. Q. Should fire-fighters carry a self-rescuer along with their other protective equipment?

A. Yes, because in the event of failure of the self-contained oxygen breathing apparatus or the all-service gas mask the self-rescuer will provide protection for at least a half hour providing there is sufficient oxygen.

4. UNSEALING MINE FIRES

82. Q. Is unsealing a mine fire considered a hazardous job?

A. Yes.

83. Q. What is the premature opening of a sealed mine fire most frequently due to?

A. The lack of knowledge of the inherent dangers involved and to extreme eagerness to restore the sealed area to a production basis.

84. Q. What are the four most important factors that govern the time involved between sealing and unsealing a mine fire?

A. (1) the oxygen content within the sealed area, (2) the carbon monoxide content within the sealed area, (3) the extent and intensity of the fire at the time of sealing, and (4) the character of the burning material.

85. Q. Which type of fire will cause the oxygen content within the sealed area to diminish the most rapid -- an active fire or a smoldering fire?

A. An active fire.

86. Q. Why does the extent and intensity of the fire at the time of sealing effect the time involved between sealing and unsealing a mine fire?

A. The extent and intensity of the fire determines how long is required for the area to cool down after the fire becomes inactive.

87. Q. What are the factors that may influence the rekindling of a mine fire when fresh air is admitted?

A. The character of the burning material, the rate of burning, and the change of gas composition.

88. Q. What coals burn faster and are more likely to rekindle when fresh air is admitted?

A. Those that are high in volatile-combustible matter.

89. Q. What type of material should the fire seals be made?

A. Incombustible.

90. Q. When building a fire seal, what provisions should be made for collecting air samples within the sealed area?

A. Pipes with suitable valves, reducers, etc., should be placed in the seals as they are being built.

91. Q. If the percentage of oxygen within the sealed area does not decrease constantly, what is usually the reason?

A. It is usually due to leaky stoppings or breaks in the strata permitting air to enter the sealed area.

92. Q. Is it advisable to erect double stoppings when sealing a mine fire?

A. Yes, as this will help prevent leaky stoppings and also help prevent the fire from burning around the stoppings.

93. Q. Do temperatures on the outward side of seals indicate the temperature within the sealed area?

A. Not necessarily; however, if the outward side of the seal is hot it is evident that the temperature within the sealed area is high.

94. Q. What are the 7 preparations which must be made before a sealed area can be unsealed?

A. (1) an organization must be formed including completely equipped oxygen breathing-apparatus and gas mask crews, (2) only those people that are actually part of the organization should be permitted in and around the area, (3) all necessary equipment and material should be assembled outby the sealed area, (4) all electric current should be shut off, (5) all slopes, entries, cross cuts, etc. near the sealed area should be heavily rock dusted, (6) all brattices needed to insure that the air from the sealed area will go directly to the outside should be erected before the area is opened, and (7) an attendant should be conveniently located to warn the men if the fan does not continue to operate properly.

95. Q. What are the 2 methods generally used for recoverying a sealed area?

A. Recovery by use of air locks and recovery by use of reventilation.

96. Q. When is the air lock method preferred?

A. When the fire area is large, the fire inaccessible, or bodies are to be recovered.

97. Q. When is the reventilation method preferred?

A. When the fire area can be explored by rescue crews under reasonably safe conditions and where there is every indication that the fire has been extinguished.

98. Q. What is an air lock?

A. It consists of two stoppings about 15 feet apart each equipped with doors, one of which must be kept closed at all times.

99. Q. What, in general, is the principal of the air lock system of recovery?

A. An airlock is constructed outby the fire seal on the intake side; then, fully equipped oxygen-breathing apparatus crews advance through the air lock, remove the fire seal, and explore ahead for approximately 500 feet. If all is well, another air lock is built here, the first air lock removed, and the 500 foot area reventilated. After this is completed, the process is repeated again and again until the whole sealed area is reventilated.

100. Q. What, in general, is the principal of the reventilation system of recovery?

A. An air lock is constructed outby the fire seal on the intake side; then, a fully equipped oxygen-breathing apparatus crew advances through the air lock, removes the fire seal, and explores the fire area. If all is well, the fire seal on the return side is removed and the doors of the air lock opened.

F. RESCUE AND RECOVERY OPERATIONS

1. Q. What are the most important things for a successful rescue and recovery operation following a mine fire or explosion?

A. (1) efficient organization, (2) adequate and proper equipment, (3) sufficient materials, and (4) proper procedure.

1. ORGANIZATION

2. Q. When should the organization of mine rescue and recovery crews take place?

A. Before a fire or an explosion occurs.

3. Q. Who should be notified in the event of a fire or an explosion?

A. All mine officials, oxygen breathing apparatus and gas mask crews, doctors, and other government officials connected with mining.

4. Q. What precautions should be taken before men are permitted to enter a mine after a fire or an explosion?

A. All men should be searched for matches, lighters, and other smoker's articles; arrangements should be made to check all men in and out of the mine; permit only permissible equipment to be carried by the men; and issue flame safety lamps only to those authorized to use them.

5. Q. Who should be in charge of each underground shift?

A. A man experienced in mine rescue and recovery operation.

6. Q. What should be marked on the up-to-date mine map furnished by the engineer to the man in charge of the shift as recovery work progresses?

A. Areas explored; stoppings erected; ventilation restored; location of bodies, cars, pumps, mining equipment, and falls; and any other important data.

7. Q. Why should the change of underground shifts be made as quickly as possible?
A. To prevent interruption of the work.

8. Q. What is the minimum number of oxygen breathing apparatus crews that should be employed underground during rescue and recovery operations?
A. At least two.

9. Q. When an oxygen breathing or gas mask crew is working, where should a reserve oxygen breathing apparatus crew be stationed?
A. At the fresh air base.

10. Q. What are the duties of the brattice crew?
A. To erect in fresh air, temporary stoppings or line brattices where necessary.

11. Q. What are the duties of the track crew?
A. To repair and clean track in order to facilitate the movement of material to the advance workers.

12. Q. What are the duties of the material crew?
A. To handle and transport material such as brattice cloth, boards, timbers, etc., from the mine portal to the advance crews.

13. Q. What other crews are necessary in a properly organized mine rescue and recovery operation?
A. Timbermen, laborers to clean up falls, electricians, stretcher bearers, and first aid men.

14. Q. Who is in charge of the foremen in charge of the brattice crew, the track crew, the material crew, the other various crews?
A. The person in charge of the underground shift.

15. Q. Who is the person in charge of the underground shift responsible to?
A. The person in charge of the rescue and recovery operations.

16. Q. Who should be permitted underground during rescue and recovery operations?
A. Only those directly engaged in the operation.

17. Q. What personnal should the surface organization include?
A. The personnel necessary to handle the equipment and material required in the underground work; to provide facilities for housing and feeding the underground and surface workers; and to adequately operate the general headquarters, the lamp house, the apparatus room, and the emergency hospital.

2. EQUIPMENT

18. Q. What equipment should be available for rescue and recovery crews?
    A. Protective, detective, lighting, and fire-fighting.

19. Q. What type of equipment should be available to protect the rescue and recovery crews?
    A. Self-contained oxygen breathing apparatus, all-service gas masks, and self-rescuers.

20. Q. What type of equipment should be available to furnish adequate light for the crews?
    A. Permissible electric cap lamps, permissible flash lights, and permissible flood lights.

21. Q. What type of equipment should be available to detect the various mine gases?
    A. Permissible flame safety lamps, carbon monoxide detectors, methane detectors, and gas-analysis outfits.

22. Q. What type of fire-fighting equipment should be available for use of the crews?
    A. Portable fire extinguishers, rock dust, and water or water boxes.

23. Q. What miscellaneous type of equipment should be available for use?
    A. Maps, hand tools, telephones, locomotives, cars, animals, pumps, anemometers, thermometers, water gages, oxygen inhalers, stretchers, first-aid equipment, life lines, buckets, etc.

24. Q. What type of equipment will protect the wearer against poisonous mine gases regardless of concentration or against atmospheres containing little or no oxygen?
    A. Only the self-contained oxygen breathing apparatus.

25. Q. Name the different types of self-contained oxygen breathing apparatus available today.
    A. Two-hour McCaa, M.S.A. one-hour oxygen breathing apparatus, M.S.A. demand apparatus, and M.S.A. chemox oxygen breathing apparatus.

a. McCaa 2-HOUR SELF-CONTAINED OXYGEN BREATHING APPARATUS

26. Q. What are the essential parts of the McCaa?
    A. Steel cylinder or oxygen bottle containing oxygen, valves to control pressure and circulation, cooler, rubber breathing bag, breathing tubes, mouthpiece, and regenerator.

27. Q. What is the pressure of the oxygen in the steel cylinder?
    A. 2250 pounds per square inch.

28. Q. What is the function of the by-pass valve?
A. To furnish oxygen direct to the wearer independent of other working parts.

29. Q. What is the function of the reducing valve?
A. To reduce the high pressure of the oxygen bottle to a lower pressure suitable for breathing.

30. Q. What controls the admission valve?
A. The demand of the wearer's lungs.

31. Q. When the wearer inhales, how does the oxygen get from the oxygen bottle to the wearer?
A. The oxygen goes from the oxygen bottle through the closing valve to the reducing valve; thence from the reducing valve through the supply tube and the metal tube in the cooler to the admission valve. From the admission valve the oxygen goes to the breathing bag then to the cooler then through the inhalation tubes to the inhalation valve in the mouthpiece. The oxygen then goes from the mouth piece to the lungs through the wearer's mouth.

32. Q. When the wearer exhales, were does the exhaled air go?
A. On exhalation the air passes through the exhalation valve, the exhalation tube, and on into the bottom of the regenerator. From the regenerator through the "cardoxide" to the cooler where it is enriched with pure oxygen supplied through the admission valve. Then the air passes to the breathing bag from which breathable air is drawn by the wearer at the next inhalation.

33. Q. How much does the McCaa two-hour apparatus weigh?
A. Approximately 40 pounds.

b. M.S.A. ONE-HOUR OXYGEN BREATHING APPARATUS

34. Q. What is the operational principal of the one-hour M.S.A. breathing apparatus?
A. The same as the two-hour McCaa oxygen breathing apparatus.

35. Q. How much does the model which is worn on the back weigh?
A. 24 pounds.

36. Q. How much does the model which is worn on the chest weigh?
A. 18 pounds.

c. M.S.A. DEMAND APPARATUS

37. Q. For how long a period of service time is this apparatus approved?
A. 30 minutes.

38. Q. How much does this apparatus weigh?
A. 32 pounds.

39. Q. How is the oxygen or air supplied to the wearer?
A. The air is supplied from a bottle of compressed oxygen or air through a demand type regulator to the face piece of the wearer.

40. Q. Where is the exhaled breath expelled?
A. Direct to the atmosphere through an exhalation valve in the face piece.

d. M.S.A. CHEMOX OXYGEN BREATHING APPARATUS

41. Q. Is this a self-contained oxygen breathing apparatus?
A. Yes.

42. Q. Does this apparatus contain compressed oxygen?
A. No.

43. Q. Where does the oxygen come from since this apparatus does not contain any oxygen under pressure?
A. The oxygen is furnished from a replaceable canister which contains a chemical that liberates oxygen in more than sufficient amounts when this chemical comes into contact with the moisture from the exhaled breath.

44. Q. How is the carbon dioxide in the exhaled breath taken care of?
A. The chemical in the canister absorbs the carbon dioxide.

45. Q. Does the chemox apparatus give complete protection in all atmospheres?
A. Yes.

46. Q. What is the service time of the chemox?
A. A minimum of 45 minutes.

47. Q. How much does the apparatus weigh?
A. 13½ pounds.

48. Q. How long can a chemox canister be stored before it is opened?
A. Indefinitely.

49. Q. What is the proper procedure in discarding a used chemox canister?
A. After the canister is removed from the apparatus it should be punctured on front, back, and on the bottom with a small clean nail and placed in a nearly full bucket of water. After the bubbling ceases, the canister can be discarded. The water, which is caustic, should be poured down a drain.

50. Q. In addition to the timer, what other indications are there that the canister is approaching the end of its service life?
A. The lens fogs during inhalation and the breathing bag gradually deflates.

51. Q. What is the purpose of the manual pressure relief valve?
A. It is a means of releasing excess pressures which might build up in the breathing system.

52. Q. What is the purpose of the breathing bag?
A. To provide a breathing reservoir and to cool the oxygen coming from the canister.

53. Q. What is the purpose of the hard rubber tubes in the breathing bag?
A. To insure proper circulation of the oxygen through the breathing bag.

54. Q. What is the purpose of the plastic spacer between the inhalation elbow and the plunger casting?
A. To serve as an insulator using the air space to prevent heat transfer and thus aid in maintaining cooled oxygen for breathing.

55. Q. What is the purpose of the metal deflectors in the facepiece?
A. To insure that the dry inhaled oxygen is directed across the lenses preventing fogging.

56. Q. What is the purpose of the lip around the inside edge of the facepiece?
A. To prevent leakage and provide a comfortable fit.

57. Q. Explain the circulation through the chemox.
A. The exhaled breath passes from the facepiece through the exhalation check valve and exhalation breathing tube to the canister, passing down the center and up through the chemical removing the exhaled carbon dioxide and moisture, and evolving oxygen to mix with the exhaled oxygen. The oxygen flows into the bottom of the breathing bag on the exhalation side through a hard rubber tube and is directed to the inhalation breathing tube then through the inhalation check valve to the facepiece.

58. Q. At what temperatures should the chemox be stored and started?
A. Above freezing or 32 degrees Fahrenheit.

59. Q. After the chemox is started, at what temperatures can it be used?
A. At any temperature above a minus 20 degrees Fahrenheit.

e. M.S.A. ALL-SERVICE GAS MASK

60. Q. What are the limitations of this gas mask?
    A. It must not be worn in an atmosphere where a flame safety lamp will not burn or an atmosphere containing more than 2 percent by volume of any poisonous gases including carbon monoxide.

61. Q. Does this gas mask protect the wearer against smokes, dusts, vapors, or mists?
    A. Yes, providing there is sufficient oxygen and not more than 2 percent poisonous gases.

62. Q. What is the normal service time of the all-service canister?
    A. Two hours of continuous or intermittent use.

63. Q. Does the M.S.A. gas mask have a timer?
    A. Yes.

64. Q. What precaution should be taken with regard to the timer when a new canister is inserted?
    A. It should be set back to zero.

65. Q. How do you test an all-service gas mask for leaks?
    A. (1) see that all gaskets are in place, (2) connect timer to canister and mask, (3) adjust mask to face and head, and (4) hold hand over opening in bottom of canister and inhale gently. If there are no leaks the facepiece will collapse on the face.

66. Q. After a canister has been used, what should be done with it?
    A. It should be plainly marked and then thrown away.

67. Q. What instrument should always be carried with a gas mask?
    A. A flame safety lamp.

f. SELF-RESCUER

68. Q. What is the purpose of the self-rescuer?
    A. To provide an individual with protection from carbon monoxide for at least a half-hour in an atmosphere containing enough oxygen to support life.

69. Q. Who should carry a self-rescuer?
    A. All men engaged in rescue and recovery operations.

70. Q. Is the self-rescuer intended for use by parties attempting the rescue of others?
    A. No, it was designed purely as an emergency device to help a person escape from a mine in which a fire is burning, an explosion has occured, or his other protective devices have failed.

71. Q. How much does the self-rescuer weigh?
A. $13\frac{1}{2}$ ounces ready for use.

72. Q. How does this self-rescuer protect a person from carbon monoxide?
A. It contains a chemical known as "hopcalite" which changes carbon monoxide into carbon dioxide.

73. Q. How does this self-rescuer protect a person from smoke?
A. It contains cotton filter pads which filter out the smoke.

74. Q. After the self-rescuer has been used, can it be used again?
A. Yes, providing the replaceable cartridge containing the cotton filter pads and the hopcalite is replaced.

75. Q. What is the procedure for using the M.S.A. self-rescuer?
A. (1) remove the unit from the case and plastic bag, (2) break the seal of the cartridge by lifting up the lever, (3) push the plunger located at the center of the cartridge, (4) place the mouthpiece and nose clip in the proper position, and (5) tighten the neck strap.

3. MATERIALS

76. Q. What are the two most common uses of brattice cloth?
A. For temporary stoppings and line curtains.

77. Q. What materials are used in building a permanent stopping or a fire seal?
A. Bricks, rocks, cement, and mortar.

78. Q. What materials should always be available to mine rescue and recovery crews?
A. Brattice cloth, timbers, bricks, and mortar.

79. Q. What other materials are some times needed?
A. Lumber, nails, cement, pipe, pipe fittings, mine ties, mine track, spikes, switches, frogs, and repair parts for available equipment.

4. RECOVERY PROCEDURE

80. Q. What is a rescue crew?
A. A group of men trained and equipped with gas masks or oxygen breathing apparatus.

81. Q. What are the duties of the rescue crew?
A. To explore ahead of fresh air, to reach live men, to locate bodies, test the mine air, look for fires, and erect stoppings where respiratory protection is required.

82. Q. What is a recovery crew?
A. A group composed of brattice men, transportation men, telephone attendants, timbermen, trackmen, and the men necessary to carry on recovery operations.

83. Q. What are the duties of the recovery crew?
A. To perform all the necessary work required in a recovery operation in FRESH air.

84. Q. After an explosion, should the mine fan be run or shut down?
A. It should be run so that normal ventilation can be restored as quickly as possible.

85. Q. What should be done if the fan has been damaged?
A. Repairs or replacements should be made immediately as little or no recovery progress can be made without adequate ventilation.

86. Q. Where should the fresh-air base be set up?
A. Just outby that point where ventilation has been destroyed.

87. Q. Should the recovery crew advance farther than the fresh-air base?
A. No, only the rescue crew properly equipped with respiratory protection should advance past the fresh-air base.

88. Q. When rescue and recovery crews enter the mine, what precaution should be taken?
A. All men should be checked to see that they are properly equipped, and that only persons whose services may be of definite use are allowed to enter.

89. Q. Between what parties should telephone communications be maintained?
A. Between the advance crews and the fresh-air base.

90. Q. What type of telephones should be used underground during rescue and recovery operations?
A. Permissible portable telephones.

91. Q. When can gas mask crews explore ahead of the fresh-air base?
A. When it is known that the bad air contains sufficient oxygen to support life and not more than 2 percent toxic gases.

92. Q. When gas mask crews are used for exploration work, what type of crew should be kept in reserve at the fresh-air base?
A. A rescue crew equipped with oxygen breathing apparatus.

93. Q. If an oxygen breathing apparatus crew is used to explore ahead of fresh air, should a reserve crew be standing by?
A. Yes, a reserve crew equipped with oxygen breathing apparatus should be at the fresh-air base.

94. Q. When should advance rescue crews make long trips ahead of the fresh-air base?

A. To save lives or when a long trip is necessary to do work positively required for the continuance of the recovery operation.

95. Q. What instructions should be given to the captain of the rescue crew before they advance past the fresh-air base?

A. The instructions should include such things as the extent of the trip, distance to travel, things to observe, time to be taken in making the trip, emergency signals, etc.

96. Q. Who should give the captain of the rescue crew these instructions?

A. The man in charge of the fresh-air base.

97. Q. When the rescue crew leaves the fresh-air base, how should they advance?

A. Slowly, in single file, and about 6 feet apart.

98. Q. As the rescue crew advances, what should they mark with chalk?

A. The direction of travel, arrows pointing to the fresh-air base, the name of the crew captain at the farthest point of the trip, and the day, month, and year on the faces of all places inspected.

99. Q. What should the advance rescue crew inspect?

A. They should examine the roof, the roadway, and carefully note the conditions.

100. Q. If the advance crew finds that there is no indication of fire in the area examined, what is the next step they should take?

A. They should erect the necessary stoppings so that ventilation can be restored to the explored area.

101. Q. After ventilation is restored in the area explored by the advance crews, what should then be done?

A. The fresh-air base should then be advanced and another area explored.

102. Q. How long should this process of examining an area, restoring ventilation to the area, and advancing the fresh-air base be kept up?

A. Until ventilation is restored through out the entire mine.

103. Q. Where should temporary stoppings be built in relationship to the break-thru or cross cut?

A. They should be built far enough inside the cross cut or other openings in order to leave space for later construction of permanent stoppings.

104. Q. When a large number of temporary stoppings are in use, what precaution should be taken to insure that they remain airtight?

A. Men should be appointed on each shift to patrol and keep these stoppings as nearly airtight as possible.

105. Q. When ventilating any portion of a mine after an explosion, how should the afterdamp be conducted to the outside?

A. By the most direct route.

106. Q. Should air be permitted to travel through unexplored portions of the mine?

A. No, because if this is permitted an explosive mixture of gas may be brought in contact with a fire, thereby causing another explosion.

107. Q. If a rescue crew finds a fire smoldering or an active fire, what should they do?

A. They should immediately attempt to put it out with water, rock dust, or fire extinguishers before the fresh air is advanced.

108. Q. If the rescue crew can not put a fire out by direct methods, what should they do?

A. They should seal off the fire area promptly and effectively.

109. Q. Usually live men found after an explosion are suffering from poisonous gases, burns, or injuries; what should a rescue crew do if they find live men in an atmosphere containing afterdamp?

A. Men thus found should have an oxygen breathing apparatus or, if sufficient oxygen is present, a gas mask or self-rescuer placed on them immediately and then carried to fresh air.

110. Q. If live men are found behind a barricade, what precautions should be taken in rescuing them?

A. Great care should be exercised to prevent poisonous gases from entering the barricade while the men are being rescued.

111. Q. How is the best method to rescue live men from behind a barricade to prevent poisonous gas from entering the barricade during the rescue?

A. By advancing the fresh air to the barricade before attempting to rescue the men.

112. Q. After live men have been rescued, where should they be taken?

A. They should be taken to the hospital for further observation and treatment.

113. Q. As soon as possible after an explosion, what should be done to the main haulage road?

A. It should be retimbered, and the track cleaned and repaired.

G. COAL MINE ACCIDENTS

1. FROM FALLS OF ROOF AND COAL

1. Q. When are falls of mine roof most common?
   A. Within a short time after the roof is first exposed by the mining of coal.

2. Q. When is a fall of the roof, face, or rib considered an accident?
   A. When it falls unexpectedly.

3. Q. Are mine workers who travel around the various parts of the mine as likely to be injured by a fall of the roof, face, or ribs as the mine worker who works in one place?
   A. No, because he that travels is only exposed a relatively short time to any one section of the mine.

4. Q. Why is moisture from the air which is deposited on the roof considered a cause of roof falls?
   A. This moisture reduces the strength of the roof rock by its weathering action and causes the roof rock to swell, crack, and spall off.

5. Q. What is a "bump"?
   A. It is the sudden rupture or settling of coal pillars or of coal from an advancing entry or room face.

6. Q. Are bumps very common in coal mines?
   A. Not as a general rule; however, many miners refer to the popping noises as bumps.

7. Q. What usually occurs in a mine when there is a bad bump?
   A. Coal is thrown from the face or ribs, the floor is upheaved, timbers are broken or thrown out, cars are overturned, draw slate or pieces of roof are thrown down, and a wind blast produces a dense cloud of dust.

8. Q. Does the mining method have any bearing on the roof condition?
   A. Yes, a mining method that does not suit the natural conditions of a mine can be the cause of a bad roof.

9. Q. Where the mine roof and floor are strong, what happens when too small pillars are left?
   A. The pillars will begin to crush or squeeze.

10. Q. Where the mine roof and floor are weak, what happens when too small pillars are left?
    A. The pillars will push into the roof and floor.

11. Q. What effect on the roof does working areas to close to the haulage road have?
A. It tends to weaken the roof, thus making it more likely to have roof falls along the haulage road.

12. Q. What is the greatest factor in the prevention of accidents caused by falls of the roof?
A. Constant inspection of the roof by all men working in the mine.

13. Q. How is the roof generally tested?
A. By striking it with a bar or other tool.

14. Q. If the roof is solid, what type of sound is produced when it is struck by a bar?
A. A ringing or bell-like sound.

15. Q. If the roof has a break in it, what type of sound is produced when it is struck by a bar?
A. A drummy or hollow sound.

16. Q. How often should the roof be tested in a working place?
A. Very frequently and in some cases every few minutes.

17. Q. Generally speaking, where is the most dangerous zone in a coal mine in relation to falls of the roof, face, and ribs?
A. Within 25 feet of the face.

18. Q. What two ways is timbering responsible for falls of roof?
A. By insufficient or improper timbering and by delay in setting the timbers.

19. Q. What should be done in the face region while it is being cleaned up in preparation for timbering?
A. Safety posts should be set.

20. Q. What is the best method to insure adequate timbering?
A. To have a systematic timbering plan which is always followed.

21. Q. What is a good policy or motto to follow in regards to timbering?
A. If the roof is sound, support it and keep it good; if the roof is bad, support it to prevent it from falling.

22. Q. When a miner is taking down draw slate or loose roof material, what should he make sure of?
A. That the place where he is standing has a good roof and is safe.

2. FROM HAULAGE

23. Q. What two classes can haulage accidents generally be grouped?
A. Those do to physical defects in haulage equipment and those due to human failures.

24. Q. What are a few of the things that can cause defective haulage equipment?

A. Poorly maintained equipment; poorly alined, cleaned, and maintained track; obstructions on main haulage roads; poorly installed switches; inadequate side and overhead clearances; etc.

25. Q. What are a few of the things that can cause human failures?

A. Such careless practices as jumping on and off of moving trips, coupling moving cars, operating equipment too fast, the wearing of loose or torn clothing, and above all the failure to obey instructions.

26. Q. What is the foundation of a good haulage system?

A. The roadbed.

27. Q. What all should be done to insure a good roadbed?

A. It should be properly graded, adequately drained, have properly spaced track ties, and a good ballast.

28. Q. What size track should be used on the roadbed?

A. Heavy enough to handle the weight of loaded cars and locomotives.

29. Q. When possible, how much clearance should there be along the clear side of the mine track?

A. At least 30 inches from the nearest obstruction to the farthest projections of the moving equipment.

30. Q. Where along the haulage road should man holes be placed?

A. They should be on the clear side, suitably marked, and free from any loose rock, coal, or supplies.

31. Q. What is meant by the clear side?

A. The side opposite the trolley wire.

32. Q. Should lights be provided on mine cars?

A. Lights should be placed on the front and back of every trip of mine cars -- if only one car is hoisted at a time then it should be equipped with 2 lights.

33. Q. When hoisting mine cars up a slope, what precaution should be taken?

A. A safety drag should be attached to the last car to prevent the trip from going backwards in the event of a hoisting rope or hoist failure.

34. Q. When hoisting mine cars up a slope or a shaft, how often should the rope, links, chains, and rope sockets be checked?

A. At least once every 24 hours.

35. Q. When cars are left standing in a mine, where should they be?

A. On a side track, never leave mine cars standing on the main haulage road.

36. Q. When is it permissible to couple moving cars?
A. Never, cars should always be completely stopped before they are coupled together.

37. Q. Where and how should man trips be operated?
A. They should be operated at a safe speed and not behind other trips on ascending grades or in front of other trips on descending grades.

38. Q. At man trip loading and unloading points, what should be done?
A. A safe and suitable place should be provided for the men and all trolley wires in the area should be adequately guarded.

39. Q. Can explosives be carried in a man trip?
A. No, they should never be carried in a man trip.

40. Q. Can tools and supplies be carried in a man trip?
A. Yes, providing they are carried in a separate car.

41. Q. What precaution should be taken when a man trip is operated on a slope or incline?
A. A safety rope which is connected to the main rope at a point above the regular hitching and extending around or through all man trip cars should be provided.

3. FROM ELECTRICITY

42. Q. What type of accidents, not classed as electrical, are actually due to electricity?
A. Accidents caused by mine fires and explosions from electrical origin or accidents caused primarily by electrical contact by which a person is thrown under or against haulage or mining equipment.

43. Q. What is the main cause of electric-shock accidents in coal mines?
A. Contact with trolley wires.

44. Q. What happens when an unprotected person touches a trolley wire?
A. The electric current which is being carried by the wire passes through his body and into the ground.

45. Q. Why are some electrical cables in a coal mine a shock and fire hazard?
A. Because they are usually of a temporary nature and are repaired in a slipshod manner when they break.

46. Q. Why are the metallic frames of some electrical equipment considered shock hazards?
A. Because the frame has become "alive". This is caused by failure of insulation or the frame has come into contact with a "live" wire.

47. Q. What is the best way to prevent a piece of electrical equipment from becoming a shock hazard?
A. By being sure that it is properly grounded

4. FROM EXPLOSIVES

48. Q. What is cardox?
A. It is a blasting device composed of a strong, hollow, cylindrical, steel shell charged with liquid carbon dioxide at high pressure.

49. Q. In general, what is the principal of cardox?
A. The liquid carbon dioxide is gasified; this produces enough pressure to shear the replaceable steel disk allowing the gasified carbon dioxide to escape into the bore hole at high enough velocity and pressure to dislodge the coal.

50. Q. How is the liquid carbon dioxide gasified?
A. An electrical heater element is inserted in the steel shell and when an electric current is applied to the heater the heat thus produced converts the liquid carbon dioxide into gas almost instantaneously.

51. Q. What is the principal hazard of cardox?
A. The danger of the shell flying out of the bore hole when fired and expending its energy in the mine workings near the hole.

52. Q. What is the best method of preventing injuries due to blasting with cardox?
A. Everyone should be at least a hundred feet away from the bore hole and have two or more intervening right angles between him and the shot.

53. Q. What is airdox?
A. It is similar to cardox except that the pressure is released by a valve instead of through a steel rupture disk and it is charged with compressed air instead of liquid carbon dioxide.

54. Q. At what average pressure is the compressed air compressed to when charging an airdox shell?
A. Approximately 11,500 pounds per square inch.

55. Q. How many times can an airdox shell be used?
A. Unlimited amount of times. The shell simply has to be replaced in a bore hole, recharged with compressed air and it is ready for use. This process can be repeated over and over again.

56. Q. Is there any gas or dust explosion hazard with airdox?
A. No, because only compressed air is used.

57. Q. Are there any hazards connected with using airdox?
A. Yes, the hazard of flying shells as with cardox and also the general hazards due to handling high pressure compressed air.

58. Q. What is a permissible explosive?
A. It is essentially dynamite that has been modified so that the flame produced when exploded is smaller in volume, shorter in duration, and of a lower temperature than that of black blasting powder or dynamite.

59. Q. Generally speaking, why is black blasting powder dangerous to use around a coal mine?
A. It is dangerous because of the ease of ignition by flame or sparks, the dangers that attend the handling of metal kegs, the toxic gases resulting from firing, and the long duration, large volume, high temperature flame which results when fired.

60. Q. Why are fuses dangerous to use in blasting coal?
A. They are dangerous because they require an open light to ignite them.

61. Q. At what rate of speed does the average fuse burn?
A. From 30 to 40 seconds per foot.

62. Q. What material should never be used as stemming material?
A. Coal dust, wads of paper, or any other combustible material.

63. Q. What should tamping bars be made out of?
A. They should be made entirely out of wood.

64. Q. What does an electrical detonator consist of?
A. It contains a detonating compound consisting of a pressed primer load, a loose ignition charge, and an electric firing element with leg wires.

65. Q. What are the leg wires usually made out of?
A. Out of iron covered with white, wax-impregnated, cotton insulating material and with the ends twisted together.

66. Q. When should the ends of the leg wires be untwisted?
A. Just immediately before connecting them to the shot-firing circuit.

67. Q. How should the shot-firing cable be made for use in coal mines?
A. It should be made out of sturdy, flexible, rubber insulated wire with one wire slightly shorter than the other.

68. Q. How long should a shot-firing cable be?
A. At least a hundred feet.

69. Q. When should the shunt at the battery end of the shot-firing cable be removed?
A. After all is ready to fire or immediately before connecting to the battery or blasting unit.

70. Q. What are the four types of blasting units in use today?
A. (1) dry cell, (2) wet cell, usually the cap-lamp battery, (3) magneto, and (4) generator.

71. Q. Before loading the explosive charge into the bore hole, what should be done?
A. The bore hole should be cleaned out so as to prevent the cuttings from getting between the cartridges of explosives.

72. Q. How should the primer cartridge be placed in the bore hole?
A. With the detonator pointing toward the bulk of the charge.

73. Q. How should the entire charge, including the primer, be loaded into the bore hole?
A. It should be loaded in the hole with the cartridges placed end to end and pushed gently toward the bottom of the hole until seated.

74. Q. After the charge is placed in the hole, what should be done with the remaining space in the hole?
A. It should be filled with incombustible stemming material.

75. Q. When ready to fire the hole, what type of warning should the shot-firer give?
A. He should yell "fire" three times at 2 second intervals before firing the shot.

76. Q. In the event of a misfire, how long should the shot-firer wait before examining the misfired shot?
A. At least 10 minutes.

77. Q. How many holes should be fired at one time?
A. Only one.

H. FIRST AID

1. Q. What is first aid?
A. It is an emergency treatment of a person who is injured or ill to protect him until medical or surgical aid can be obtained.

2. Q. What are the 5 objects of first aid?
A. (1) prevention of further injury, (2) checking conditions known to be endangering life, (3) protecting injuries from infections and complications, (4) making the patient as comfortable as possible, and (5) transporting the patient, if necessary, to medical assistance without injuring the patient further.

3. Q. What, in general, should a first aid man do?
   A. (1) he should send for medical aid in serious injuries, (2) have the patient checked in all cases of injury, (3) take command and give orders, (4) locate the injury, (5) know what to do and do it, (6) if artificial respiration is indicated, start it without delay, (7) look for bleeding and check it, (8) keep the patient lying down, (9) treat for physical shock, (10) treat all wounds, (11) treat any fractures or dislocations, and (12) move the patient to medical aid if necessary.

4. Q. What is the human body composed of?
   A. Solids (bones and tissues) and fluids (blood and various secretions).

5. Q. What are the names of the 3 main parts of the human body?
   A. The head, trunk, and extremities (upper and lower).

6. Q. What is included in the head?
   A. The skull and face.

7. Q. How many bones are in the head?
   A. 22

8. Q. What is included in the trunk?
   A. In the upper portion there is the chest, its cavity and organs and in the lower portion there is the abdomen, its cavity and organs. The upper and lower portion is separated by a muscular partition known as the diaphragm.

9. Q. How many bones are in the trunk?
   A. 54

10. Q. What is included in the upper extremities?
    A. The upper extremity on each side consists of the shoulder joint, the arm, the forearm, the wrist, and the hand.

11. Q. How many bones are in the upper extremities?
    A. 32 on each side or a total of 64.

12. Q. What is included in the lower extremities?
    A. The lower extremity on each side consists of the hip joint, the thigh, the leg, the ankle, and the foot.

13. Q. How many bones are in the lower extremities?
    A. 30 on each side or a total of 60.

14. Q. How many bones are in all the extremities?
    A. 124

15. Q. What are the two types of bandages generally used in first aid?
    A. The triangular and the cravat.

16. Q. What is a triangular bandage?
A. It is made from a piece of cloth one meter square by folding the square diagonally and cutting along the fold.

17. Q. What type of knot is used to tie the ends of a triangular bandage?
A. A square or reef knot.

18. Q. What is a bandage compress?
A. It consists of a pad made of several thicknesses of sterile gauze sewed to the middle of a strip of muslin.

19. Q. What is a tourniquet?
A. It is an appliance used to check severe bleeding from an artery.

20. Q. What are splints?
A. They are appliances usually made out of wood and are used to support and protect injured parts such as fractures and dislocations.

21. Q. What is respiration?
A. It is breathing by which air is taken into the lungs during inspiration and forced out during expiration.

22. Q. What is artificial respiration?
A. It is a method by which normal respiration is imitated, by manual movements, to induce breathing in persons whose respiration has stopped.

23. Q. What type of injury usually calls for artificial respiration?
A. Electric shock, gas poisoning, drowning, and suffocation from various causes.

24. Q. What is the circulatory system?
A. It consists of the heart, arteries, veins, and the capillaries by which blood is carried to and from all parts of the body.

25. Q. Approximately what percent of the weight of the human body is blood?
A. Between 7 and 8 percent.

26. Q. What does blood consist of?
A. A fluid called plasma, red blood cells, and white blood cells.

27. Q. What is the purpose of blood in the human body?
A. To carry nourishment to all the tissues of the body, furnish heat and oxygen, and remove waste matter from tissue activity to the excretion organs.

28. Q. What are the excretion organs?
A. The lungs, skin, kidneys, and bowels.

29. Q. What is the heart?
A. It is a hollow, muscular organ, about the size of a fist which by its pumping action keeps the blood circulating through out the body.

30. Q. What are blood vessels?
A. They are tubes, or pipes which carry the blood through out the body.

31. Q. What are arteries?
A. They are blood vessels which carry pure blood away from the heart to all parts of the body.

32. Q. What are veins?
A. They are blood vessels which carry the impure blood back to the heart.

33. Q. What is the function of the lungs?
A. To purify the blood by exchanging the carbon dioxide and volatile waste products for oxygen.

34. Q. What is the average time required for the blood to make one complete circulation of the body?
A. About $1\frac{1}{4}$ minutes.

35. Q. What is bleeding?
A. The flow of blood from an artery, vein, or capillary.

36. Q. How do you tell whether an artery, vein or capillary is bleeding?
A. If the blood is bright red and comes in spurts, it is an artery; if the blood is dark red and flows steady, it is a vein; and if the blood just oozes from a wound, it is a capillary.

37. Q. How much blood can an average person loose before it becomes serious?
A. One to two pints, the lose of 3 pints can be fatal.

38. Q. If the principal blood vessels in the arm or thigh are cut, how long will it take a person to bleed to death?
A. Between one and three minutes.

39. Q. What are the three main methods used to control bleeding?
A. (1) pressure applied at a pressure point, over the wound, or near the wound, (2) the position of the wounded part of the body, and (3) the appliciation of cold packs near the wound.

40. Q. How would you control arterial bleeding?
A. By placing a tourniquet over the pressure point between the heart and the wound, and by finger pressure.

41. Q. How would you control venous bleeding?
A. By constricting the part below the wound away from the heart or by pressure over the wound.

42. Q. How would you control capillary bleeding?
A. By applying pressure directly over the wound.

43. Q. What is the nervous system?
A. It is made up of nerves which keep in touch with all parts of the body and control the various body functions. It is divided into two parts, the cerebrospinal and the sympathetic.

44. Q. What does the cerebrospinal part of the nervous system consist of?
A. The brain and the spinal cord.

45. Q. What is the brain?
A. The brain is the collection point of nerve centers.

46. Q. What is the spinal cord?
A. The spinal cord is that part of the body which passes down through the center of the backbone and holds the trunk nerves which enter and leave the brain.

47. Q. What are the two type of nerves in the spinal cord?
A. The sensory nerves and the motor nerves.

48. Q. What are the sensory nerves?
A. They are the nerves which convey impressions of sensations such as heat, cold, touch, and pain from different parts of the body to the brain.

49. Q. What are motor nerves?
A. They are the nerves which convey impulses from the brain to the muscles, causing movement of the muscles.

50. Q. What does the sympathetic part of the nervous system consist of?
A. A series of nerve centers in the chest and abdomen.

51. Q. What part of the body does the sympathetic part of the nervous system control?
A. The heart, blood pressure, digestion of food, excretory organs, and breathing.

52. Q. What is physical shock?
A. The state of collapse that interferes with normal action of the heart, respiration, and circulation.

53. Q. What causes physical shock?
A. The lack of proper balance within the sympathetic nervous system caused by injuries, severe pain, loss of blood, severe burns, accidents due to electricity or gas, poisons, exposure to extreme heat or cold, fright, anger, joy, etc.

54. Q. What is fainting?
A. A temporary loss of consciousness caused by an inadequate supply of blood to the brain.

55. Q. What is an Abrasion?
A. It is an open wound caused by rubbing or scraping of the skin leaving a raw bleeding surface. The bleeding is usually capillary.

56. Q. What is an incised wound?
  A. It is an open wound caused by a sharp cutting edge such as a knife.
     An incised wound usually bleeds freely.

57. Q. What is a lacerated wound?
  A. It is an open wound with ragged edges caused by the skin being torn or mashed by a blunt instrument. A lacerated wound usually does not bleed to freely.

58. Q. What is a puncture wound?
  A. It is an open wound caused by a pointed instrument such as a needle. A puncture wound usually bleeds very little.

59. Q. What is a bruise?
  A. A closed wound caused by a blunt instrument striking the body and injuring the tissues beneath the skin.

60. Q. What is a strain?
  A. A closed wound caused by sudden movement, by exertion in lifting, or by moving heavy weights and overstretching a muscle or a tendon of a muscle.

61. Q. What is a sprain?
  A. A closed wound caused by a sudden twist or wrench and stretching or tearing the ligaments or other tissues around a joint.

62. Q. What is a rupture?
  A. It is the protrusion of a portion of an internal organ, usually the bowel, through the muscular wall of the abdomen. Most ruptures occur in or just above the groin; however, they may occur at other places over the abdomen.

63. Q. What usually causes a rupture?
  A. Ruptures are usually caused by muscular strains from lifting or pushing, violent coughing, sudden jars in jumping, and similar acts.

64. Q. What should a first aid man do about foreign bodies such as dirt sand, cinders, coal, fine pieces of metal, etc. which lodge in the eye of a patient?
  A. If they cannot be easily removed the patient should be sent to a doctor at once.

65. Q. What is a burn?
  A. An injury caused by the body coming into contact with a dry heat such as fire or heated objects, electricity, chemicals, etc.

66. Q. What is the difference between a burn and a scald?
  A. A burn is an injury caused by dry heat and a scald is an injury caused by hot solution, hot vapors, or steam.

67. Q. What is the chief cause of death which occurs in the first day or two after a person has been seriously burned?
A. Physical shock.

68. Q. What is a first degree burn?
A. The outer skin is reddened and there is slight swelling.

69. Q. What is a second degree burn?
A. The underskin is affected and blisters are formed.

70. Q. What is a third degree burn?
A. The skin is destroyed, and tissues underneath are damaged. In severe cases, muscles, nerves, and blood vessels may be destroyed and the whole area charred.

71. Q. How much of the surface of the human body that has been injured by a second degree burn is usually considered fatal?
A. one-third of the surface.

72. Q. What is the primary emergency or first aid treatment of a burn?
A. The exclusion of air from the burned surface.

73. Q. When a person is burned by a chemical, what treatment should the first aid man render?
A. He should thoroughly wash the surface with clean water and then dress the area the same as for any burn.

74. Q. What is a fracture?
A. A broken bone.

75. Q. What is a simple fracture?
A. Where the bone is broken but no wound extends from the broken ends of the bone out through the skin.

76. Q. What is a compound fracture?
A. Where the bone is broken and a wound extends from the bone out through the skin.

77. Q. What is a joint?
A. Where two or more bones come together without any bony union between them.

78. Q. What holds the bones together in a joint?
A. The strong, fibrous tissues known as ligaments.

79. Q. What is a dislocation?
A. It is the slipping out of normal position of one or more of the bones forming a joint.

80. Q. What happens to the ligaments of a joint when a dislocation takes place?
A. They are stretched and sometimes torn loose.

81. Q. After a patient has been treated for his injuries and must be moved, how should he be moved?
A. A patient should always be carried on a stretcher.

82. Q. What is sunstroke?
A. A sudden attack of illness from prolonged exposure to the direct rays of the sun or to other high temperatures.

83. Q. What are the symptoms of sunstroke?
A. Intense headache and dizziness before becoming unconscious; the face is red and flushed; the skin is hot, dry, with no perspiration; pulse is strong and rapid; breathing is labored; and the pupils of the eyes are enlarged, but of equal size.

84. Q. What is the treatment for sunstroke?
A. The treatment centers around reducing the temperature of the body such as moving the patient to a cool place, applying cold applications etc. Rub the patients limbs toward the heart and if he is conscious give him cool water. Never give him a stimulant.

85. Q. What is heat exhaustion?
A. A collapse from the effect of heat.

86. Q. What are the symptoms of heat exhaustion?
A. The patient is very weak, usually conscious, his face is pale and covered with cold perspiration. His pulse is rapid but weak and his breathing is shallow.

87. Q. What is the treatment for heat exhaustion?
A. The same as for physical shock; namely, keep the patient lying down with head low, body wrapped with blankets, apply hot applications, use stimulants, rub the extremities, and call a doctor.

88. Q. What are heat cramps?
A. The cramping of the muscles of the abdomen or extremities caused by the loss of the body's salt content through sweating.

89. Q. What is the treatment for heat cramps?
A. For a mild case increase the salt intake, warm baths, and rest. For a severe or persistent case call a physician.

90. Q. What is frostbite?
A. An intense coldness and numbness, usually of the nose, cheeks, ears, toes, and fingers, caused by prolonged exposure to severe cold. The frostbitten area is usually dead white.

91. Q. What is the treatment for frostbite?
A. As quickly as possible the affected area should be gradually warmed by placing the area in luke warm water. Never use hot water, heat lamps, hot-water bottles, or stove heat to warm a frostbitten area.

92. Q. What is apoplexy?
A. Apoplexy, cerebral hemorrhage, or stroke is spontaneous rupture of a blood vessel within the skull causing a hemorrhage into the brain tissues.

93. Q. What are the 3 general groups of poisons which enter the human body by way of the mouth?
A. Corrosive poisons, irritant poisons, and systemic poisons.

94. Q. What does a corrosive poison do to the human body?
A. It corrodes, burns, or eats into the tissues when it comes in contact with the mucous membrane of the lips, mouth, throat, gullet, and stomach.

95. Q. What does an irritant poison do to the human body?
A. It sets up irritation within the stomach which causes distress, nausea, vomiting, and severe pain.

96. Q. What are the two general groups of systemic poisons?
A. The depressant poisons and the convulsant poisons.

97. Q. How does a depressant poison affect the human body?
A. It progressively lowers the vital functions of circulation and respiration.

98. Q. How does a convulsant poison affect the human body?
A. It produces convulsions with rapid paralysis of the vital functions of circulation and respiration.

99. Q. How does a person contact rabies?
A. The salvia from a rabid animal enters the wound caused by the bite and the disease is transmitted to the person bitten.

100. Q. How does the poison from a poisonous snake get circulated through out the body?
A. The poison from the snake enters the skin through the bite of the snake and is then circulated through the body by the venous circulation system.

101. Q. What are the 3 most common poisonous plants?
A. Poison-ivy, poison-oak, and poison-sumac.

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APPENDIX

SUGGESTED TEACHING OUTLINE

The roman numerials found below designate section numbers of the text "Safety in Coal Mining for Afghanistan"; other numbers and letters also refer to the text "Safety in Coal Mining for Afghanistan".

Each lesson is designed to last approximately one and one-half hour; however, due to circumstances which may arise in class they may vary by as much as an hour.

LESSON NUMBER

1. Purpose and organization
   a. General explanation of what will be taught
   b. Organization of course e.g. time, place, and names

2. Flame safety lamp and associated mine gases
   a. Oxygen (III-E-1)
   b. Methane (III-E-3)
      aa. Methane detectors other than safety lamp (III-F-1)
   c. Flame safety lamp (I-E-1-a,b,c,d)

3. Flame safety lamp and associated mine gases
   a. Nitrogen (III-E-2)
   b. Carbon dioxide (III-E-4)
   c. Flame safety lamp (I-E-1-e,f,g)

4. Flame safety lamp
   a. Class participation in assembly and nomenclature

5. Measuring mine air
   a. Anemometer (I-E-2)
   b. Amount of air required (II-B)
   c. Measuring mine air (II-C)

6. Carbon monoxide gas and various detectors
   a. Carbon monoxide (III-E-5)
   b. Hoolamite carbon monoxide detector (I-E-3)
   c. Other detectors for carbon monoxide (III-F-2)

7. Fire bossing
   a. Lecture (I-A,B,C,D)

8. Review
   a. Fire boss (IX-A)
   B. Flame safety lamp (IX-A-1)

9. Review
   a. Anemometer (IX-A-2)
   b. Oxygen (IX-C-3-a)
   c. Nitrogen (IX-C-3-b)

10. Review
   a. Carbon monoxide detector (IX-A-3)
   b. Methane (IX-C-3-c)
   c. Carbon dioxide (IX-C-3-d)
   d. Carbon monoxide (IX-C-3-e)

11. Mine gases
   a. Property of gases (III-D-1)
   b. Normal air (III-B)
   c. Mine air (III-C)

12. Mine gases
   a. Those that are sometimes found in coal mines, but only rarely (III-E-6,7,8,9,10)
   b. Review carbon monoxide (IX-C-3-e)

13. Gas mask and self-rescuer
   a. Lecture (VI-C-2)
   b. Lecture (VI-C-3)

14. Gas mask
   a. Demonstration to class of how to put on and wear all service gas mask
   b. Class practice in putting mask on

15. Gas mask
   a. Class participation in demonstrating effectiveness of mask in room filled with coal smoke

16. Self-contained oxygen breathing apparatus
   a. Various apparatus other than chemox (VI-C-1-a,b,c)
   b. Open discussion on all service gas mask

17. Chemox
   a. Lecture (VI-C-1-d)
   b. Demonstration to class on how to put on chemox apparatus and how to insert canister.

18. Chemox
   a. Demonstrate to class the effectiveness of chemox -- wear apparatus for 45 minutes
   b. Demonstrate to class how to destroy a used canister

19. Chemox
    a. Class participation in wearing chemox for 45 minutes --
       ½ class only

20. Chemox
    a. Same as 19 only with other half of class

21. Review
    a. Gas mask (IX-F-2-e)
    b. self-rescuer (IX-F-2-f)
    c. Chemox (IX-F-2-d)

22. Review
    a. Methane (IX-C-3-c)
    b. Flame safety lamp (IX-A-1)
    c. Fire boss (IX-A)

23. Review
    a. Carbon monoxide (IX-C-3-e)
    b. Carbon monixide detector (IX-A-3)
    c. Anemometer (IX-A-2)

24. Review
    a. Air (IX-C-1)
    b. Carbon dioxide (IX-C-3-d)
    c. Oxygen (IX-C-3-a)
    d. Nitrogen (IX-C-3-b)

25. Review
    a. Other gases (IX-C-3-f,g,h,i,j)
    b. Property of gases (IX-C-2)

26. Chemox
    a. Class participation in wearing chemox for 45 minutes
       while doing work -- ½ class only

27. Chemox
    a. Same as 26 only with the other half of the class

28. Discussion
    a. When you would wear chemox in actual practice
    b. When you would wear the all service gas mask in practice
    c. Questions from class

29. Mine fires
    a. Introduction (V-A)
    b. Causes (V-B)

30. Mine fires
    a. Prevention (V-C)

31. Mine fires
    a. Fighting (V-D-1-a,b)

32. Mine fires
    a. Fighting (V-D-1-c & V-D-2,3)

33. Mine fires
    a. Unsealing (V-E-1,2)

34. Mine Fires
    a. Unsealing (V-E-3,4)

35. Review
    a. Gas masks (IX-F-2-e)
    b. Carbon monoxide (IX-C-3-e)
    c. Flame safety lamp (IX-A-1)

36. Gas mask
    a. Class participation in wearing gas mask while building a wall in a room filled with coal smoke.

37. Anemometer
    a. Review (IX-A-2)
    b. Class participation in determining amount of air flowing in an entry in the mine

38. Coal Mine Accidents
    a. Falls of roof and coal (VII-A)
    b. From haulage (VII-B)

39. Coal mine accidents
    a. From electricity (VII-C)
    b. From explosives (VII-D)

40. Discussion
    a. Answer questions from class concerning anything taught up-to-date

41. Review
    a. Mine Fires (IX-E-1,2)

42. Review
    a. Mine fires (IX-E-3)

43. Review
    a. Mine fires (IX-E-4)

44. Coal mine explosions
    a. Introduction (IV-A)
    b. Gas (IV-B)
    c. Coal dust (IV-C)

45. Coal mine explosions
    a. Prevention (IV-D)

46. Coal mine explosions
    a. Course of action after (IV-E)

47. Chemox
    a. Review (IX-F-2-d)
    b. Class demonstration to me of how to put on and start apparatus

48. Chemox
    a. Class participation in wearing the chemox apparatus for 45 minutes while doing work in the mine -- ½ class only

49. Chemox
    a. Same as 48 only with the other half of the class

50. Mine ventilation
    a. Introduction (II-A & II-D-1)
    b. Amount of air (II-B,C)

51. Mine ventilation
    a. Ventilation plans (II-D-2)
    b. Ventilation pressure (II-D-3)
    c. Mine resistance (II-D-4)

52. Mine ventilation
    a. Control of air (II-D-5)
    b. Splitting the air (II-D-6)

53. Mine ventilation
    a. Fan (II-D-7)
    b. Suggestions (II-E)

54. Review
    a. Coal mine accidents (IX-G-1,2)

55. Review
    a. Coal mine accidents (IX-G-3,4)

56. Review
    a. Fire boss (IX-A)
    b. Anemometer (IX-A-2)
    c. Safety lamp (IX-A-1)
    d. Carbon monoxide (IX-C-3-e)
    e. Oxygen (IX-C-3-a)

57. Fire bossing
    a. Review (IX-A)
    b. Class participation in making a fire boss run of the mine

58. First aid
    a. Introduction
    b. Object (VIII-A)
    c. What to do (VIII-B)

59. First aid
    a. Anatomy (VIII-C-1)
    b. Dressings (VIII-C-2)
    c. Artificial respiration (VIII-C-3)

60. First aid
    a. Control of bleeding (VIII-C-4)
    b. Nervous system (VIII-C-5)

61. Review
    a. Coal mine explosions (IX-D-1,2)

62. Review
    a. Coal mine explosions (IX-D-3,4)

63. First aid
    a. Wounds (VIII-C-6)

64. First aid
    a. Dressings for wounds (VIII-C-7)
    b. Demonstrate to class the dressings on pages 53-58 of USBM publication, FIRST AID*.
    c. Class participation in demonstrating these dressings

65. First aid
    a. The same as 64 above

66. First aid
    a. Burns and scalds (VIII-C-8)
    b. Review dressings on pages 53-58 of USBM publication, FIRST AID

67. Review
    a. Mine ventilation (IX-B,B-1)

68. Review
    a. Mine ventilation (IX-B-2,3)

69. Chemox
    a. Class participation in wearing chemox for 45 minutes while doing work inside the mine -- $\frac{1}{2}$ class only

70. Chemox
    a. The same as 69 only with the other half of the class

* - A publication by the Bureau of Mines, United States Department of the Interior, titled "FIRST AID, A Bureau of Mines Instruction manual".

71. First aid
    a. Demonstrate to class the dressings for wounds on pages 59-66 of USBM publication, FIRST AID
    b. Class participation in demonstrating these dressings

72. First aid
    a. The same as 71 above

73. Review
    a. Mine fires (IX-E)

74. Review
    a. Mine accidents (IX-G)

75. Rescue and Recovery
    a. Introduction (VI-A)
    b. Organization (VI-B-1,2,3)

76. Rescue and Recovery
    a. Auxiliary equipment (VI-C-4 thru C-12)
    b. Auxiliary material (VI-D)

77. Rescue and recovery
    a. Procedure (VI-E)

78. First aid
    a. Demonstrate to class the dressings for wounds on pages 67-71 of USBM publication, FIRST AID
    b. Class participation in demonstrating these dressings

79. First aid
    a. The same as 78 above

80. First aid
    a. Review of dressings on pages 53-71 of USBM publication, FIRST AID

81. Review
    a. Coal mine explosions (IX-D)

82. Review
    a. Mine ventilation (IX-B)

83. First aid
    a. Handling patients (VIII-C-11)
    b. Sunstroke (VIII-C-12)
    c. Heat exhaustion (VIII-C-13)
    d. Heat cramsp (VIII-C-14)
    e. Frostbite (VIII-C-15)

84. First aid
    a. Apoplexy (VIII-C-16)
    b. Poisons (VIII-C-17)

85. First aid
    a. Fractures (VIII-C-9)
    b. Dislocations (VIII-C-10)

86. Review
    a. Mine gases (IX-C)

87. Review
    a. Safety lamp (IX-A-1)
    b. Carbon monoxide detector (IX-A-3)
    c. Anemometer (IX-A-2)
    d. Gas mask (IX-F-2-e)
    e. Chemox (IX-F-2-d)
    f. Self rescuer (IX-F-2-f)

88. First aid
    a. Demonstrate to class how to use splints for fractures on pages 88-93 of USBM publication, FIRST AID
    b. Class participation in demonstrating how to use splints for these fractures.

89. First aid
    a. The same as 88 above

90. Review
    a. Rescue and recovery (IX-F-1, F-2-a,b,c, F-3)

91. Review
    a. Rescue and recovery procedure (IX-F-4)

92. First aid
    a. Demonstrate to class how to use splints for fractures on pages 94-99 of USBM publication, FIRST AID
    b. Class participation in demonstrating how to use splints for these fractures

93. First aid
    a. The same as 92 above

94. First aid
    a. Demonstrate to class how to use splints for fractures on pages 100-103 of USBM publication, FIRST AID
    b. Class participation in demonstrating how to use splints for these fractures

95. First aid
    a. The same as 94 above

96. First aid
    a. Demonstrate to class how to use splints for dislocations on pages 104-110 of USBM publication, FIRST AID
    b. Class participation in demonstrating how to use splints for these dislocations

97. First aid
    a. The same as 96 above

98 Review
    a. First aid (IX-H1 thru H50

99. Review
    a. First aid (IX-H51 thru H101)

100. Discussion
    a. Questions from class concerning anything on first aid
    b. Questions from class concerning anything on safety

101. First aid same as 58

102. First aid same as 59

103. First aid same as 60

104. First aid same as 63

105. First aid same as 64

106. First aid same as 66

107. First aid same as 71

108. First aid same as 78

109. First aid same as 80

110. First aid same as 83

111. First aid same as 84

112. First aid same as 85

113. First aid same as 88

114. First aid same as 92

115. First aid same as 94

116. First aid same as 96

117. First aid same as 98

118. First aid same as 99

119. First aid
   a. Demonstrate to class how to dress burns and scalds on pages 73-78 of USBM publication, FIRST AID
   b. Class participation in demonstration of these dressings

120. First aid
   a. Same as 119

NOTE:

This is the scheduled lessons for a complete course and is estimated that it will require at least 200 hours of teaching. If the class is sufficiently versed in mine safety at the close of lesson 120 then a new class will be started -- using two members of the old class as teachers.