SOME PROBLEMS OF GAS WARFARE[1]

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THE initial use of gas by the Germans at Ypres in 1915 and the subsequent adoption of gas warfare by the allied armies introduced a large number of problems of vital importance to the nations involved in the World War. While these problems taxed to a very great degree the ingenuity of the scientist, the engineer, the military strategist and the manufacturer, they by no means lacked that fascination which characterizes all research, an intellectual journey into the unknown. Although this fascination was augmented by the fact that the problems were nearly all new and the field almost limitless, nevertheless the flight of the imagination was circumscribed by the stern condition of immediate practical utility and the necessity for rapid solution.

Another feature especially prominent in the early stages of gas warfare was the unstable nature of the problems. The act on the screen was continually changing. The solutions of yesterday might not meet the requirements of to-day, and the practise of to-day might become archaic by to-morrow. The kaleidoscopic nature of these changes can be best illustrated by a brief account of the tactics of the offensive and the development of the defense, the chief feature of which is the gas mask.

The first object of the use of gas by the military strategist was, of course, to destroy the enemy. With this purpose in view the Germans made their first gas attack by means of poisonous clouds. Chlorine was compressed into cylinders that were placed in their own front-line trenches. The cylinders were fitted with a suitable hose and nozzle so that at the appointed time the valves could be opened and the gas allowed to escape. Chlorine is particularly adapted for this method of attack. It is fairly easily compressible into the form of a liquid, but six atmospheres being necessary at ordinary temperature. It is very poisonous, one to two parts per ten thousand of air sufficing to result in death if breathed for five minutes. It has the additional property of being heavy, about two and one-half times the weight of an equal volume of air. Consequently it does not tend to rise rapidly into the upper air, but, on the con-

[1] Figures 1 to 8 inclusive are published with the permission of the Director of the Chemical Warfare Service.

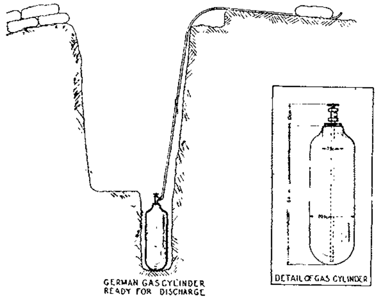


FIG. 1.

trary, rolls along the ground, seeking out and filling all the low places such as trenches, dugouts, shell holes and so on.

The result of the attack is now a matter of history. The French Colonial black troops broke and fled. Who can blame them? The Canadians went into this particular sector twelve thousand strong. When they were relieved five days later but two thousand remained alive. A very large portion of the ten thousand died as a result of the effects of the gas. In fact, had it not been for the presence of mind of some of the officers who ordered the men to put wet cloths over their faces and lie flat on the ground face downwards the entire force would have been annihilated. Fig. 1 shows a German gas cylinder in position in the trench.

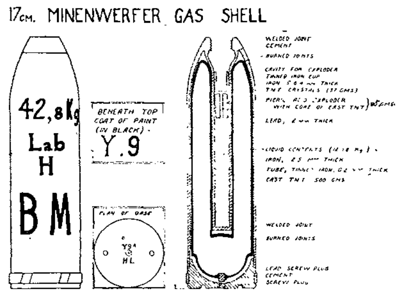


FIG. 2. GERMAN GAS SHELL.

Although successful at times this form of gas warfare was seldom used in the later stages of the struggle, owing to the inherent disadvantages of the method. In the first place the wind must obviously be in the right direction. It must not be too strong—less than twelve miles per hour—or the gas will be whirled about and dissipated before the goal is reached. It must not be too low or it may change its direction, in which case the offense may suffer more than the defense. In the second place, the greatest concentration is at the wrong end, directly before the trenches of the attacking party. Consequently if the gas is to be followed by an infantry attack the offense must endure more than the defense, or the attack must be delayed until most of the opportunities created by the gas are lost. A much more effective method depending upon the wind was being developed by the

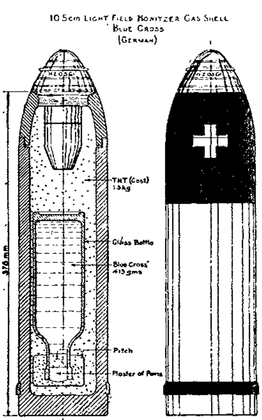


FIG. 3. GERMAN GAS SHELL.

American gas offensive, the details of which are not yet for publication.

It was soon realized by both sides that some more dependable means must be devised to create an efficient concentration of gas in the enemy's territory and the development of the gas shell is the result of these researches. Figs. 2 and 3 give schematic views of German gas shells. Gas shells are made for both large and small caliber guns. The former may deliver several quarts of the poisonous liquid at a single shot.

For certain kinds of work, gas shells have a great advantage over even the high-explosive variety. The latter may kill by direct hit or by the subsequent explosion. The former may do all this; but in addition the liberated gas may be carried to considerable distance from the spot where the explosion takes place and gas the enemy who has been protected from the high explosive by dugouts, etc.

However, the disastrous effects of both the gas cloud and the gas shell are largely offset by the high efficiency of the modern gas mask, and this brings us to the second object of the military strategist, viz., to annoy and hinder, or in military parlance, to "neutralize" the effectiveness of the enemy. It will be obvious even to the casual observer that the ability of the soldier to serve a gun, to shoot or to transport supplies is greatly reduced if he is obliged to wear a gas mask. In point of fact it is claimed by military men that the effectiveness of artillery is cut down sixty per cent., while the infantry fares scarcely any better, two men being required to perform the functions of one unhampered by this impediment.

For purposes of "neutralizing," ordinary poison gas may of course be employed. An occasional gas shell will prevent the enemy from removing his mask, but his life may be rendered almost unendurable by many substances really not gases in the accepted sense of the term. Lachrymators or tear gases, such as benzyl bromide, are heavy liquids which when sprayed over the ground in small quantities by the explosion will cause a copious flow of tears for hours if the eyes are not protected by the gas mask or other device. Moreover the celebrated "mustard gas," also a heavy liquid, will cause burns on the skin of such a vicious character that the soldier may be incapacitated for months. A partial list of gases that have been employed on the battlefield is given below.

Gas Clouds:

Chlorine.

FIG. 4. AN AMERICAN SOLDIER WEARING A CAPTURED GERMAN RESPIRATOR. The face piece is made of leather.

Shells:

Phosgene.
Sulfur trioxide.
Benzyl bromide, German T-Stoff.
Xylyl bromide, German T-Stoff.
Dichloro-diethysulfide, "Mustard Gas," German Yellow Cross.
Diphenyl-chlorarsine, "Sneeze Gas," German Blue Cross.
Trichlormethyl-chloroformate, German Green Cross.
Monochlormethyl-chloroformate, German K-Stoff.
Nitrotrichloromethane, "Chlorpicrine."
Brominated-ethyl-methyl ketone.
Dibromo-ketone.
Allyl-iso-thiocyanate.
Dichlormethyl ether.
Phenyl carbylamine chloride.

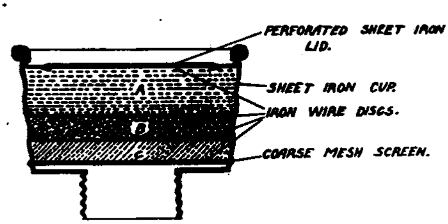
Hand Grenades:

Bromacetone.
Bromine.
Chloracetone.
Chlorsulfonic acid.
Dimethyl sulfate.
Methyl-chlorsulfonic acid.

THE DEVELOPMENT OF THE GAS MASK

When the Germans launched their first gas attack they were provided with a crude and inefficient device similar to the one shown in Fig. 6. Later they developed a much more serviceable mask as represented in Figs. 4 and 5. The British, as already stated, first employed a wet cloth. Even damp earth was found to have some virtue as a protection against gas. In a very short time English scientists had devised several types of respirators. These consisted chiefly of cotton wool soaked in photographer's "hypo" and washing soda. The deleterious effect of the latter upon the skin was reduced somewhat by adding a small amount of glycerine. The wool was attached to a cloth that was bound

CANISTER OF GERMAN RESPIRATOR



A-Granules of baked earth soaked in Potassium carbonate solution and covered with powdered charcoal.
B-Charcoal.
C-Pumice stone mixed with Urotropine.

FIG. 5.

around the mouth and nose, as shown in Fig. 6, or it was held in the mouth until the cloth could be placed in position. The wool was then shoved up around the nostrils. These primitive masks would stop a considerable amount of chlorine if properly cared for and adjusted. Unfortunately the soldier too often dipped them in the solution and did not sufficiently wring out the excess liquid. As a consequence he could not breathe freely, thought he was being gassed, and frantically repeated the operation, often equally unsuccessfully. Moreover, the masks were not carried upon the person, but rather were placed in the trenches so that the soldier usually got one that had been worn by some one else. Beside the obviously unsanitary arrangement, another disadvantage presented itself. When the alarm was given several men frequently rushed for the same mask with the inevitable result that some of them were gassed.

FIG. 6. EARLY BRITISH RESPIRATOR.

A very decided improvement was next introduced in the form of the "smoke hood." Fig. 7 shows one of the latest models of these fairly efficient masks. Its great advantage lay in the fact that the breathing surface was large, resulting in a very material decrease in resistance. Another prominent feature was the valve that allowed the exhaled air to escape. It is made of rubber and is called technically the "flutter" valve. So successful is its operation for this purpose that it was subsequently adopted in the latest types of both British and American box respirators.

FIG. 7. BRITISH SMOKE HOOD.

It was soon realized by scientists that while "hypo" and alkalis would take care of chlorine and hexamethylenetetramine would stop large quantities of phosgene, many other gases, such as the chemically sluggish

FIG. 8. THE FIRST AMERICAN GAS MASK.

FIG. 9. THE MOUTH PIECE AND NOSE SNUBBERS IN PLACE.

chlorpicrine, could not be easily removed by chemical means. It was therefore necessary to combine with the chemicals a universal adsorbent, and carbon, because it has this property to an exceptional degree, was chosen for the purpose. In the meantime the British had invented a mask of extraordinary efficiency. The details are given in Figs. 8, 9, 10, 11, 12. Fig. 13 represents an early French type of mask.

THE AMERICAN MASK

When the United States of America entered the World War the newly organized American Gas Defense had on its hands the enormous problem of supplying every soldier who went abroad with an efficient protection against poison gas, and every soldier in the concentration camps at home with a mask for training purposes. The Gas Defense did not wait to develop

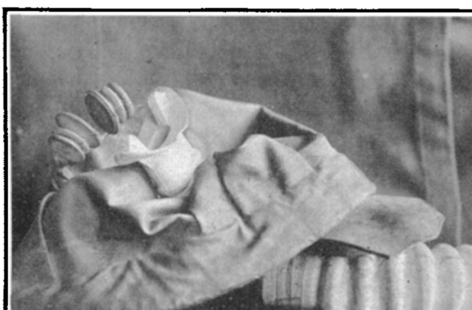


FIG. 10. THE MOUTH PIECE AND SNUBBERS.

FIG. 11. THE CANISTER STANDING BESIDE ITS CONTAINER.

an ideal device, but wisely chose to adopt the British type of mask. Incidentally this was a fine tribute to the British scientist, because the mask was much superior to any in use at that time by the European armies. However, American scientists did not rest satisfied with the results of their allies, but on the contrary began to develop the existing devices. It has been said that Americans invent and other nations improve upon the inventions while we are resting on our oars. In this particular instance the tables were turned, for in a few months we were producing carbon for gas masks fifty to one hundred times as valuable as any known to our allies and certainly vastly superior to that which the Germans were using. Equally important advances were made in the soda-lime,

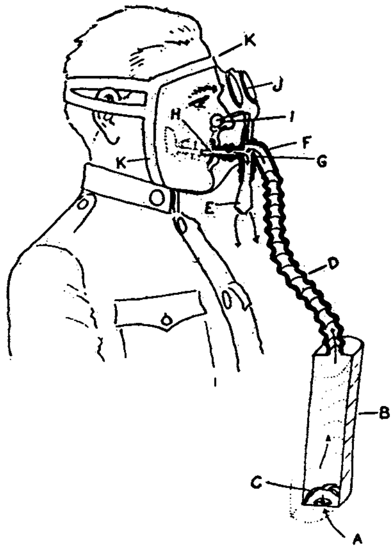


FIG. 12. CROSS-SECTION AMERICAN RESPIRATOR. *A* is the air inlet. *B* is the canister containing granules of soda lime impregnated with sodium permanganate, and carbon granules about one quarter the size of ordinary peas. *D* is a flexible rubber tube the end of which, *H*, is held in the mouth. *E*, is the outlet flutter valve for the exhaled air. *I* represents the nose snubbers. The great virtue of this mask lay in the fact that the soldier could not be gassed as long as he breathed through the tube in his mouth, even if the face piece became punctured or did not fit properly.

FIG. 13. AN EARLY FRENCH MASK.

and the American mask soon became the object of admiration of both friend and foe. It should be said in justice to German chemists that they too succeeded toward the close of the war in greatly increasing the efficiency of their carbon.

DEFECTS OF THE MASK

Every driver of an automobile recalls unpleasant experiences with the fogging or clouding of the wind shield in cold or damp weather. The same problem was met with to an accentuated degree in the gas mask. The moisture from the breath or even from the eyes condenses on the eye pieces, causing them to fog. In cold weather the condensation is great enough to create droplets that hang suspended or run down in an irregular manner over the surface. The result is distorted and obscure vision. The Germans partially overcame this difficulty by inserting gelatin-like disks on the inside of the eye pieces. Sooner or later the gelatin-like substance becomes soft and sags, so that the vision is imperfect. Several fairly efficient anti-dimming preparations were compounded by American chemists to be applied to the inside of the lenses by the soldier before the mask was required for use. This problem was largely solved in the latest type of American mask by a very ingenious device. The intake manifolds were carried up to a point directly underneath the eye pieces, so that the cold air played on the lenses, keeping them cool on the inside. As a consequence the condensation was reduced to a minimum and anti-dimming compounds were seldom necessary. The nose snubbers and the rubber tube that was held in the mouth in the old mask were eliminated in the new type. This was a boon to the soldier, for he could now breathe in the normal manner through the nose, thus being relieved to a very considerable extent from the discomfort of the old type mask.

Another defect was discovered in the matter of the construction of the eye pieces. All the armies were using celluloid because it would withstand hard usage. It was found, however, that the surface of the celluloid soon became wavy and the resulting uneven vision caused headaches, indigestion and even nausea. For this reason triplex glass that will withstand a severe shock is employed in the latest American mask.

Experience with long-continued wearing of the gas mask in the field proved that the soldier became exhausted. Some interesting and valuable physiological experiments revealed the fact that if one is obliged to breathe against a resistance equivalent to a column of water two to six inches high, an inadequate amount of air is taken into the lungs to oxygenate the blood sufficiently. The resistance offered to the air by the contents of the canister in the American and especially the British masks was much too high. Consequently the soldier when working hard did not get enough air to purify his blood and partial or complete exhaustion resulted. This is believed to have been a large factor in the collapse of the Fifth British army last March. The men had been obliged to wear their masks for days because of the constant bombardment with gas and were exhausted when the Germans finally attacked.

At the close of the war a new type of canister was being produced in America in which the resistance was reduced below the danger point. The new canister was also designed to meet the requirements of the latest developments of gas warfare, the "smoke" problem. Certain substances, such as sulfur trichloride, were used in gas shells to produce, not gases, but very fine particles that remain suspended in the air often for long periods. In the case mentioned the sulfur trioxide unites with moisture of the air to form tiny particles of sulfuric acid. Many of these small particles produced in this or a similar manner were not removed by the contents of any mask in use on the battle field. The latest American canister gives an almost perfect protection against this insidious form of gas warfare.

With regard to gas warfare the American Gas Offense held the same views as their contemporaries in the field. The best kind of defense is to strike back harder than the enemy can. With this end in view enormous quantities of deadly gases, especially phosgene and "mustard gas," were being produced for our army at the close of the war and preparations were nearly completed to increase the production to several hundred tons per twenty-four hours.