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GAS MANUAL

Part I

Tactical Employment of Gases

General Headquarters
American Expeditionary Forces, France
March, 1919

GENERAL HEADQUARTERS
AMERICAN EXPEDITIONARY FORCES

March, 1919.

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PART I

TACTICAL EMPLOYMENT OF GASES

IMPORTANCE OF GAS AS A WEAPON IN MILITARY OPERATIONS.

1. The introduction and development of the use of gas in military operations has had a marked effect on the action and employment of troops in combat. A proper tactical training now requires careful instruction not only in measures of defense against gas, but in the use of gas against the enemy in offensive and defensive operations. Beginning in April, 1915, with the first successful use of gas in the form of a gas cloud projected from cylinders the forms and methods of use have been extended to include the use of the usual arms of combatant troops in the projection of gas and the employment of special arms for its projection.

2. The general term "Gas" as now used in warfare embraces all poisonous gases used in war, whether in cylinders, shells, or otherwise, and in addition, smoke, incendiary and irritating substances. The chemical substances designated as "Gases" have a great variety of properties and effects. To think of all "gases" as having substantially the same properties and tactical uses is a serious mistake. The "gases" used in warfare include not only true gases, but solids and liquids of widely varying properties, that are converted in their actual use into "particulate" gases and vapors. This makes possible a wide variety of tactical uses in combination with other means of warfare. The effect of gas persists after the explosion, imposing upon the enemy the necessity of wearing masks. This is a source of discomfort and impairment of vision and efficiency. Gas is, moreover, capable of penetrating certain means of defense, such as trenches and dugouts, sometimes more effectively than other forms of ammunition.

3. In order to realize the value of the employment of gas in military operations and the need of the measures of defense against gas, as well as to determine the conditions under which the use of gas is applicable, a knowledge of the physical properties and the physiological effects of gases and their behavior upon release, is essential.

PHYSICAL PROPERTIES.

4. The most important physical property is that which determines the "persistency" of the substance when used in the field. This property depends chiefly upon the rapidity of evaporation, which may be roughly estimated from the boiling point of the liquid. According to this criterion, we may name the following classes, giving the most prominent example of each:

GROUP I—Substances which are gases at ordinary temperatures (of low persistency)—Phosgene.

GROUP II—Moderately volatile liquids (of moderate persistency)—Chlorpicrin.

GROUP III—Slightly volatile liquids (of high persistency)—Mustard "Gas."

GROUP IV—Toxic smoke producers—Diphenylchlorarsine.

(I) *Gases at ordinary temperatures* (like phosgene), when released from containers, will be blown about by the air currents; hence, if the air is relatively still, as when the wind is low, or in a dense wood, such a gas may persist for some time. On the other hand, in the open, and when the wind is blowing, it will be quickly dissipated. Such a gas can be used advantageously against positions to be attacked shortly after the release of the gas.

(II) *Moderately volatile liquids* (like chlorpicrin), when splashed upon the ground, will vaporize rather slowly, and will continue to contaminate the air in the neighborhood. In woods or in dugouts, or when the air is still, this contamination may persist for considerable lengths of time. However, that portion of the liquid which has vaporized is no more persistent than the gases in Class I.

(III) *Slightly volatile liquids* (like mustard gas) will give off their vapors still more slowly, so that an infected area will remain dangerously infected for a greater length of time. However, it is difficult to get their vapors into the air in high concentrations. Only by breaking them up to form a mist can high concentrations and rapid deadly effects be realized. Substances of this class are accordingly especially useful in harassing an enemy and in preventing him from attacking over areas drenched with them It has, in fact, been possible to ascertain positions which the enemy expected to attack by noting gaps left in territory otherwise heavily shelled with mustard "gas."

(IV) *Toxic smoke producers* (as diphenylchlorarsine) are substances which can be made to give a suspension of extremely fine particles of poisonous dust, or mists in the air. Such clouds are no more persistent than those caused by gases in Class I. Their chief value lies in their ability to penetrate, more or less, the enemy masks. Usually when the cloud has settled upon the ground the amount of vapor given off is too small to have any toxic effect. Such effect is only produced by the inhalation of the particles themselves while suspended in the air.

PHYSIOLOGICAL EFFECTS.

5. The toxic substances may be classified according to the predominant effects which they exert, with the understanding, however, that the action of any substance is not limited to a single tissue or group of tissues. Thus, a substance, the vapor of which causes injury to the respiratory passages, may, when applied to the skin, cause blistering. If the sole or chief usefulness of a substance in warfare depends upon its effect on the respiratory tract, it is classed as a respiratory irritant. If its power to produce casualties is due to its action on the skin, it is classed as a skin irritant. If both actions are useful, it is placed in both groups.

6. Respiratory Irritants. By far the greatest number of substances thus far used injure the respiratory apparatus. Three groups may be differentiated:

(a) Those which exert their shief effects upon the delicate membranes in the lungs through which oxygen passes from the air into the blood. The main result of this injury is to cause fluid to pass from the blood into the minute air sacs and thus to obstruct the oxygen supply to the blood. Death from one of these substances may be compared to death by drowning; the water in which the victim drowns being drawn into his lungs from his own blood vessels. Examples: Phosgene, chlorine, chlorpicrin, diphosgene.

(b) Substances which injure the membranes which line the air passages. During normal life these membranes insure protection to the lungs against mechanical injury by particles which may be taken in with the air and against bacterial infection. As a result of the action of substances of this group their protective power is lost. Portions of the membrane may become swollen and detached and may plug up the smaller passages leading to the lung tissue, or the damaged tissue may become the seat of bacterial infection, thus setting up bronchitis and pneumonia. Examples: Mustard gas, ethyldichlorarsine.

(c) Substances which affect chiefly the upper air passages, i.e., the nose and throat. These substances cause intense pain and discomfort but are not dangerous to life. They cause sneezing, painful smarting of the nose and throat, intense headache, a feeling of severe constriction of the chest, and vomiting. For varying periods after exposure they may cause general muscular weakness and dizziness, loss of sensation in parts of the body or even transitory unconsciousness. Examples: Diphenylchlorarsine, diphenylcyanarsine.

7. Tear Producers (*lachrymators*). Certain substances have a powerful effect upon the eyes, causing copious flowing of

tears, followed by reddening and swelling of the eyes, producing thereby effective temporary blindness. These effects are often produced by extremely minute quantities of tear producing substances. Larger quantities of the same substances usually act as lung irritants as well. Examples: Brombenzylcyanide, bromacetone, ethyl idioacetate, chlorpicrin.

8. Skin Blisterers (*vesicants*). Certain substances have a powerful irritating effect upon the skin, very much like that produced by poison ivy. The same effect is produced upon all the surfaces of the body with which the substance may come in contact, such as the eyes and the breathing passages. Accordingly, a substance producing skin blistering will, if inhaled, also act as a powerful irritant of the air passages. Example: Mustard gas.

9. The following table includes the most important substances now in use in Chemical Warfare, grouped according to persistency, with brief indications of their physiological effects. Little attempt is made to describe the odors, as this is very difficult. However, all who have any responsibility in connection with Chemical Warfare, should become familiar with the various odors by actual experience:

PROPERTIES OF SUBSTANCES USED IN CHEMICAL WARFARE.

NAME	PROPERTIES	
	Physical	*Physiological*
GROUP I—*Gases at Ordinary Temperatures.* (Readily dissipated by wind. Non-persistent.)		
Chlorine (Berthollite)	Greenish Yellow Gas.	Lung irritant, death rapid or delayed. Less toxic than phosgene. Odor like that of bleaching lime.
Phosgene (C. G.) (Collongite)	Colorless gas, easily liquified.	Lung irritant, death rapid or delayed. Mouldy odor.
Hydrocyanic Acid (V. N.) (Vincennite)	Colorless gas, easily liquified.	Nerve poison. Immediate death if concentrated; very litte effect if dilute. Rapid recovery with no after effects.
GROUP II—*Moderately Volatile Liquids.* (Moderately persistent.)		
Chlorpicrin (P. S.)	Liquid less volatile than water.	Lung irritant, slightly less toxic than phosgene. Tear producer.
Diphosgene (S. P.) (Superpalite) (Green Cross)	Liquid less volatile than water.	Lung irritant.
Dichlorethylarsine (Yellow Cross 1) (New Green Cross 3)	Moderately volatile liquid.	Nerve poison and respiratory irritant. Produces pain in throat, chest and head.

GROUP III—*Slightly Volatile Liquids.* (Highly persistent.)

Brombensylcyanide (C. A.). (Other tear producers similar in properties and effect.)		Powerful tear producer.
Mustard gas (H. S.) (Yperite) Dichlorethylsulphide. Yellow Cross	Liquid, boiling at 217° C. (423° F). Faint pungent odor when pure. Garlic odor from shell bursts.	Air passage irritant, producing death, and skin blistering agent. Eyes and genital very sensitive. Effects often delayed 3 hours to 2 days.

GROUP IV—*Toxic Smoke Producers.*

Diphenylchlorarsine (D. A.) Sternite, (Blue Cross).	Solid, melting at 39° C. (102° F.), boiling at 333° C. (632° F.) vapor condensing to smoke.	Produces violent pain in head, throat and chest, with sneezing and coughing.
Diphenylcyanarsine.	Similar to diphenylchlorarsine.	Same effects as D. A., but more powerful.
Stannic chloride (K. J.)	Volatile liquid forming solid smoke with moisture of the air.	Little toxic. Gives opaque cloud and penetrates German mask, producing coughing.

EFFECT IN RELATION TO DENSITY OF GAS AND TIME OF EXPOSURE.

10. The degree of the physiological effects stated in the preceding paragraph depends on the time of exposure and the density of the gas. It is evident that the more dilute the gas, the greater is the time of exposure necessary to produce an equally toxic effect. We may say roughly that doubling the concentration of a given gas reduces the time of exposure necessary to kill by at least half, and usually by more than half. This is very important in connection with tactical considerations, because the chief effectiveness of the gases of the non-persistent type, like phosgene, is attained through surprise-poisoning the enemy before he is able to put on his mask. It is exceedingly important, from this standpoint, to surround him suddenly with gas of sufficient concentration before his mask is in place.

11. The effectiveness of mustard gas is partly due to the fact that it retains its proportionate effectiveness at very low concentrations. The low concentration of one part in 100,000 acting for 20 minutes produces as much effect as the high concentration of one part in 10,000 acting for 2 minutes. This is also true to a large extent with chlorpicrin. On the other hand, the toxicity of hydrocyanic acid (the toxic constituent of Vincennite), falls off much more abruptly as the concentration diminishes, so that a dilution is very soon reached at which it can be breathed almost indefinitely with no bad results.

12. The following table gives the concentrations necessary to produce death, or other characteristic effects, upon exposure for different lengths of time:

CONCENTRATION NECESSARY TO PRODUCE DEATH.

Gases	Exposure for 5 minutes.		Exposure for 30 minutes.		Exposure for 2 hours.	
	Conc. by Vol.	Gms. per M^3	Conc. by Vol.	Gms. per M^3	Conc. by Vol.	Gms. per M^3
Phosgene	1 per 5,000	0.82	1 per 25,000	0.16	1 per 100,000	0.04
Chlorpicrin	1 per 2,500	2.7	1 per 20,000	0.34	1 per 50,000	0.14
Mustard Gas	1 per 13,000	0.5	1 per 100,000	0.07	1 per 800,000	0.02
Hydro-cyanic acid	1 per 2,000	0.06	1 per 8,000	0.14	1 per 10,000	0.1

INTOLERABLE CONCENTRATIONS

Gases	Exposure for 5 minutes.		Exposure for 30 minutes.			
	Conc. by Vol.	Gms. per M^3	Conc. by Vol.	Gms. per M^3		
Diphenylchlorarsine	1 per 10,000,000	0.0001	1 per 100,000,000	0.00001		
Brombenzylcyanide	1 per 20,000,000	0.0004				

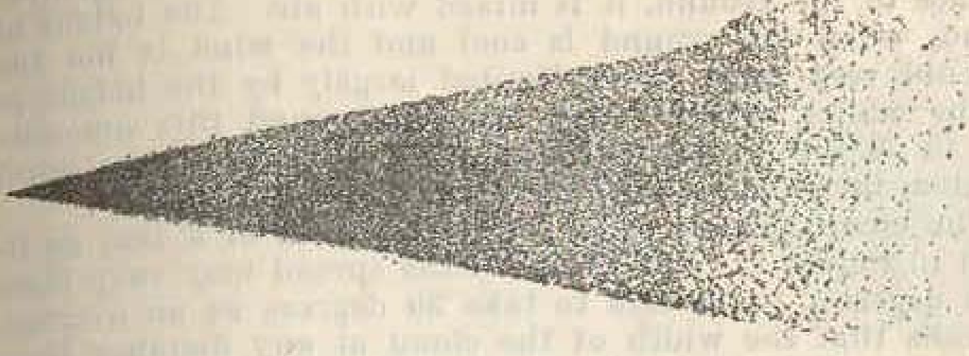

Fig. 1.

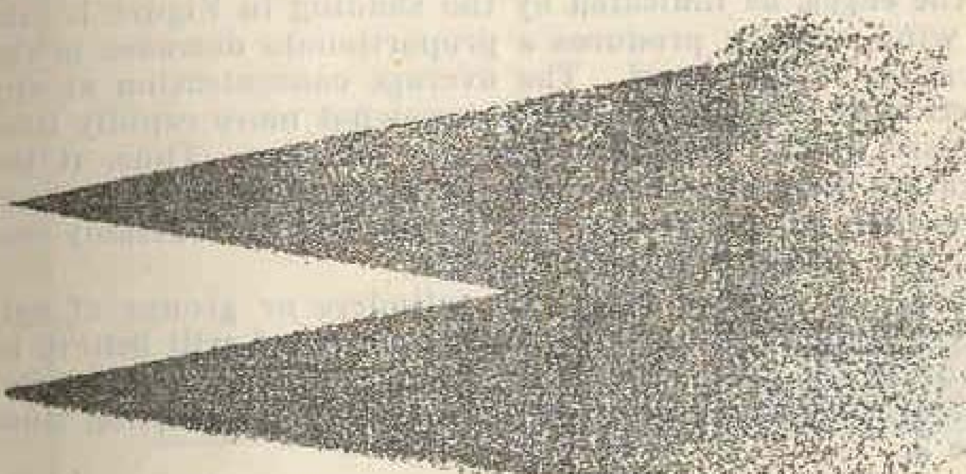

Fig. 2.

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ACTION OF GAS UPON RELEASE FROM CONTAINERS.

(1) Gas from Cylinders.

13. When gas is liberated from a cylinder it is blown along the wind and as a result of the eddies set up by its passage over the surface of the ground, it is mixed with air. The height of the cloud, when the ground is cool and the wind is not too high, is not very great, being limited largely by the height to which the eddies extend. Over smooth ground this amounts roughly to 30 feet at a distance of 100 yeards from the point of emission, increasing only slowly at greater distances.

14. The cloud spreads laterally in the form of a fan, as illustrated in Figure 1. The angle of this spread may vary from 15 to 25 degrees. It is safe to take 20 degrees as an average. This means that the width of the cloud at any distance from the cylinder will be about 0.4 of the distance. An increase in this angle seems to be favored by decreases in wind velocity and by increase in the rate of emission of the gas. It is possible, for practical purposes, to calculate the concentration of gas in the cloud at varying distances from the cylinder provided the velocity of the wind and the rate of emission of gas are known. The concentration will be gratest in the middle, decreasing toward the edges, as indicated by the shading in Figure 1. Increased wind velocity produces a proportionate decrease in the concentration of the cloud. The average concentration at any cross section of the cloud falls off somewhat more rapidly than the increase of the distance from the cylinder. Thus, if the concentration were one per cent at 50 yards, it would be somewhat less than 0.5 per cent at 100 yards, and considerably less than 0.05 per cent at a thousand yards.

15. If gas is emitted from the cylinders or groups of cylinders at a distance from each other, each cloud will behave as above, but at the point where they begin to intersect dilution will become very slow, as illustrated by the intersecting lines in Figure 2.

(2) *Gas from Shells.*

16. As the clouds formed from bursting gas shells proceed down the wind, the rate of speed is roughly the same as for the fan shaped cylinder discharge, as shown in Figure 3, in which A, B, and C represent horizontal cross sections of the cloud at the point of burst and at two later intervals, respectively. Viewed from the side in elevation, these clouds are seen to spread out to a very great extent in the direction of travel. This is due to the friction offered by the ground to the passage of the wind, that portion of the gas cloud closer to the ground being retarded the most. Figure 4 illustrates the appearance of the cloud in elevation at the three points of its path shown above in Figure 3.

17. This longitudinal spreading of the cloud from a single shell burst causes it to dilute much more rapidly, as it pro-

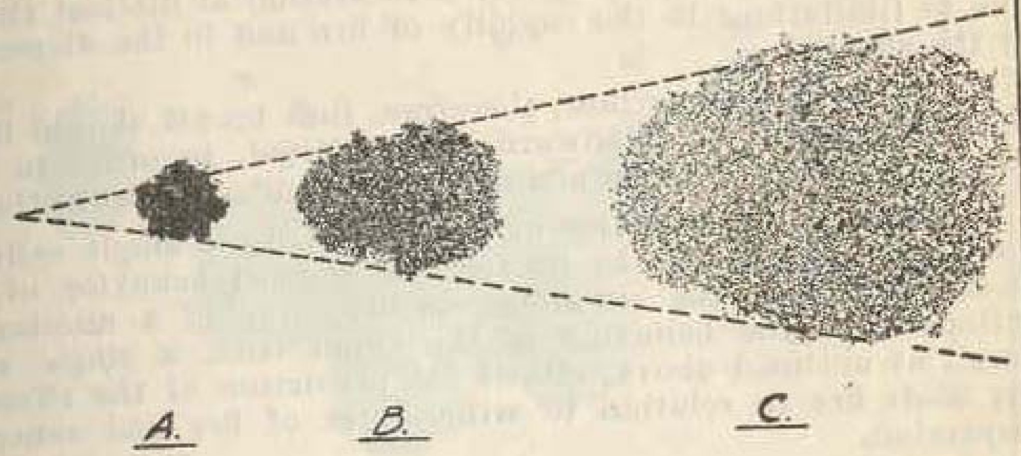


Fig. 3.

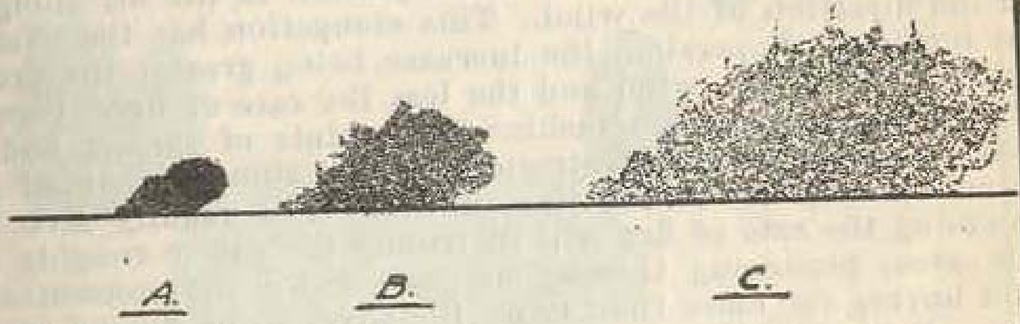


Fig. 4.

ceeds from the point of emission, than does the cloud from a cylinder discharge. Of course, the retarding influence of the ground operates in both cases, but the continuous supply of gas from the cylinder tends to keep up the concentration. The result of artillery fire is usually a succession of distinct clouds, due to limitations in the rapidity of fire and to the dispersion of the shots.

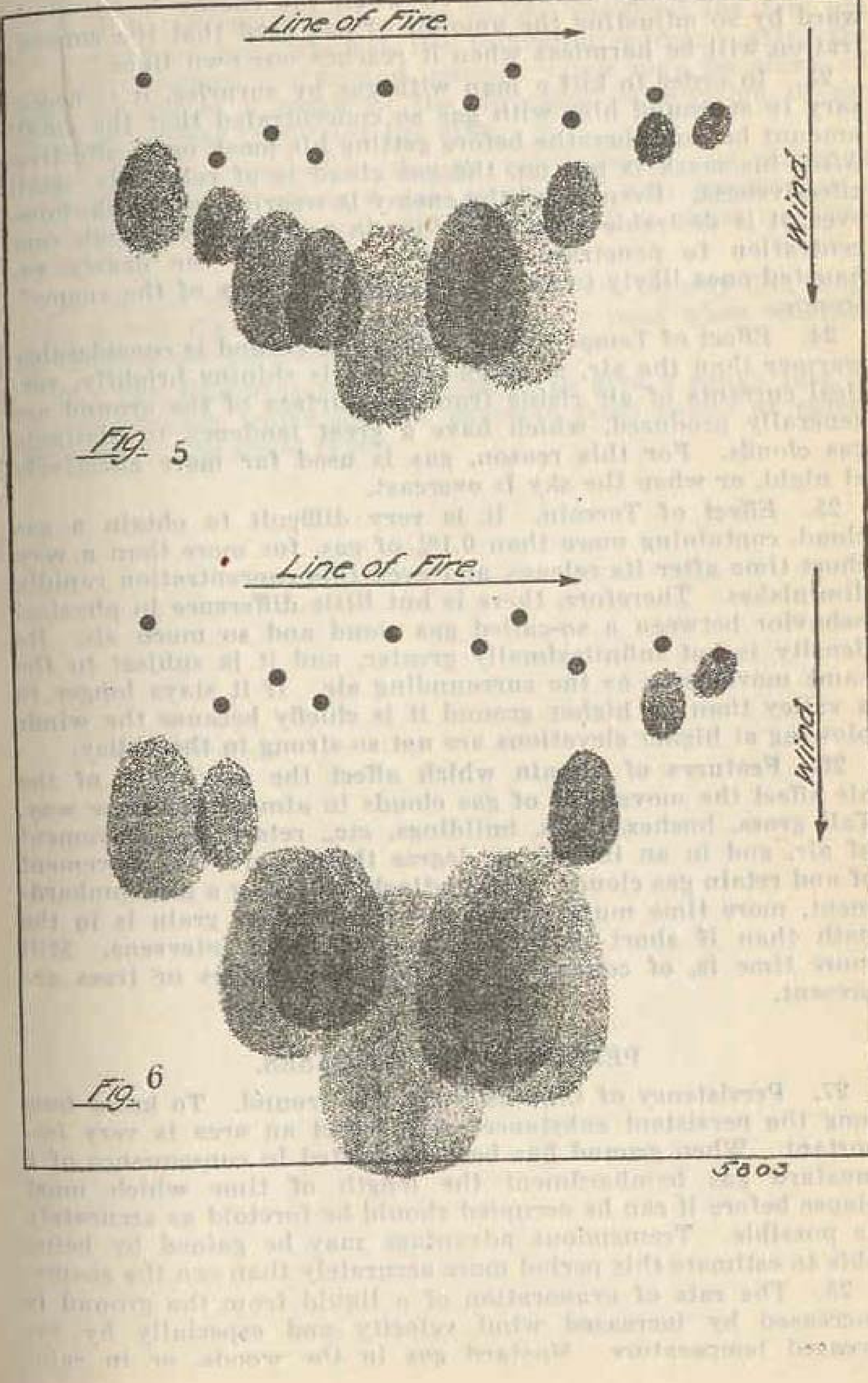
18. It is very important, therefore, that bursts should be as close as possible to windward of the target, in order to surround the target with clouds of the maximum concentration.

19. Just as the behavior of the cloud from a single cylinder discharge enables one to predict the general behavior of the cloud formed by the simultaneous discharge of a number of cylinders, so the behavior of the cloud from a single shell burst, as outlined above, allows the prediction of the effect of gas shell fire in relation to wind, rates of fire and zones of dispersion.

20. Artillery "Gas Zones of Dispersion." When gas shells are fired at a position the shells do not burst simultaneously. The zone of dispersion of a gun is the pattern produced upon the ground by the impact of a large number of shells from a single piece. This pattern is independent of the rate of fire. The individual gas clouds move at once with the wind from the points of burst, each growing and diluting as indicated by the above paragraphs. If, as is usually the case, the shells do not fall simultaneously the effective zone of dispersion becomes not a pattern on the ground but a pattern in the air elongated in the direction of the wind. This elongation has the effect of an increased dispersion, the increase being greater the greater the velocity of the wind and the less the rate of fire. Figure 5 represents, in idealized fashion, the points of impact and the sizes, position and concentrations of the clouds produced in a wind blowing across the line of fire. It is readily seen that doubling the rate of fire will distribute the gas in roughly half the area, producing thereby at least twice the concentration and having far more than twice the effect in producing casualties. It is evident, also, that an increase in the wind velocity will distribute the gas over a larger area, decreasing the concentration of the cloud. (As shown in Figure 6 as compared with Figure 5.)

21. One of the chief reasons for the *effectiveness of gas* is the fact that the cloud of gas is present for an appreciable length of time after its emission from cylinder or shell and is capable of producing casualties until the division becomes too great, or until it is blown away.

22. Increased wind velocity reduces rapidly the length of time that gas remains in the neighborhood. Gas is used most effectively in winds under 3 meters per second. However, too low a velocity is objectionable in the case of gas emitted near


Line of Fire.
Wind.
Fig. 5
Line of Fire.
Wind.
Fig. 6
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our own lines because of the possibility of a variation in wind direction bringing the gas back. Gas may be used in artillery shell fire at longer ranges even when the enemy is to windward by so adjusting the amount of gas used that the concentration will be harmless when it reaches our own lines.

23. In order to kill a man with gas by surprise, it is necessary to surround him with gas so concentrated that the small amount he must breathe before getting his mask on is effective. After his mask is put on, the gas cloud is of relatively small effectiveness. Even when the enemy is wearing his mask, however, it is desirable to subject him to gas of high enough concentration to penetrate the mask, especially the nearly exhausted ones likely to be in possession of many of the enemy's troops.

24. Effect of Temperature. When the ground is considerably warmer than the air, as when the sun is shining brightly, vertical currents of air rising from the surface of the ground are generally produced, which have a great tendency to dissipate gas clouds. For this reason, gas is used far more effectively at night, or when the sky is overcast.

25. Effect of Terrain. It is very difficult to obtain a gas cloud, containing more than 0.1% of gas, for more than a very short time after its release, and even this concentration rapidly diminishes. Therefore, there is but little difference in physical behavior between a so-called gas cloud and so much air. Its density is but infinitesimally greater, and it is subject to the same movements as the surrounding air. If it stays longer in a valley than on higher ground it is chiefly because the winds blowing at higher elevations are not so strong in the valley.

26. Features of terrain which affect the movement of the air affect the movement of gas clouds in almost the same way. Tall grass, bushes, trees, buildings, etc., retard the movement of air, and in an increasing degree they retard the movement of and retain gas clouds. In an attack following a gas bombardment, more time must be allowed if a field of grain is in the path than if short grass or ploughed fields intervene. Still more time is, of course, necessary where bushes or trees are present.

PERSISTENCIES OF GASES.

27. Persistency of Liquids Upon the Ground. To know how long the persistent substances will infect an area is very important. When ground has been evacuated in consequence of a mustard gas bombardment the length of time which must elapse before it can be occupied should be foretold as accurately as possible. Tremendous advantage may be gained by being able to estimate this period more accurately than can the enemy.

28. The rate of evaporation of a liquid from the ground is increased by increased wind velocity and especially by increased temperature. Mustard gas in the woods, or in calm

weather, will persist much longer than in the open or in windy weather. It will last longer on cold ground than on hot ground. However, during a cold night, an infected area may perhaps be traversed with little danger provided the feet are properly protected, whereas the following morning, after the sun has warmed the ground, enough vapor may be given off into the air as a result of the increased evaporation to gas severely anyone traversing the area.

29. Moisture produces (though very slowly) the chemical decomposition of mustard gas so that it will persist for a shorter time in moist soil than in dry soil of equal temperature.

30. If the mustard gas liquid is dispersed in very fine droplets, it will disappear much more rapidly than when splashed in large drops upon the ground.

31. The following table will serve to give a rough idea of the persistency which may be expected from gasses as spread by shell of the usual types:

THE PERSISTENCY OF GASES.

GAS			PERSISTENCE		REMARKS
Name	Class	Symbol	In Open	In Woods	
Vincennite Vitrite Collongite (Phosgene)	Non Persistent	V. N. C. C. C. G.	10 minutes	3 hours	These gases are very volatile, they are vaporized entirely at the moment of explosion, forming a cloud, capable of giving deadly effects, but which loses, more or less rapidly, its effectiveness by dilution and dispersion into the atmosphere.
Aquinite (Chlorpicrin) and (Opacite) (Stannic Chloride.) Aquinite Chlorpicrin Martonite (Bromacetone)	Moderately Persistent	N. C. P. S. B. A.	3 hours	12 hours	These gases, having moderately high boiling points, are only partially vaporized at the moment of explosion. The cloud formed upon explosion is generally not deadly, but it immediately gives penetrative lachrymatory, or irritant effects. The majority of the «Gas» contents of the shell is pulverized and projected in the form of a spray or fog which slowly settles on the ground and continues to give off vapors which prolong the action of the initial cloud.
Yperite (Mustard Gas) Camite (Brom Benzyl Cyanide)	Highly Persistent	H. S. C. A.	3 days	7 days	These gases, having a very high boiling point, are but little vaporized at the moment of explosion. A small portion of the contents of the shell is atomized and gives immediate effect, but by far the greater part is projected on the ground in the form of droplets which slowly vaporize and continue the action of the initial cloud.

NOTE—The above figures on time of persistency are approximate only and for calm weather. Persistency is dependent to a large extent on temperature, wind velocity, and amount of gas liberated, especially in woods or other more or less closed places. High temperatures and wind velocities decrease persistency and low temperatures and wind velocities increase it.

32. The persistency of mustard gas on the ground is diminished by heavy rain, which washes it away, or by sunshine or strong wind which hastens its evaporation. Sunshine, on the morning after a bombardment, may produce a dangerous concentration of gas, where no marked effect had been noticed during the night. The wind limits for mustard gas are from calm to 12 m. p. h.; the lower the velocity of wind, the greater the local concentration of gas. Variations may be expected according to the principles above discussed. In the case especially of chlorpicrin, the air may have become safely free from the gas while the ground still contains enough to make it dangerous to entrench in it.

33. Infected areas may be crossed at night when the ground is cold at shorter intervals than those indicated by the above tables. It is always legitimate to take some risk of injury when important military advantages may be gained thereby. It is no more necessary to seek absolute safety from gas than from other forms of ammunition.

METHODS OF PROJECTION.

34. Chemical substances may be projected in military operations as follows:

(a) In form of cloud gas discharged from gas cylinders.
(b) In steel bombs fired from Livens Projectors.
(c) In steel bombs fired from four nich Stokes mortars.

In the American Expeditionary Forces the three methods mentioned above are used by Gas Troops for projecting gas.

(d) In shells of various calibre fired from Artillery weapons.
(e) In grenades (including smoke grenades), thrown by hand or rifle.
(f) In form of smoke bombs thrown by 3-inch Stokes mortars.
(g) In form of smoke candles set off in place.

The last three forms are used by Infantry.

(h) In form of incendiary and smoke bombs dropped from airplanes by the Air Service.

The various methods of projection are described in detail in Part II to Part V, inclusive of the Gas Manual.

EMPLOYMENT OF CHEMICAL SUBSTANCES IN TACTICS.

35. Meteorological, topographical and other pertinent conditions being favorable to the use of gas in a given tactical situation the kind of gas to be employed in the tactical operation depends on persistency and nature of the effect of the gas, whether temporary, permanent or delayed. It is relatively unimportant to distinguish between the various physiological effects which may be included under the above headings. For example, it is not of great consequence in planning an operation to distinguish between temporary casualties produced by coughing, by vomiting, or by lachrymation. It is important to

know only whether the effects will be produced rapidly and whether they will persist for a long time. Moreover, it is unimportant to distinguish between substances on the one hand which produce bad burns, and those on the other hand which produce lung lesions. Both can be used to decrease the effective strength of the enemy.

36. The following table, considered in connection with Table of Persistencies, Par. 31, illustrates the tactical possibilities of the substances described in the preceding paragraphs.

PERSISTENCE		NATURE OF CASUALTY PRODUCED		
		Temporary	*Permanent*	*Delayed*
Group I.	Low	Diphenyl-chlorarsine.	Phosgene-Chlorine	....
Group II.	Moderate	....	Chlorpicrin	....
Group III.	High	Brombenzyl cyanide and other lachrymators (tear producers).	....	Mustard Gas.

37. Smoke, although used for screening purposes rather than for toxic effect, falls within the scope of Chemical Warfare, and may be considered as a separate group—Group IV. This group includes Tin Tetrachloride, Silocon Tetrachloride, Titanium Tetrachloride, and White Phosphorous. The Tetrachlorides are liquids, non-poisonous, but producing a dense smoke, principally useful in ranging. Being liquids, shells filled with them have the same ballistic characteristics as gas. White Phosphorous is a solid which, upon bursting in air, burns with a dense white smoke. It is useful for smoke screens. Phosphorous burns make ugly wounds.

38. The chemical substances described in the preceding pages may be employed in support of troops acting either offensively or defensively.

39. Offensively they must be employed for the purpose of assisting in gaining and maintaining that fire superiority necessary for the infantry to advance.

This may be accomplished by:

Producing casualties among the enemy personnel directly employed in the delivery of fire.

Limiting the maneuvering ability of hostile forces by forbidding or rendering impracticable the use by them of certain areas heavily gassed.

Producing casualties among hostile reserves thereby reducing the strength of a counter-attack.

Reducing the effectiveness of hostile fire by compelling enemy personnel to wear gas masks.

Reducing effectiveness of hostile fire by establishment of a smoke screen, thus preventing aimed fire and observation of effect of fire by the enemy

By deceiving the enemy regarding the place or direction of the attack.

Reducing the effectiveness of hostile fire by lowering the morale of the troops continuously exposed to the effects of gas.

40. Gas in offensive operations may be used for purposes mentioned in preparation for the attack or during the attack.

41. Troops on the defensive may employ gas to prevent the enemy gaining or maintaining the fire superiority necessary to advance. This may be accomplished by one or more of the methods mentioned in Par. 39.

42. Troops on the passive defense have a wide field of use for gas because none of the restrictions which exist when gas is used to assist troops acting offensively are imposed.

43. When, however, troops are acting on the defensive awaiting a favorable opportunity to attack, gases must be so employed that they shall not interfere when an otherwise favorable opportunity is presented to resume the offensive.

44. In a withdrawal or in a retreat the employment of chemical substances is especially applicable as they may then be freely used without fear of deleterious effect on our own troops. Gases may be used under such tactical situations to reduce casualties among friendly troops, by screening movements of friendly troops and to prevent or delay pursuit, by denying hostile troops the use of landmarks on which to guide through causing them to advance through smoke clouds and thereby favoring loss of direction by enemy units and their mixing in the advance, and by causing casualties among pursuing troops by heavily gassing areas included in their line of advance

45. The most effective gas against hostile personnel may, under a given tactical situation, be one against which the enemy has no or only indifferent means of defense, even though such a gas may be of low persistence or have only a temporary effect on hostile personnel. For this reason it is necessary to know what are the limitations of the means of defense against gas available for use by the enemy. Assuming the enemy means of defense are efficient against all available gases, the kinds of gases used in any tactical situation depends upon time available before friendly troops, under the plan of operation, will probably occupy the area gassed, as well as upon meteorological and topographical conditions and the persistency and effect of available gases.

46. Therefore, knowing the tactical requirements consult the meteorological and topographical conditions, the persistencies and effects of available gases to determine the place, time and kinds of gas to employ.

SPECIAL APPLICATION OF THE VARIOUS GROUPS OF CHEMICAL SUBSTANCES.

Group I.

47. *Phosgene.* During the entire period of preparation for an attack, as well as in the earlier stages of preparation, when

mustard gas is being used, put over phosgene in sudden two-minute bursts of artillery fire, at repeated intervals of from 8 to 12 hours, upon strong points, concentration areas, woods and ravines, and upon groups of trenches and dugouts, to kill those whose masks are worn out or those who, through recklessness or carelessness, have removed their masks.

On targets, distant 1900 meters or more, use artillery to carry out the tactics outlined in paragraph above. Whenever possible, the area within 1900 meters of our line should be taken care of by Gas Troops, using cylinders for cloud gas, when the wind is favorable, and projectors and 4" Stokes mortars, all of which can produce much higher gas concentration than artillery.

When the wind is favorable, (blowing toward the enemy), launch against the entire front to be attacked, and for miles along the front not to be attacked, heavy phosgene gas attacks by all methods, including cloud gas from cylinders.

If the wind is unfavorable, phosgene may still be used with artillery, projectors and Stokes mortars by simply reducing the amounts put over in accordance with the tables of safe distances given in Part II.

When immediate neutralization is required, phosgene is generally preferable on account of its immediate effect.

Gas troops with Stokes Mortars, projectors and cylinders are trained to keep up with infantry reserves, whence they can be directed to the support of attacks of strong points, machine gun nests and enemy troops concentrating for counter-attacks, by projection of phosgene, or by projection of phosphorous for smoke screens. They are also equipped to fire upon hostile personnel with thermite, phosphorous and incendiary bombs and drums thrown from mortars and projectors.

With unfavorable winds phosgene and chlorpicrin may be used by artillery, and by Gas Troops, employing projectors and 4" Stokes mortars, which should direct their fire just beyond the nearest enemy masses so as to let the gas drift back over them. The amount of gas must be reduced, but not necessarily to the amounts given as safe under rules for firing of gas by artillery. Some chances must be taken with our own gas even to the extent of an occasional casualty as with H. E. and shrapnel. With the new comfortable mask, giving perfect vision, accidental casualties should be rare.

Group II.

48. *Chlorpicrin* is stopped by the mask much less readily than phosgene, and in the high concentrations attainable in projector attacks heavy casualties may be expected. It is moderately persistent, and its value in artillery shell is due to this fact and to its lachrymatory power. From 3 to 12 hours should be allowed where troops are to cross the infected area, depending upon whether the area is open or wooded.

Group III.

The characteristics which make mustard gas so valuable are:

(a) It has very little odor.

(b) The absence of immediate effect.

(c) Its effectiveness in low concentrations.

(d) Its persistence.

49. *Mustard Gas.*

(a) Use for harassing fire against batteries, strong points, woods, cross roads and enemy concentrations everywhere at all times prior to attacking. (See c. d. and e.)

(b) As is affects eyes, lungs, body and food, and persists for days, it wears down the enemy morale and vigor by forcing constant wearing of the mask and the necessity of always taking other extensive precautions.

(c) In the open it may be used when the weather is clear and warm up to 3 days before an attack.

(d) When weather is cloudy and warm, add 1 day to (c).

(e) When weather is cold and especially cloudy, allow 4 to 7 days.

(f) In thick woods or brush heavily bombarded with mustard gas, allow 5 days in warm weather and 7 days in cold weather before attacking through them, except under special conditions

(g) An infected area may be crossed more safely when the ground is cold, as during the night The above intervals may be reduced if this precaution is taken.

(h) Continue neutralizing and harassing fire against strong points, battery positions, cross roads and any possible concentration points during the entire battle, in accordance with the schedules given in (c), (d), (e), and (f). The flanks, where no attack is to be made by our troops, should be kept smothered with mustard gas to prevent the possibility of a flank counter-attack.

(i) It may prove possible in the future to change the burst of mustard gas shell so as to diminish the persistency, allowing earlier attack following its use, and producing greater concentrations.

(j) When the enemy succeeds in halting our attack at any point, use mustard gas in accordance with the schedules given under (e) and (f), and in the intervening period up to the moment of the attack, pour in phosgene with both artillery and Gas Troops. When the wind is unfavorable, i. e., blowing toward our troops, merely reduce the amounts sent over.

(k) Gas used as explained under (j) is a valuable weapon to break up resistence in general, and is especially valuable for use against enemy troops concentrated for counter-attacks.

(l) The use of mustard gas must be continuous on woods, ravines, roads, villages, railroads, and any other places where enemy troops can concentrate or where they must move. Fields that the enemy may cross should be thoroughly gassed.

(m) Used in this way, it should be very effective in inflicting serious losses from burns, even if the mask fully protects.

(n) Mustard gas can be used in the offensive without endangering our troops, beyond or to the flanks of an objective. When the objective is a limited one, always allow clearance of one mile as a safety factor in case the wind should prove adverse.

(o) Bombardments with mustard gas are best carried out at night, when the atmospheric conditions are most likely to be favorable, and, when, owing to the difficulty of seeing while wearing a respirator the maximum amount of interference with movement is caused. In addition, the evacuation of shelled areas is most difficult at night.

50. *Brombenzylcyanide* (lachrymator).

(a) Use anywhere to force immediate wearing of the mask. It is a powerful lachrymator, and very persistent, but not poisonous unless one is very close to a bursting shell. It is two to three times as persistent as chlorpicrin.

(b) It is useful to save mustard gas, phosgene and chlorpicrin, and still harass the enemy by forcing him to wear masks. For this purpose it is many times more effective than phosgene and chlorpicrin.

(c) It is especially useful against active combatants, as few guns are necessary to produce the desired effect.

51. *Smoke.* The following substances are used in our service for producing smoke:

(a) Phosphorous.

(b) Tin, Titanium, Silicon } Tetrachloride.

(c) Special Smoke Mixtures.

Phosphorus, when exposed to air, quickly produces great volumes of dense white smoke, the particles burning on the ground persisting for several minutes. Phosphorous gives smoke of the highest obscuring power and greatest persistency of any of the smoke producing substances. Moreover, the burning particles of phosphorous make deep and serious burns in flesh and hence it has a decided value against troops exposed to it. Phosphorous is therefore used for smoke barrages and screens, in artillery shell, trench mortar bombs, and hand and rifle grenades.

Tin, Silicon, and Titanium Tetrachlorides are liquids which give smoke when liberated in the air. They are not as effective as phosphorous for smoke barrages and screens because their smokes have a smaller obscuring power and less persistency.

They are, however, more abundant than phosphorous and are in the nature of substitutes where phosphorous cannot be obtained. These materials are, therefore, loaded as phosphorous substitutes into artillery shell, trench mortar bombs, and hand grenades. Due to the fact that these substances are liquids, they are peculiarly suited for smoke ranging shell, as they exhibit the same ballistic characteristics as liquid "gases." The relative merits of these three substances are as in the order named above; and, as compared with white phosphorous, may be taken as follows:

White Phosphorous	100%
Silicon, Titanium, Tin } Tetrachloride	40%

Other smoke mixtures include:

The British "S" Mixture, consisting essentially of the following:

Saltpetre
Sulphur
Pitch
Borax
Glue

This mixture has been used in smoke candles effectively and as compared with phosphorous has the following relative screening value:

White Phosphorous	100%
"S" Mixture	20%

The B. M. Mixture, consisting essentially of:

Powdered Zinc
Carbon Tetrachloride
Sodium Chlorate
Magnesium Carbonate

This has recently been used as a substitute for phosphorous in hand grenades and also in smoke candles. It is claimed that this mixture has an obscuring value equal to phosphorous and a relative persistency of about one-half that of phosphorous.

WHO USES SMOKE.

52. Smoke is used by:

Artillery, with smoke shell for distant smoke barrages and for ranging gas shell.

Infantry, with 3 in. Stokes smoke bombs for smoke screens up to a range of 1,800 yards; with hand and rifle smoke grenades to protect advancing troops against machine gun nests, etc.; with smoke candles to conceal troop movements, etc.

Gas troops, with 4-inch Stokes smoke bombs for conducting special tactical operations, often combine with use of gas; for establishing smoke screens of large dimensions up to a range of 1,000 yards.

Air Service, with small smoke drop bombs used for training observers in bomb dropping, etc.

53. The description of the material above mentioned will be found in other parts of this Manual.

54. The following table gives a rough idea of the comparative weight of phosphorous and the approximate efficiencies of the several British smoke producing devices now in use:

Device	*Weight of Phosphorous*	*Efficiency*
No. 27 Smoke Grenade.	14 oz. White.	3
P. Bomb.	16 oz. Red.	3
18 lb. Artillery Shell.	10½ oz. White.	1
45 lb. Artillery Shell—Howitzer.	4 lb. White.	10
4 in. Stokes Mortar Bomb—Light Smoke.	4½ lb. Red.	10
4 in. Stokes Mortar Bomb—Heavy Smoke.	7½ lb. White.	15

USE OF SMOKE IN OPERATIONS.

55. Smoke, if its use is carefully studied, will be found of great value in modern infantry tactics, as it confers many of the advantages which are to be gained by conducting operations at night, while few of the disadvantages are present. Use of smoke must be very carefully planned in order to avoid certain serious disadvantages likely to accrue under conditions unfavorable to its use or if smoke be improperly employed.

Smoke screens may be employed with one or more of the following objects in view:

(a) To mask known enemy observation posts: To conceal and protect the front and flanks of attacking troops from enemy observation; and to blind hostile machine guns.

(b) As a feint to draw enemy's attention to a front on which no attack is being made, so as to hold his troops to their positions and prevent them from rendering assistance to the sector attacked; in inducing him to expend ammunition needlessly and to put down a barrage in the wrong place.

(c) In the case of a smoke cloud used offensively to simulate gas, with a view to lowering the enemy's morale and forcing him to use his gas masks. It may also be used to extend the front of a gas attack.

To make this effective, gas should occasionally be mixed with smoke in order to impress upon the enemy the belief that it is never safe to remain in a smoke cloud without wearing his mask.

(d) In flat or open country to conceal concentrations of guns and troops, and to screen roads, forming-up places and lines of advance. To blind the flashes of a battery in action in view of the enemy's observation posts and to hamper observation from the air.

(e) To cover the construction of bridges, trenches, etc., in the face of the enemy.

Ground and troops behind smoke screens can seldom be concealed from hostile airplanes or kite balloon observation.

If troops are hidden in smoke clouds such clouds attract the enemy's fire and are therefore dangerous; for this reason, smoke screens intended to conceal concentrations should normally be formed at some distance—about 400 yards—from the object to be concealed.

In frontal screens, care must be exercised to place the screen so that an enemy barrage laid on it will not catch advancing troops. Such a screen should preferably be placed on the enemy trench system.

The necessity for anticipating the effect which a smoke cloud will have in impeding our own observation and artillery fire should be considered, as well as the possibility of troops being hidden from our contact patrol airplanes.

When smoke is liberated on the flank of an assault, care should be taken, by defining permissible wind limits beforehand, that the cloud does not pass across the front of the assaulting troops, as the latter attacking through smoke are very liable to lose direction.

When the use of a smoke screen in operation is contemplated, the enemy should be educated to associate such a screen with some object other than the real one, e. g., he may, by means of a practice smoke screen, followed by no action, be led to suppose that the object of the demonstration is to compel him to expend ammunition uselessly.

It is obvious from the foregoing that it is of the utmost importance that the use of smoke should be systematic but varied instead of casual and haphazard.

Initiative at the critical moment means the saving of valuable lives and the avoidance of delay in the progress of the attack. If this is to be cultivated, and if misuse and waste are to be prevented, the most careful training is required, not only of the individual, but also of companies, battalions, and even brigades.

SMOKE SCREENS.

56. The amount of smoke-producing material required to form a screen depends on a number of considerations, the most important of which are as follows:

(a) The extent of the screen. As a rough guide it may be assumed that the width of the screen should be from two to three times the width of the object to be concealed (as seen by observers from the points from which it is intended to prevent observation).

(b) Duration of the screen.

(c) The direction of the wind. A cross wind requires, as a rule, less expenditure of smoke than one at right angles to the front; and the difficulty of concealment increases if the direction of the wind is variable.

(d) The velocity of the wind. The density of the smoke cloud diminishes considerably in proportion as the velocity of the wind increases. In a wind of over 20 miles per hour it is very difficult to form an opaque screen without excessive expenditure of material.

(e) The number of directions from which the enemy can observe the object or area to be concealed. The greater the number of points from which an object can be observed by the enemy, the greater will be the extent of the screen required and therefore of the amount of smoke producing substances necessary to form it.

(f) The distance of the object from the enemy's observation posts. The greater this distance the more effective the smoke cloud will be.

In forming a screen with any form of smoke producer, it is necessary for the formation of the smoke screen to be very carefully organized, so that the best results may be obtained with the greatest economy of material. All personnel required for providing smoke screens should be trained beforehand in the use of the actual material which is to be employed and a simple rehearsal is most valuable. The program which is to be followed should state in detail the rate of expenditure of the smoke producing substances and should be given in writing to the personnel at each smoke source.

PROTECTION OF TANKS.

57. Since the enemy artillery is the most dangerous adversary of the tanks, one of the vital conditions for the successful operation of tanks is blinding the ground observation posts which look out on the field of attack by means of a very dense well regulated smoke screen. In front of the artillery in position, a natural or artificial fog is a necessity to the tanks. Batteries assigned to support infantry, especially when latter is supported by tanks, and artillery assigned to direct support of tanks should have on hand at all times a sufficient supply of smoke shells to take prompt advantage of opportunities for its use. The efficacy of smoke screen properly placed in assisting tanks to accomplish their mission has been amply demonstrated in action.

Smoke shells should not be employed in the rolling barrage alone. In different sections, notably that just cited, the method of forming a "smoke cage," or box barrage, gave excellent results. This method consists in establishing a smoke barrage on all points from which the objective to be taken could be seen at a distance of 500 to 600 meters. An enclosed area is thus formed in which the infantry and tanks may operate, screened from the view of the enemy observers, without themselves being bothered by lack of visibility within combat distance.

GAS AND SMOKE DURING A WITHDRAWAL OR ON STABILIZED FRONTS.

58. Gas and smoke on these fronts should be used according to the directions heretofore given. On a retirement maximum amounts of mustard gas should be used from close up to our retiring troops to as far back as the longest range guns will reach.