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Respirators, Gas Masks, Hose Masks and Breathing Apparatus

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EXHIBIT NSC-9 8/31/88

Safe Practices Pamphlet No. 64

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This pamphlet is a compilation of experience in accident prevention. It must not be confused with Federal, State or insurance requirements, or with National Safety Codes.

1054 ✓

1. The hazards to life and health from working in certain dusts, fumes and gases have long been recognized, and many law-enforcing bodies require that employers provide protection for workers exposed to these hazards. Progressive employers are giving careful consideration to numerous protective measures and are encouraging the development of respirators, gas masks and breathing apparatus designed and built to meet industrial conditions. This is much better than endeavoring to use inadequate respirators, salvaged army and navy gas masks, or obsolete oxygen breathing apparatus.

2. The field of usefulness of each type of equipment is quite definite:

(a) **Respirators** provide protection against certain forms of dust. It is difficult to obtain a complete seal against the finest and most dangerous dusts, especially those containing silica.

(b) **Gas masks,** properly selected for the conditions encountered, afford good protection against certain fumes, gases or dusts which are poisonous or have an irritating effect upon the nose and eyes, where the atmosphere contains sufficient oxygen to sustain life.

(c) **Hose masks,** providing fresh air through a hose from a safe distance, will protect the wearer from any conditions of gas, fumes or smoke that the exposed parts of the body may be able to withstand.

(d) **Self-contained oxygen breathing apparatus** is particularly useful where the atmosphere contains insufficient oxygen to sustain life, or where the concentration of irrespirable gases exceeds two per cent. In cases where the hose mask is too cumbersome, the self-contained breathing apparatus may be more adaptable.

Courtesy, U. S. Bureaus of Mines

Figure 1. Fireman wearing canister gas mask. This mask is provided with the all-service canister, which gives protection against carbon monoxide as well as several other gases.

Respirators

3. The respirator is essentially a mechanical filter. It can be used successfully where insoluble dusts prevail. It is of no value, however, in reducing the ill effects of fumes or gases and should never be preferred to a gas mask. It does protect against coarse dust particles present in the air, but when a vast amount of fine particles and poisonous dusts are in suspension a considerable quantity of such dust adheres to the damp sponge or other filter used. While the amount of dust breathed is thus reduced the wearer cannot help but inhale vapors that are being generated by the contact of poisonous substances and the filter. (*See Figure* 2.)

4. Despite the fact that respirators have been known and used for a comparatively long time, the problem of protecting workmen from the effects of various kinds of dusts has often been better solved by the installation of exhaust systems. This subject is fully discussed in the National Safety Council's *Safe Practices Pamphlet No.* 32. Only a few of the manufactured respirators are recognized as effective protective appliances. The chief objections to many respirators are: (1) some are too heavy, irritating the face; (2) on others the straps around the head irritate the ears; (3) they are uncomfortable; (4) men cannot talk or chew or expectorate when wearing the respirator; (5) they do not fit the face accurately so that dust enters the mouth and nostrils between the respirator and the face, or dust is blown into the eyes when exhaling; (6) they are not properly maintained where it is necessary to moisten or renew the filtering medium, and often this medium is not properly cleaned; (7) workmen have a serious objection to wearing them due to the ridicule to which they are subjected; (8) they interfere with wearing goggles; and (9) the men often disregard hygienic suggestions because the respirator gives a false sense of security.

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Courtesy, Youngstown Sheet & Tube Co.

Figure 2. Two types of manufactured respirators. The respirator on the right is the "Pig Snout" type, one of the earliest developed and which has been generally replaced by other types. The one on the left is more satisfactory.

5. A respirator, just as any other article of clothing, should fit with reasonable comfort. It is possible to secure commercial respirators which are light in weight and constructed of materials that are pliable enough to insure an accurate fit to the various facial contours encountered among a large number of employees. Better maintenance of the filtering medium is possible only through *supervision* and through an appreciation of the necessity for wearing the respirator properly, on the part of the workmen themselves. Improving the appearance of the respirator to eliminate the ridicule of fellow workers is desirable; ridicule is harder to combat than all other objections.

6. The area of the filtering medium must be as large as possible. The smaller the area of the medium, the greater will be the resistance to breathing. Other things being equal, increased resistance means smaller and fewer air passages through the medium and increased velocity of air through the passages. An increase in velocity in turn tends to increase the amount of dust which is drawn through the respirator.

7. The United States Bureau of Mines has completed experimental and investigation work on mediums suitable for respirator filters. The results of these experiments are now available in Technical Paper 394 of the Bureau of Mines. It was found that all filter substances do not have the same retarding power on dust, even when of equal porosity. Many filtering materials which offer great resistance to the passage of inspired air, permit the flow of dust quite freely, while others which offer but little resistance to breathing are found to be surprisingly efficient. These experiments and research work have aided manufacturers of respirators to produce personal protection to meet special occupational conditions. If employers will fully explain their requirements, there should be little further difficulty in enabling workmen to withstand dusty conditions of employment without harm.

8. A home-made respirator, (*Figure* 3) made of a piece of muslin 33 inches long by 5 inches wide, with absorbent cotton as a filtering medium, has found favor with many men. A respirator of this kind has been used successfully in many different plants. Absorbent cotton is an excellent filter when placed under compression. It is rapidly replacing a handkerchief—often dirty—which workmen tied around the nostrils and mouth. The device is easy to make, and so inexpensive, if made in large quantities, that it is practicable to give each workman a clean one every day or shift.

9. The Bureau of Inspection of the New York State Industrial Commission has tested several commercial respirators and the home-made respirator described above. The greatest efficiency was obtained with the home-made respirator. Dust-laden air containing basic lead salt was drawn through the filtering medium at a rate corresponding to the amount of air breathed by an average individual. Careful analytical tests revealed no lead drawn through the home-made respirator. Other advantages of the home-made respirator are: (1) it does not obstruct vision, (2) it can be washed if desirable, (3) it offers less incentive for one workman to appropriate the respirator of another, (4) it does not unduly increase the expense by breaking, rusting, and wearing out, (5) it does not cause excessive perspiration or irritaton of the cheeks, nose, chin, or ears, and (6) it can be more easily arranged to fit various facial contours. The home-made respirator will absorb perspiration in many instances, and thus avoid troublesome skin eruptions caused by some dusts, notably that of fulminate of mercury.

Gas Masks

10. Gas masks of the canister type should not be used in atmospheres where there is a deficiency of oxygen (less than 16 per cent of oxygen). There are two general types of gas masks (not including self-contained breathing apparatus); (1) those having canisters which purify the air and (2) those with hose attached which introduces a fresh air supply. The latter style of mask is available with either a face piece or a helmet covering the entire head.

11. The average gas mask is not cumbersome; it is simple and easy to wear. Special canisters can be secured to give protection from one gas or one class of gases, or to give protection against practically all kinds of gases. The mask illustrated in *Figure* 4 is equipped with an All-Service canister. When workers are required to stay in one gaseous location, and the hazard is from one particular kind of gas, it is usually more convenient and economical to provide a canister for that specific gas. (*See Figure* 1.)

12. As a guide to the choice of the correct canister to be used in con-

nection with a gas mask, the accompanying table, prepared from information supplied by the U. S. Bureau of Mines and the Chemical Section of the National Safety Council, can be used authoritatively.

13. Gas masks are constructed largely of rubber and rubberized fabrics. Rubber hardens and cracks under the action of light and air, and fabric deteriorates if allowed to remain moist. Therefore, gas masks should be kept in a cool dry place and protected from light and air as much as possible. Manufacturers of gas masks generally provide wood or metal cases with each mask sold, and inform the buyer that the mask will last longer if kept in the original case when not in actual use. It is suggested that cabinets containing masks be sealed as shown in *Figure* 5.

14. It is difficult to estimate the life of a gas mask in use or in storage, but under ideal conditions, the manufacturers claim that a mask should retain its usefulness for about two years. If not given proper care in storage, the life will probably not exceed one year. The rubber parts deteriorate rapidly when carelessly stored.

15. After a mask has been used, it should be carefully wiped with a damp cloth and dried before being put back in the case, special care being taken to see that there are not sharp folds or creases in the mask when put away.

16. When the same mask is used by several persons, it is always advisable to clean and disinfect the mask after use. It is recommended that the mask, separated from the canister, be immersed and washed in a two per cent solution of lysol and then dried in the open air with the lysol solution adhering. After the mask has been washed, the eye pieces should be thoroughly cleaned, as clean glass has less tendency to fog from moisture and permits better work.

17. It is impossible to estimate the life of a canister after use without testing it against gas, which, of course, renders it useless. If there is any reason to believe that the canister is almost or entirely exhausted, a fresh canister should be attached to the mask. The resistance to the flow of air may indicate the probable life in the carbon monoxide or All-Service masks. Manufacturers deliver canisters with plug seals covering the bottom valve, and

TYPES OF CANISTERS FOR PROTECTION UNDER VARIOUS CONDITIONS

Conditions	Contents of Canister	Color of Canister
A. Protection in low concentrations of acid gases such as chlorine, formic acid, hydrogen sulphide, nitrogen peroxide, sulphur dioxide, and the like (average 1 per cent in air).	Gas masks with canisters containing 600 cubic centimeters or more of soda-lime or caustic soda fused on pumice granules. The time of protection decreases rapidly as the concentration increases. Canisters of dry activated charcoal last only about one-fifth as long as soda-lime.	White
B. Protection in high concentrations of acid gases (exceeding 2 per cent in air).	Canister gas masks do not protect sufficiently well to assure safety. They should not be used.	
C. Protection in low concentration of organic vapors such as aniline, benzene, ether, toluene, gasoline, and the like (average 2 per cent in air).	Gas masks with canisters containing 600 cubic centimeters or more of activated charcoal. The time of protection decreases rapidly as the concentration increases. Canisters containing gas absorbents other than activated charcoal are useless.	Black
D. Protection in high concentrations of organic vapors (exceeding 5 per cent in air).	Canister gas masks do not protect sufficiently well to assure safety. They should not be used.	
E. Protection against ammonia gas (not exceeding 3 per cent in air).	The above mentioned canisters containing lime, soda, and charcoal absorbents do not protect against ammonia. Special canisters for that purpose are required. These contain silica gel. The 3 per cent maximum cannot be long endured by the wearer of the mask, because of the severe skin irritation from ammonia gas.	Green
F. Protection against carbon monoxide (not exceeding 3 per cent in air).	Special canisters containing Hopcalite, which catalyzes the action of carbon monoxide with oxygen of air to produce relatively harmless carbon dioxide, protect against carbon monoxide. They have some action on hydrogen sulphide and some other gases, but can be considered safe for use only in carbon monoxide. The masks protect in concentrations exceeding 3 per cent, but the intense heat produced cannot be long endured.	Blue
G. Protection against a combination of organic and acid fumes.	Gas masks with canisters containing activated charcoal and soda-lime.	Yellow
H. Protection against acid and organic vapors and ammonia.	Gas masks with canisters containing soda-lime, activated charcoal and silica gel.	Brown
I. Protection against dusts, smokes, and mists in combination with any of the above gases.	Canisters containing cotton-wool filters.	A contrasting black or white stripe on the canister indicates the filter.
J. Protection against mixtures of the above gases in air. (The All-Service Canister.)	Canisters containing two or more of the above mentioned absorbents protect against more than one gas or class of gases, but the total concentration of mixed irrespirable gases in air should not exceed that allowed by the lowest maximum figure for any of the classes included. When more than one absorbent is contained in a canister the action of each is usually independent of the others and its capacity dependent upon its volume. Thus the capacity of the canister containing several absorbents is less for a single gas than that of the canister filled only with the suitable absorbent.	Red

with corks closing the hose nipple, unless the latter is attached to the face piece. When completely protected from the outside air, canisters should last a year, but when an excess of outside air is allowed to enter, they may deteriorate rapidly, especially canisters containing sodalime. Canisters in continuous use under a wide variety of circumstances have shown a variation of life from a few hours to many weeks.

18. Canisters should be protected, especially from dampness and air when not in use, and should be kept in a cool place. When a canister has become water saturated, it should not be used again. When an assembled gas mask is stored for future use, the bottom opening of the canister should be closed with the plug stopper furnished with the canister.

19. The man who is to wear the mask should test the face piece to make sure that it fits and does not leak, before he enters a gaseous location. To do this, the plug that seals the bottom opening is removed, the mask put on and the head bands adjusted until the mask fits closely, but comfortably. There should be no kinks in the tube between mask and canister. Resistance

to natural breathing should be very slight. The bottom opening should be closed with the palm of the hand and suction exerted with the lungs until the face piece collapses. The tube and face piece should be examined at the same time to locate

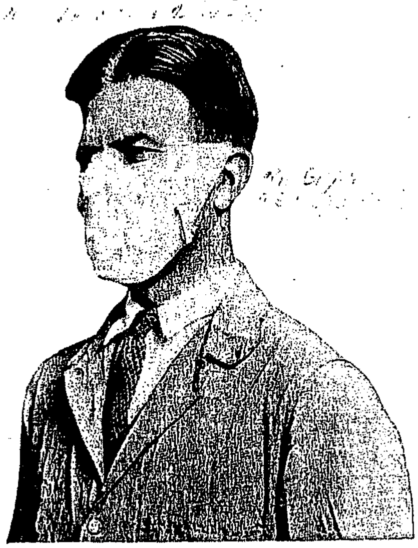


Figure 8. The home-made respirator, made of a piece of muslin with absorbent cotton as a filter, which has been very popular.

possible leaks. If there are no leaks, the mask and the canister will hold a vacuum for about 15 seconds. If the gas mask is tight, the wearer can proceed, but he should enter the gas cautiously to see that the canister is active. If the mask leaks, or if the canister is used up, fumes will be noticed (except in carbon monoxide). When this evidence of failure is known, the wearer should immediately return to fresh air and obtain a new canister, being sure to get the right canister for the gas to be encountered. Each person who learns to use a gas mask should undergo a physical examination, especially as to the condition of the lungs and heart.

Hose Masks

20. Hose masks afford protection in any irrespirable atmosphere, but they are somewhat cumbersome, and the length of the hose limits the distance the wearer may move from the source of fresh air. (*See Figure* 6.) The masks are simply a means of providing ventilation for an individual entering an irrespirable atmosphere; they consume no chemicals and are not limited in the length of time for which they may be used. It is recommended that a safety belt and life line be used in every case where the wearer of a hose mask enters a confined, irrespirable atmosphere. If desired, the man watching the life line may operate a blower to provide an ample supply of fresh air to the hose mask wearer at all times.

21. For many jobs the hose masks have several advantages. The mask is arranged so the air in the hose travels in one direction only, the exhaled breath passing through a valve in the face mask. The exhalation valve should be so constructed that it is normally closed and cannot under any condition permit the outside air to pass back into the mask. The Chemical Warfare Service has found that the so-called flutter valve such as was used on United States Army Gas Masks, is the best and safest for the variety of conditions encountered. Hose masks protect against all deficiencies of oxygen, since they are not dependent on the air surrounding the wearer. They likewise protect against any concentrations of any kind of gas, so that they can be used as long as the wearer is not working more than the hose length away from an uncontaminated air supply.

22. Where hose masks are used, with a hose of greater length than 25 feet, it is recommended that an air blower be used to force a supply of air to the wearer. This is essential to overcome the friction of the hose. The air blower should always be of the centrifugal type, so in case of failure of the person operating the blower to maintain sufficient speed or to keep the blower in operation, the air supply to the person wearing the hose mask will not be entirely cut off and air may be drawn through the hose and pump by the wearer. Enough air may be drawn through long lengths of hose in this way to permit the wearer to escape from an irrespirable atmosphere in safety and without removing the mask.

23. In the presence of ammonia, hose masks will protect against any concentration that the skin will bear. If carbon monoxide is to be encountered, a hose mask is probably safer to wear than a canister mask, as carbon monoxide is odorless and tasteless. (*See paragraph* 19.) The hose mask weighs about five pounds, while the gas mask weighs four to eight pounds, according to the size of the canister and style of support for the canister. There is practically no upkeep or maintenance cost with a hose mask.

24. When 25-foot lengths of hose are coupled together the weight and stiffness of the hose may cause the couplings to unscrew. To prevent this, a lock that prevents free movement of any part of the coupling can be provided.

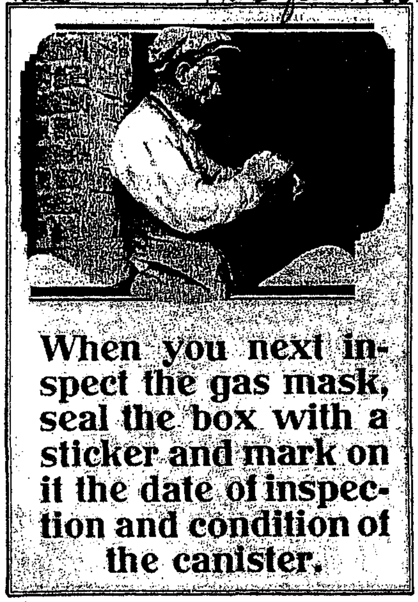
25. Compressor air should not be used for respiratory purposes unless no other source of air can be provided.

Breathing Apparatus

26. Self contained oxygen breathing apparatus protects against deficiencies of oxygen and also any concentration of gases and vapors. It is not dependent on surrounding air, so is especially useful in exploring and rescue operations.

27. Oxygen breathing apparatus was developed to assist in the rescue and recovery of persons in mines, following explosions or fires, in heavy concentrations of noxious gases. The United States Bureau of Mines has summarized the value of oxygen

Figure 4. The All-Service gas mask, showing timer on the top of the canister and a carbon monoxide detector. With this equipment, a man can enter a dangerous atmosphere, and soon know if the degree of concentration of carbon monoxide is or is not dangerous for him to work in. Such a canister will be safe to wear in atmospheres containing not more than 2 per cent of carbon monoxide.



Reproduction of N. S. C. Poster C 128
Figure 5. One good method of marking gas masks when packed in the box for further use.

breathing apparatus by comparison with conditions before its general use. Prior to the use of breathing apparatus many rescue men lost their lives and the work of rescue was delayed by men rushing into the afterdamp.

28. Rescue crews have been killed by second explosions resulting from fires, making it hazardous to advance the ventilation, whereas under similar conditions the breathing apparatus has been of great value in making it possible for men to reach and put out fires in advance of the ventilation. Breathing apparatus is also used effectively in connection with the control and the re-establishment of ventilation following mine fires and explosions. The training of a large number of miners in the use of the apparatus and in organized methods of procedure has brought about an improvement in discipline following mine disasters and fires. The great majority of the comparatively few deaths to persons while wearing breathing apparatus have been due to failure to use it properly.

29. In order that the wearer can be assured of safety, a physical examination and a thorough course of instruction and training in the use of the apparatus are needed. The training should cover a period of several days under an experienced and competent instructor. The United States Bureau of Mines is prepared to give instructions to qualified persons without cost.

30. The apparatus should be examined, tested and overhauled at intervals of about one month by skilled mechanics or other competent persons who thoroughly understand the action and function of each part. Failure to keep the apparatus in perfect condition may jeopardize the life of the wearer. (This also applies to gas masks and hose masks.) *See Figure* 7, for an excellent method of storing breathing apparatus.

31. Self contained breathing apparatus is available in two general types: apparatus which will supply oxygen for one-half hour and apparatus which will furnish an ample supply of oxygen for two hours. The half-hour apparatus weighs 15 to 17 pounds and the two-hour apparatus 30 to 45 pounds. When discharged, they require renewal of oxygen and chemical charges. Various types of breathing apparatus are illustrated in *Figures* 8, 9, 10 *and* 11.

32. The work of the United States Bureau of Mines in developing, perfecting, and investigating the various types of breathing apparatus has been of inestimable value to the mining industry. The valuable contributions of that organization have many applications in industry generally. It is, therefore, recommended that the Bureau of Mines be consulted whenever there is a need for breathing apparatus.

33. Several pamphlets on this subject have been issued by the Bureau of Mines. One pamphlet entitled "Self-Contained Mine Rescue Oxygen Breathing Apparatus," is a valuable work for anyone interested in purchasing this type of equipment. The pamphlet can be secured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a cost of 20 cents.

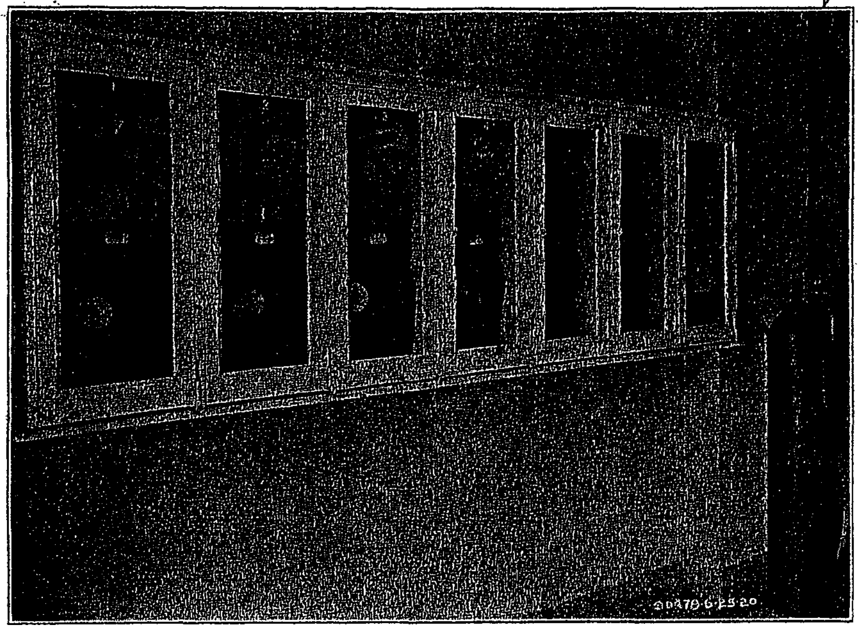
34. The types of two-hour oxygen breathing apparatus commonly used in mine rescue work in the United States are described in that pamphlet. Concerning other apparatus, the Bureau states:

Courtesy, U. S. Bureau of Mines
Figure 6. Hose mask with Tissot face piece. A helmet can be used instead of a face piece, but the latter is now preferred by most persons. The hose is strongly fastened to a wide heavy web belt, which precludes pulling the mask away from the face of the wearer.

Two-hour mine rescue apparatus that depends upon sodium peroxide, potassium peroxide, or liquid air for its oxygen supply has been used in Europe, but little is known of it here. The objections to apparatus that use peroxides as the source of oxygen supply are that much heat is freed with the oxygen, the rate of oxygen flow is hard to control, and the foaming of material tends to block the air ducts. Liquid air or liquid oxygen are not always available and cannot be stored for any great length of time.

Half-hour, three-quarter hour, and one-hour apparatus, so-called because they will supply oxygen for these periods of time, are useful in other industries. The Bureau of Mines does not use such apparatus in rescue and recovery work due to their time limitations. A two-hour oxygen supply is desirable in mine rescue work.

Several types of half-hour oxygen breathing apparatus that are on sale in the United States resemble the Fluess-Proto, the Paul, the Gibbs and the Draeger apparatus in construction and operation. Tests like those run on two-hour apparatus to see that they are air-tight and to see that they are in good working condition, should be run on half-hour apparatus before they are used in bad air. Half-hour apparatus is useful at plants where employees work in irrespirable air for short periods, but it should be used only by men thoroughly trained in its use.



Courtesy, Ford Motor Company

Figure 7. A good way to store breathing apparatus when not in use. Note the cylinder of compressed oxygen, ready to recharge individual oxygen bottles on the apparatus.

35. Two-hour breathing apparatus, to be safe and efficient, should meet the following requirements, according to the Bureau of Mines:

a. The amount of oxygen or air supplied by the apparatus should meet the needs of the wearer at all times. The reducing valve of every breathing apparatus which aims to deliver oxygen at a uniform rate should be adjusted to supply not less than 2 liters (122 cubic inches, or about 2 quarts) of oxygen per minute.

b. Regenerating material, if used, should absorb so much carbon dioxide from the exhaled air that there will be not more than 2.5 per cent at any time in the inhaled air. The average carbon dioxide content in inhaled air should not be more than 1 per cent during any 2 hour test period.

c. Apparatus should be free from mechanical obstructions in order that the wearer may breathe freely at all times. The resistance of the apparatus as a whole to the passage of air will show whether circulation is free or obstructed. The highest resistance of an apparatus should not exceed 2 inches water gage.

d. The temperature of the inspired air should not exceed a maximum of 110° F. when that of the external air does not exceed 85° F. A much lower temperature than 110° F. for the inspired air is desirable.

e. The apparatus should be durable and all vital parts protected to prevent material damage or rapid wear.

f. Every oxygen breathing apparatus should have a by-pass valve which permits a free flow of oxygen or air from the oxygen or air container to the circulatory system of the apparatus, independent of the reducing valve.

g. The apparatus, when worn in irrespirable atmospheres, should supply enough oxygen to its wearer for not less than 2 hours without recharging. However, "half-hour" apparatus may be used for certain auxiliary purposes in rescue work underground, if these apparatus pass the tests for two-hour apparatus, with the exception of those on oxygen and regenerator capacity.

h. The apparatus should be of a design that uses a mouth-breathing device or other face attachment that when properly adjusted to the wearer's face can not have more than 250 cubic centimeters of dead space inside, including the tubes or connections attached up to the inhalation and exhalation valves.

i. A fully-charged apparatus complete with a headpiece should not weigh more than 40 pounds. The lightest weight compatible with safe and durable construction is desirable.

j. The mechanical construction of the apparatus should be such that every part can be tested, inspected and repaired by persons skilled in such work. All parts which need sterilizing should be readily accessible.

k. All parts of the apparatus subject to, or liable to be subject to, pressures higher than 5 pounds per square inch should be of such construction or equipped with such devices as will insure the wearer's safety.

l. The inhalation and exhalation compartments of apparatus equipped with a breathing bag or bags or their equivalent, should have a combined capacity of at least 9 liters (488 cubic inches or about 8 quarts); however, if a breathing bag with but one compartment is used it should have a capacity of not less than 5 liters (305 cubic inches or about 5 quarts).

m. The apparatus should have no zone of constant negative pressure in its circulatory system.

n. The apparatus should have a release valve, operated by hand or automatically, at some point in the circulatory system of the apparatus for releasing to the outside air when desirable part of the air in the circulatory system of the apparatus. It should not be possible for an apparatus wearer to draw outside air through this valve.

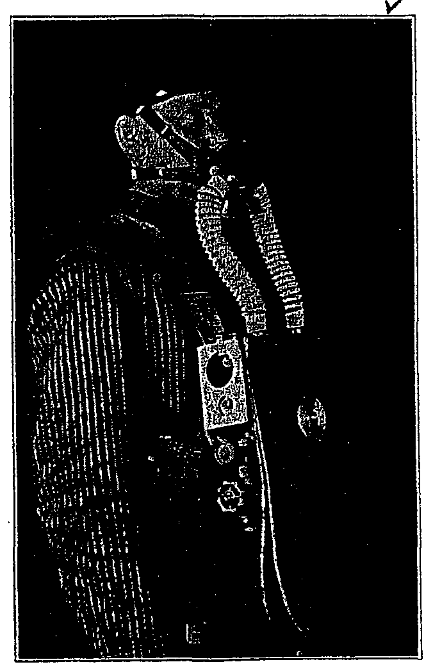
o. If the apparatus is equipped with high-pressure oxygen bottles, these should meet the test requirements of the Interstate Commerce Commission. If there is a safety cap attached to the main bottle valve of the apparatus bottle or bottles holding high-pressure oxygen, this safety cap should have the usual disk and in addition be filled with a metal that fuses at about 94° C. This fusible metal should not extrude from the safety cap under a pressure of 150 atmospheres.

p. All apparatus should have gages for recording time or pressure of oxygen supply; such gages should be of tested accuracy and should be placed on the apparatus where they can be read easily by the wearer. The flow of oxygen to the gage should be controlled by a gage valve placed so that it can be readily manipulated by the wearer independent of the circulatory system of the apparatus.

q. When the oxygen supply of the apparatus is controlled by automatic devices, these should adjust themselves readily to the wearer's needs.

r. The main bottle valve of the high-pressure oxygen bottle or bottles should be so made that an apparatus wearer can not screw the valve stem entirely out of the valve. The main bottle valve should also have devices that will enable the ap[illegible] wearer to lock the valve open.

s. Any apparatus equipped with [illegible] breathing device should have a saliva [illegible] and a firmly fitting nose clip. The saliv[illegible]



Courtesy, U. S. Bureau of Mines

Figure 8. The McCaa half-hour self contained oxygen breathing apparatus.

Also: A.P.P.9-p.5

Courtesy, Youngstown Sheet & Tube Co.
Figure 9. The Draeger two-hour self contained oxygen breathing apparatus.

trap should be so designed that outside air cannot be drawn through it.

t. Oxygen used in breathing apparatus should have at least 98 per cent of oxygen, no hydrogen, and not more than 2 per cent of nitrogen, with traces of argon.

Compressed Air Helmets

36. Persons not familiar with the problems to be encountered in irrespirable atmospheres and with the need for apparatus to work safely in such locations have, from time to time, expressed the opinion that an apparatus supplying compressed air to the wearer should be the most efficient one of all. Authorities are of the opinion, however, that the less said about the compressed air or liquid air helmets, the better, for they are not designed to give a full supply of oxygen for a predetermined period, and they are not supplied with regenerative features. In ordinary breathing a man inhales and exhales from six to seven liters of air per minute during rest, and 60 to 70 liters of air per minute during vigorous physical exertion. It therefore appears utterly impossible, on account of the weight of the air and necessary containers, for a man to carry with him enough of either compressed or liquid air to have entirely fresh air each breath for any length of time. For service up to a maximum of ten minutes, a compressed air apparatus could probably be devised and might be serviceable, although it would probably be rather heavy and expensive.

37. In Great Britain several types of liquid oxygen apparatus which do have regenerative features have been officially approved by the British Mines department for use in mines. This type of apparatus is preferred to the self-contained breathing apparatus on account of its coolness. Such apparatus has not been sold in this country, partly because of the necessity of installing oxygen liquefying apparatus at the mine or station, but they may be used where liquid oxygen would be utilized for other purposes also.

Special Considerations

38. No particular industry or occupation except the petroleum industry has had an unsatisfactory experience with gas masks and breathing apparatus. The reason for this is the action of oil vapors upon the apparatus itself. The petroleum vapors have penetrated rubber parts and breathing apparatus at times with fatal results. The breathing bags of both half-hour and two-hour apparatus are now covered with heavy rubber, which reduces chances of loss of life of the wearer. After use, the breathing bags should be aired in fresh air for at least six hours to rid them of absorbed mixtures before further use.

39. Crude petroleum is a most complex combination of various hydrocarbons and various impurities. The different compositions of the oils have different effects upon the workers. Where natural heavy oils are present, asphyxia from gas is unknown, whereas with light oils, suffocation may be frequent. An analysis of gases at a petroleum refinery may disclose all of the following gases in various proportions:

Carbon Dioxide.
Hydrogen Sulfide.
Oxygen.
Carbon Monoxide.
Nitrogen.
Hydrogen.
Unsaturated Hydro-Carbons (Ethylene, Propylene, etc.).
Saturated Hydro-Carbons (Methane, Ethane, etc.).

40. Some of the petroleum operating men question the value of gas masks in the presence of a small quantity of petroleum vapors, as at the manhole of a storage tank or at the wells in the producing field. The chief reason for apprehension is the length of life of the contents of the canister. This is indeed a very important question for the fumes of some petroleums suffocate a person very quickly. The hose mask is believed to be safer for such use.

Also: A.P.P.9-p.6

Courtesy, U. S. Bureau of Mines
Figure 10. The Paul two-hour self contained oxygen breathing apparatus.

Also: A.P.P.9-p.6

Courtesy, U. S. Bureau of Mines
Figure 11. The Gibbs two-hour self-contained oxygen breathing apparatus.

41. The hose type of mask has been very efficiently and very satisfactorily used as protection in the petroleum industry. Several of the failures of these masks have occurred because the hose has been allowed to lie in the sludge and the oil. The hose should be either tied to some object to keep it from contact with oil in any form, or a sleeve of ordinary garden rubber hose should be used. The breathing hose is usually 3/4 inch in diameter, and garden hose of 1 1/2 inches in diameter can be used for a sleeve.

42. The Bureau of Mines has published Technical Paper 348, entitled "Gas Masks for Gasoline and Petroleum Vapors." It considers the various methods of respiratory protection in the petroleum industry and the effectiveness of the three types of personal protection: canister gas masks, hose masks, and oxygen breathing apparatus.

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