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DIGEST OF TECHNICAL ACTIVITIES

OF THE

CHEMICAL WARFARE SERVICE.

March 13, 1924.
June 30, 1924.
September 30, 1924.
December 31, 1924.

UNCLASSIFIED

Burst of a 4" Stokes Mortar Shell filled with White
Phosphorus, Booster 63 grams Tetryl, Project B1.2-1D.
Mechanical Division Test May 26, 1924.

DIGEST OF TECHNICAL ACTIVITIES

of the

CHEMICAL WARFARE SERVICE

December 31, 1924.

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Vol. I Number IV

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PHOSPHORUS AS A CHEMICAL WARFARE AGENT

The introduction of phosphorus as a weapon in the World War was one of the most effective of the various chemical innovations which have had such a marked influence on the methods of modern warfare. It was found to be highly useful as a defensive and offensive weapon, for the laying down of smoke screens, and also as an offensive weapon against personnel. It found some use also as a filling for incendiary bombs. The ability of phosphorus to thus serve in a dual capacity is due to the fact that it readily takes fire spontaneously when exposed to the air and in the process of combustion produces a dense white smoke cloud which has the highest obscuring power of any smoke material yet discovered.

The fact that, pound for pound, phosphorus is the most effective of all smoke producing materials, besides being a great casualty producer, makes it apparent that with the enormous increase in the use of smoke which is bound to take place in future wars, there will be a corresponding increase in the demand for phosphorus. The extent of its use will undoubtedly be, as in the World War, limited only by the supply.

There are in the United States ample supplies of the raw materials required for the production of phosphorus, and the methods of manufacture present no serious difficulties. The peace time requirements of phosphorus are, however, relatively small and the world's production is largely controlled by foreign interests. This situation makes it apparent that the United States faces a serious shortage of phosphorus in the event of an emergency. To meet this situation every effort should be made to foster the American manufacture of phosphorus and detailed plans must be prepared for the erection of sufficient plants to meet the phosphorus war requirements.

Properties: Phosphorus is a nonmetallic chemical element which does not occur free in nature, but always in combination usually as calcium phosphate. It exists in several forms, but only the white or ordinary yellow phosphorus and the red phosphorus are of commercial importance.

White Phosphorus, also known as yellow phosphorus, which is the form used to such a large extent in chemical warfare, is a semi-transparent solid melting at 44°C. When heated in an atmosphere free of oxygen it boils at 280°C. It is very active chemically and takes fire spontaneously when exposed to the air, due to the exothermic reaction between oxygen and phosphorus.

The burning of phosphorus results in the formation of a white smoke, phosphorus pentoxide, which is hygroscopic, and unites with the moisture in the air to form phosphoric acid. To protect white phosphorus from the air it is kept under water in which it is insoluble. It is readily dissolved by carbon disulphide and certain oils, and is slightly soluble in alcohol and ether. It is extremely poisonous and this combined with the readiness with which it ignites makes it a dangerous material to work with.

Red phosphorus, which is a solid, is formed from white phosphorus by heating under pressure. It does not take fire in the air at ordinary temperatures and is not poisonous.

Peace-time Uses: White phosphorus was formerly used as an ingredient in the composition of the heads of matches, but due to its poisonous character this is no longer permitted in most countries of the world. It is, however, used in matches indirectly, being first converted into phosphorus sesquisulphide (P_4S_3) which can replace the white phosphorus with a great decrease in danger both to the workers in match factories and to the general public. Phosphorus is also used in the manufacture of phosphorbronze; as an ingredient in rat poisons; for the production of various chemical compounds of phosphorus, and to a limited extent in medicine.

Red phosphorus is used on the scratching surface of safety match boxes, and as a catalyst in the preparation of organic compounds.

Method of Manufacture: Phosphorus used to be manufactured almost entirely from bone ash, but now the natural phosphate rock is used almost exclusively. In the older method bone ash is washed with water and sulphuric acid, followed by conversion into calcium meta-phosphate. To this is added charcoal or coke, and the mass charged in clay retorts and heated to a white heat. White phosphorus distills over and is collected under water.

At the present time this method has been largely replaced by an electric furnace process which employs phosphate rock. A mixture of phosphate rock, sand and carbon is charged into the furnace and the current turned on. The process is continuous, the phosphorus distilling over and is collected under water.

Sources of Raw Materials: Phosphates are distributed throughout the crust of the earth and are essential to all plant and animal life. The mineral matter of bones is principally calcium phosphate and, as has been stated, bone ash was at one time the principal raw material used for the production of phosphorus. With the introduction of the electric furnace process, however, phosphate rock has replaced bone ash.

Phosphate rock is found in workable quantities in five of the Eastern States, Florida, Tennessee, Arkansas, South Carolina, and Kentucky, and in four of the Western States, Montana, Idaho, Utah, and Wyoming.

By far the largest deposits in the United States are found in the western states. These deposits are so extensive that if the whole world depended upon them for its total peace time supply, they would not be exhausted for thousands of years. The total estimated available phosphate rock in the western states is given by the Geological Survey as 5,367,000,000 long tons as against 345,000,000 long tons for the eastern states.

But while the western states thus contain much more phosphate rock than the eastern states, the western deposits have been worked to only a small extent, due to isolation of many of the deposits, the high freight rates and the distance from the factories in the east where the phosphate rock is worked up.

At the present time Florida produces by far the largest amount of phosphate rock, as is shown by the Geological Survey statistics published for 1921. In that year Florida mined 2,088,251 long tons out of a total for the country of 2,426,174 long tons, while the western states mined only 4,961 long tons.

Practically all of this phosphate rock is used for fertilizer in peace time. The quantity required for the production of phosphorus being a very small percentage of the total mined.

The United States normally produces about one half the world production. Other countries which are important producers of phosphate rock are Tunis, which produces over a million tons per year or about one quarter of the world's production and stands next to Florida as a producer. Next in order follow Algeria, Belgium, France and Japan.

The highest grade of phosphate rock yet found occurs in deposits located in several islands of the Pacific and Indian Oceans. The principal producers of this high grade material are Aean Island (English), Tahiti and Mahatea (French), Navu (Japan), Christmas Island and several islands which belonged to Germany, but which have been confiscated by Japan and England. The total production of these islands in 1912 was 600,000 tons. No complete figures for later years are available.

Production of White Phosphorus:

There are only two firms in the United States which produce white phosphorus, The American Phosphorus Company of Philadelphia, Pa., and the Oldbury Electrochemical Company of Niagara Falls, New York. In 1914 the combined production of these two companies amounted to about 658 tons, about one-half of which was made into other products before being sold. During the war, the capacity of these plants was materially increased so that at the time of the Armistice the maximum capacity of the American Phosphorus Company was about 250 tons per year and the Oldbury Electrochemical Company 2,340 tons per year. Since the war the business of these companies has been at a standstill due to the fact that such small quantities as are needed commercially are imported at much lower cost than the cost of production in the United States. Unless some steps are taken to protect this industry, it would appear likely that those now engaged in the business will discontinue permanently.

This circumstance presents a rather serious situation in the event of an emergency, particularly, since even if the plants mentioned were operated at maximum capacity they could produce only about 65 per cent of the present war requirements of phosphorus for the first year of a war and these requirements will undoubtedly increase with the increasing development of the use of white phosphorus. This situation is further complicated by the fact that the Oldbury Electrochemical Company is an English owned company and according to good authority is controlled by Albright and Wilson, phosphorus manufacturers at Oldbury, near Birmingham, England. This company together with the Oldbury Electrochemical Company's plants at Niagara Falls, N.Y., and Quebec, Canada, and Cognet and Sons, in Lyons, France, manufacture 90 per cent of the world's supply of phosphorus.

Since the beginning of the World War, Japan has begun manufacturing phosphorus. In 1917 there were three Japanese companies producing phosphorus with a reported total production of about 600 tons yearly. This is over twice the productive capacity of the American Phosphorus Company, which is the only strictly American company in the United States.

This fact that the manufacture of phosphorus is practically controlled by foreign capital is significant, particularly, since the United States is the largest producer of the necessary raw material, phosphate rock. Japan and several of the European countries have, however, adequate resources of phosphate rock for very large scale production of phosphorus.

The Chemical Warfare Service is making every effort to meet the situation but has not yet been able to complete a detailed plan for the development of phosphorus production facilities beyond those in existence.

A number of manufacturers have been interviewed on the subject and the concensus of opinion appears to be that a cheap source of electric power and an advantageous position in regard to freight rate of raw materials are essential manufacturing requirements. It is also essential, of course, that there be an adequate market for phosphorus. At the present time the peace-time requirements of phosphorus are relatively small and this combined with the keen competition from abroad does not make the manufacture of phosphorus particularly alluring.

There is, however, one company, the Federal Phosphorus Company of Anniston, Ala., who are seriously considering the manufacture of phosphorus. They are large producers of other phosphate products and during the war were given cost plus $1.00 contract to produce phosphorus for the Government, but according to their statement this contract was cancelled due to the influence of opposing interests.

Further study of the phosphorus manufacturing situation will be undertaken and every effort made to encourage at least a manufacturing nucleus in this country which may be expanded in the event of war.

The Use of Phosphorus in Warfare:

White phosphorus was first used in warfare during the World War for the production of smoke screens and soon proved to be the most effective of all materials used for this purpose. This is not surprising when it is realized that for every pound of phosphorus burned, over three pounds of smoke are produced. Thus when one pound of phosphorus burns, 1.33 pounds of oxygen are taken up in the formation of phosphorus pentoxide and this phosphorus pentoxide in turn takes up .9 pounds of moisture from the air in the formation of phosphoric acid, which constitutes the particles of the smoke cloud. Phosphoric acid, itself, is very hygroscopic and will continue to take up additional water from the atmosphere.

In addition to being the best smoke producing material, white phosphorus is especially adapted for use in warfare. It can be stored for long periods of time without deterioration, so long as it is protected from the air, preferably, by covering with water. It is only essential that the container for white phosphorus shall be sufficiently tight to prevent leakage.

Phosphorus is used as a filling for grenades, Stokes mortar bombs, Artillery shell, aeroplane drop bombs. It can also be filled in cans for use as smoke candles.

The projectiles are provided with boosters containing suitable explosives which when fired ignite and scatter the phosphorus in burning fragments. These burning fragments produce the dense white smoke.

The white phosphorus grenade contains about .6 pounds of phosphorus. It is used by troops in trench and field warfare where it is desired to throw up a dense smoke screen at comparatively short distances in front of the line. The range of the hand grenade is about thirty yards and the rifle grenade about two hundred thirty yards.

Stokes mortar phosphorus shell furnish a means of maintaining the best possible smoke screen at long ranges by means of an easily portable gun. A three inch Stokes shell which contains about 2.38 pounds of phosphorus is for use by the Infantry and provides a means for forming smoke barrages at a greater distance from the lines than is possible with the rifle grenade. This shell also has an incendiary and casualty producing effect. The 4" Stokes mortar shell holds about eight (8) pounds of phosphorus and is used only by Chemical Warfare Service troops. It proved to be a very effective weapon in the World War, as is shown by General Fries' description of its use by American gas troops.

"The First Gas Regiment proved its worth and won everlasting glory by using the Stokes mortars of the British with their phosphorus bombs for attacking machine gun nests. The White phosphorus in that case had a double effect. It made a perfect smoke screen, thereby making the German machine gun shots simply shots in the dark, while at the same time the burning phosphorus forced the gunners to abandon their guns and surrender."*

Phosphorus is much the best of the various smoke producing materials which have been tried in Artillery shell. The following table gives an approximation to the relative values of these materials:

White phosphorus - - - - - - - - - - -	100%
Sulphur trioxide - - - - - - - - - - -	60-75%
Stannic chloride - - - - - - - - - - -	40%
Titanium Tetrachloride - - - - - - - -	25-35%

Phosphorus can be used in every caliber of Artillery shell and it is thus possible to establish and maintain an effective barrage over a wide front at any desired range.

White phosphorus aeroplane bombs are a post war development which has interesting possibilities. Tests which were carried out on the battleship "Alabama" show that with 100 pound phosphorus bombs a single plane might completely smother a battleship in a dense cloud of smoke. In addition, burning fragments of phosphorus scattered over the ship have a serious casualty producing effect on any exposed personnel.

Phosphorus has also been used in tracer bullets and as an incendiary, either alone or in mixtures. These uses are, however, insignificant when compared to the value of phosphorus as a smoke and casualty producer. The incidental incendiary effect produced by phosphorus is, however, not to be ignored. The burning fragments of phosphorus produced by bombs or shells are very difficult to extinguish and can only be put out by completely submerging in water. If these fragments alight amongst troops severe casualties will result.

In the foregoing paragraphs, the attempt has been made to show that phosphorus has proven to be a very effective weapon. It is not only the peer of all smoke producing materials, but will probably have no serious rival for a long time to come. It would appear, however, that phosphorus has far greater possibilities for use in warfare than have been realized. These possibilities are concerned not only with the increased use of phosphorus in the adopted types of projectiles, but also with the development of new types of containers and improved devices for the dispersion of phosphorus.

* "Chemical Warfare", by Fries and West

All armies have come to realize the value of smoke as a protective screen and in future wars the Army which has the most adequate supply of projectiles filled with phosphorus, the most effective smoke producer, and strong casualty producer, will have a decided advantage in the protection afforded its troops.

Post War Developments in the Manufacture of Phosgene

I. Introduction

In spite of the fact that large quantities of phosgene were manufactured by various countries during the war, there is very little reliable data available showing the most efficient procedure. This was due in part to the fact that fairly efficient processes were known and also to the necessity of immediate manufacture.

In view of the unsatisfactory war time data, a small scale plant was built at Edgewood Arsenal, and experiments carried out for the purpose of determining the most efficient process. These data make it appear that a basis has been established for the development of a more practical method for the manufacture of phosgene.

II. Resume of Processes for the Manufacture of Phosgene

The manufacture of phosgene is based on the reaction between carbon monoxide and chlorine

$$CO + Cl_2 = CO\ Cl_2$$

in the presence of some form of charcoal catalyst. There are a number of methods by which this fundamental process is carried out. These methods may be classified as (a) those which use relatively concentrated carbon monoxide, and (b) those which use a dilute carbon monoxide.

A. Phosgene Processes Using Concentrated Carbon Monoxide.

By far the greater part of the phosgene produced during the war was made using relatively pure carbon monoxide containing but a small percentage of other gases. This use of practically pure carbon monoxide with pure chlorine results in the production of a concentrated phosgane gas which is readily condensed with suitable refrigerating equipment.

The processes using concentrated carbon monoxide differ among themselves chiefly in the mode of manufacture of carbon monoxide. The chief methods of manufacture of concentrated carbon monoxide are based on one of the following reactions.

1. The reaction between good coke (low in hydrocarbons), carbon dioxide and pure oxygen. This was the process used at Edgewood Arsenal.

2. The partial oxidation of carbon by pure oxygen, This was used at the plant of Frank Hemingway, Bound Brook, N.J., by the French at Lyons using red hot birch charcoal, at the Plant of Ste. l'Accumulateur alcalin and Vitry where charcoal or foundry coke was employed.

3. The reduction of carbon dioxide with carbon. The British plant at Middlewich used this process and two German factories, Bayer and Hochst establishments.

4. The absorption of dilute carbon monoxide under pressure in ammoniacal cuprous chloride and subsequent regeneration of concentrated carbon monoxide by release of pressure. This scheme was used by the Germans at Ludwigshafen Works of the Badische Company.

5. Carbon monoxide from phosphorus furnaces. This source was utilized by the Oldbury Electro-Chemical Company, Niagara Falls, N.Y.

B. Phosgene Processes Using Dilute Carbon Monoxide

When a dilute carbon monoxide is used, the resulting phosgene gas is largely diluted with nitrogen from the air. It is therefore, impracticable to remove the phosgene by direct refrigeration. This difficulty is, however, overcome by absorbing the phosgene in a suitable absorbent and recovering the pure phosgene by distillation.

A British plant at Gateshead produced phosgene by this method. The carbon monoxide was produced by blowing air through hot coke and scrubbing out the carbon dioxide and sulphur dioxide. This gave a small percentage of carbon monoxide in a large amount of nitrogen. This dilute gas when mixed with chlorine and passed through the catalysers produced a dilute phosgene - the phosgene was absorbed in tetrachlorethane, from which it was recovered by distillation.

III. Outline of Processes Investigated in The Present Research.

From the brief discussion of the processes used during the war, it will be seen that there was a wide diversity in the manufacture of carbon monoxide and considerable difference of opinion exists as to whether the use of diluted or concentrated carbon monoxide is the most satisfactory. For the purpose of comparing these two methods an experimental study of each was undertaken.

(a) Outline of Concentrated Carbon Monoxide Process

The process employed is quite similar to war time procedure used at Edgewood Arsenal, the only difference being that 90% instead of (97-98%) carbon monoxide was used. To produce 98% carbon monoxide required the manufacture of oxygen. Due to the lack of funds it was not desired to operate the oxygen plant in the present work, as it was believed that the use of 90% carbon monoxide was a sufficiently close analogy to the war time process.

In the manufacture of carbon monoxide it was first necessary to make carbon dioxide. This was obtained by burning coke and scrubbing the products of combustion with potassium carbonate solution, thereby, forming potassium bicarbonate. Heating this solution gave carbon dioxide free from nitrogen. The carbon dioxide was then dried with sulphuric acid and passed through gas producers containing coke which had just been heated to incandescence, after a brief purging period, the resulting carbon monoxide was run in to a gas holder. The gas was then scrubbed with caustic soda to remove any residual carbon dioxide.

The carbon monoxide was then mixed with chlorine and passed through catalyzer boxes containing charcoal, and the resulting phosgene was condensed by direct refrigeration.

B. Outline of Dilute Carbon Monoxide Process

Dilute carbon monoxide was obtained by continuously burning coke with a deficiency of air in a gas producer. The resulting gas contained about 25% carbon monoxide, the remainder being chiefly nitrogen. The dilute carbon monoxide, after drying with sulphuric acid was mixed with chlorine and passed into the catalyzer boxes filled with charcoal. The resulting phosgene mixed with nitrogen was passed into refrigerated silica gel which at this temperature readily absorbed phosgene but not nitrogen. After the gel became saturated with phosgene, it was heated. This expelled the phosgene which was then liquefied by direct refrigeration.

Conclusions

1. The yields and cost of phosgene by either the dilute or concentrated carbon monoxide process appear to be about the same.

2. The chief cost in either case is the cost of the chlorine.

3. The dilute carbon monoxide process, however, possesses the advantage of using standard equipment while the concentrated carbon monoxide process requires special equipment which necessitates more highly trained operators. For this reason, the dilute carbon monoxide process appears the more practical for adoption in the event of an emergency.

The Development of the Manufacture of Hexachlorethane

Hexachlorethane is one of the important ingredients of smoke mixtures used for the production of screening smokes. In view of this and the fact that laboratory investigations had shown that it could be easily made, a small scale plant was erected in order to develop a manufacturing process. It was felt that the proposed method of manufacture could be developed to produce hexachlorethane at a cost less than the prevailing market price.

The process employed involves the reduction of carbon tetrachloride with metallic aluminum at 70-80°C, using aluminum chloride as a catalyst.

$$6\ CCl_4 + 2\ Al = 3\ C_2Cl_6 + 2\ Al\ Cl_3$$

The products of this reaction are aluminum chloride and hexachlorethane. Under laboratory conditions yields of 65% hexachlorethane based on the carbon tetrachloride not recovered are obtained. Aluminum chloride yields amount to 80%.

In the experimental runs carried out in the small scale plant no attempt was made to recover the aluminum chloride. It had been shown in the laboratory investigation that the recovery of aluminum chloride was feasible, but in the plant the equipment needed to carry this out was not available and the needs for hexachlorethane were so urgent that this phase of the production was abandoned.

As a result attention was given only to the production of hexachlorethane. When the reaction between carbon tetrachloride and aluminum is completed, the charge, consisting of hexachlorethane, excess carbon tetrachloride, aluminum chloride and some chlorinated by-products, is, drowned in water with the loss of the aluminum chloride. This was done because it had been found that the excess carbon tetrachloride and the hexachlorethane could not be distilled from the reaction mass without considerable decomposition due to the action of aluminum chloride.

In the drowning tank the solutions separate into two liquid layers. The water layer which contains the aluminum chloride in solution is not soluble in the carbon tetrachloride in which the hexachlorethane is dissolved. These two layers are separated by siphoning off the water solution. The carbon tetrachloride solution is then washed to remove as much aluminum chloride as possible; again separated from the water solution and distilled in steam. The carbon tetrachloride is recovered and the distilled hexachlorethane after filtering, is dried in vacuum dryers.

There was produced in the small plant 33,094 pounds of hexachlorethane which conformed to the specifications required for hexachlorethane smoke mixture.

The overall yield was 36.3% based on carbon tetrachloride unaccounted for, after standard operating practices were adopted, the average yield for one series of 14 runs was 45.6%. The average cost was $0.91 per pound. The costs were gradually reduced during production and reached a low point of $0.554 per pound.

The method of manufacture used was thus not successful from an operating and cost standpoint with the equipment available. However, with suitably designed equipment, it is believed that the process would be practical.

Development of a Manufacturing Process for Nitrogen Peroxide

The problem of finding a suitable method for the preparation of fairly large quantities of nitrogen peroxide, arose at the American University Experiment Station in connection with the war time investigations on the high explosive anilite, a mixture of liquid nitrogen peroxide and certain hydrocarbons. Later additional demands for nitrogen peroxide were made in the development of a process for the manufacture of picric acid from benzene, nitrogen peroxide, nitric acid and mercury.

Nitrogen peroxide, although well known in the laboratory, has seldom, if ever been manufactured commercially. It is ordinarily obtained by reducing nitric acid with some suitable reducing agent. It was suggested that if it could be obtained from sodium nitrate directly, instead of from nitric acid, which is in turn made from sodium nitrate, the cost might be considerably reduced and the process simplified.

Laboratory research on the problem was begun at the American University Experiment Station and after the Research Division of the Chemical Warfare Service moved to Edgewood Arsenal, an experimental plant was designed, built and put into operation.

The laboratory research disclosed that iron oxide when mixed with sodium nitrate and heated to 400°C or higher, decomposed the sodium nitrate with the formation of nitrogen peroxide and sodium ferrite.

$$2\ NaNO_3 + Fe_2O_3 = Na_2Fe_2O_4 + 2\ NO_2 + O$$

The sodium ferrite thus formed may be treated with water for the recovery of the iron oxide. This results in the formation of sodium hydroxide which may be recovered as a by-product.

$$Na_2Fe_2O_4 + H_2O = 2\ NaOH + Fe_2O_3$$

Both of these reactions are readily carried out but on a manufacturing scale the collection and liquifaction of the main product, nitrogen peroxide, free from moisture is rather difficult.

Nitrogen peroxide can be made in the laboratory from ferric oxide and sodium nitrate with yields of 95% or better, but the results secured in the plant were far below this, although it is felt that this could be definitely attributed to faulty apparatus and improper materials.

Dry sodium nitrate and iron oxide were mixed and continuously fed into a cylindrical nichrome rotary reactor heated in a furnace maintained at about 900° C. The sodium ferrite formed was discharged at the far end of the reactor while the nitrogen peroxide was removed in a current of air through the feed end and passed through a dust tank and cooled. It was then absorbed in silica gel - cooled to -10° C. The air stream now freed of nitrogen peroxide, was blown back to the rotary reactor after being preheated in the furnace.

The nitrogen peroxide absorbed in the silica gel was released by gradually heating up to 120° C., using steam under pressure in the condenser during the latter part of the expulsion. The nitrogen peroxide was then passed through suitable refrigerating apparatus and the liquid formed stored in steel cylinders.

The experience gained in the operation of this experimental plant has made it possible to formulate the conditions required to obtain high yields of nitrogen peroxide.

The ferric oxide used must be of a high degree of purity and the sodium nitrate a good commercial grade.

A mixture of three parts ferric oxide to one part of sodium nitrate gave the best results. It is also essential that this mixture be free of moisture as even a trace of water is very detrimental to the yield of nitrogen peroxide and to the apparatus. Water decomposes nitrogen peroxide with the formation of nitric acid which in turn seriously corrodes the plant equipment.

The plant equipment must be absolutely air tight. Leaks in the part of the system above atmospheric pressure result in loss of nitrogen peroxide, while leaks in the parts of the system below atmospheric pressure permit admission of moist air, which as has been shown, is very detrimental.

If these conditions are met, it should be possible to produce nitrogen peroxide free from nitric acid and obtain yields of 95%.

RESEARCH ACTIVITIES AT EDGEWOOD ARSENAL

Results of investigations, which have been carried on by the Chemical, Mechanical and Medical Research Divisions at Edgewood Arsenal during the past quarter, are summarized in the following paragraphs:

CHEMICAL AND MECHANICAL DIVISIONS

The work of the Chemical and Mechanical Divisions includes the study of screening smoke and its application, the development of lachrymatory munitions for training purposes, tests of German industrial canisters, marine piling and boll weevil investigations, and the development of mechanical devices.

Screening Smoke:

The screening smoke investigations in which progress has been reported are:

The fundamental study of smoke.
Methods of smoke generation and dispersion.
Smoke cloud travel.
The airplane smokes, both the smoke curtain and exhaust smokes.
The development of the 50# H.C. smoke candle.

Fundamental Study of Screening Smoke:

This work was undertaken to study and devise satisfactory methods of measuring the obscuring power of smokes; to determine the relative importance of the various factors influencing the total obscuring power of smokes and to establish the relative smoke producing values of smoke materials when generated by various methods.

This work is carried out in a room with a capacity of 60,000 cubic feet which was especially constructed for the purpose. Equipment is provided for circulating the air or smoke and for maintaining the conditions of temperature and humidity. An observation room is provided at one side of the building from which measurements of the smokes are made. Objects and lights placed within the concentration room at various distances from the observation window enable the observer to determine the depth of smoke required to cause total obscurance. Special apparatus connected with the concentration room also enable one to determine the size and number of particles in the smoke.

Considerable difficulty was experienced in the preliminary work in maintaining the desired atmospheric conditions. This was found to be largely due to leaks in the walls of the concentration room. This difficulty has now been overcome so that it is possible to make satisfactory quantitative comparative tests of smoke producing materials.

A study of the standard H.C. smoke was made in the concentration room to determine the effect of varying the relative humidity and temperature. It was found that the temperature had no effect on the total obscuring power (T.O.P.) of the smoke when the relative humidity was maintained constant at 60.5% in successive runs and the temperature varied from 82 to 100° F. When the temperature was maintained constant at 100° F., and the relative humidity was increased in successive runs from 44-76%, there was a corresponding increase in the T.O.P. of the smoke.

When these data were plotted, relative humidity against per cent light transmission, the latter varied in almost a straight line relation from 3.5% at 76% relative humidity to 11.75% transmission.

Experiments were also undertaken to determine the amounts in ounces of various smoke materials, which it is necessary to expend to obscure a cross sectional area of 1000 sq. ft. In these experiments approximately uniform conditions of temperature and relative humidity were maintained.

Tests were carried out in this manner to compare the standard Chemical Warfare Service H.C. smoke mixture with the British Type S smoke mixture. It was found under the conditions of the tests, that the H.C. smoke candle mixture is two or three times as effective as the British Type S mixture. Only 3.65 ounces of the H.C. mixture are required when burned to obscure 1000 sq. ft. as against 11.07 ounces of the British mixture.

Similar experiments were undertaken with liquid smoke producing materials, such as titanium tetrachloride, stannic chloride, and chlorsulphonic acid. In these experiments, it was first necessary to determine the method of dispersal most suitable for producing the most effective smoke cloud, since liquid smoke materials may be dispersed either by atomization or thermal methods.

The Travel of the Smoke Cloud:

In connection with the investigation of the travel of smoke clouds, meteorological data are being obtained in order that one may predict the behavior of smoke under varying conditions of temperature and wind velocity. In particular a study is being made of the variations of wind and temperature at various heights above the ground. To this end a thermograph and anemometer have been installed on a flag pole at an elevation of about 60 feet and continuous records of wind velocity and temperature are being taken. The records on the flag pole are being compared with corresponding records near the ground by means of graphs.

Another investigation with the same end in view, is concerned with whether or not the travel of a smoke cloud can be measured by means of a puff of smoke. If this is possible, the behavior of a smoke cloud laid down in battle can be readily predicted by first watching the behavior of a small puff of smoke. Various devices are being tried as a means of producing a satisfactory puff of smoke for this purpose.

Airplane Smokes - Smoke Curtain:

The laying down of a smoke curtain by an airplane necessitates that the smoke producing liquid (titanium tetrachloride) be discharged from the plane at the same speed as the plane but in the opposite direction. Thus the pressure required for the discharge of the titanium tetrachloride in the required time is a function of the speed of the plane. In order to determine the pressures required for varying airplane speeds, aground set up of the plane equipment was installed and water was used in tests for speeds varying from 60 to 120 miles per hour with nozzles of various diameters. From the data obtained tables and curves are being prepared for use in the production of smoke curtains using either the D.H. planes or Martin bombers.

Cylinders of carbon dioxide are used as a source of pressure for discharging the titanium tetrachloride. This has given satisfactory results but it has been felt that greater refinement of control and pressure regulation might be obtained by introducing the liquid carbon dioxide into the container for the titanium tetrachloride. Two highly successful tests have been conducted, sufficient pressure being maintained throughout the test to discharge the liquid in about twenty seconds which is within two seconds of the time calculated to discharge the liquid when the plane is traveling at maximum speed. These results demonstrate that this arrangement may possibly afford a means of securing constant pressure, and at the same time completely discharging the liquid within the required time.

In this connection small quantities of liquid carbon dioxide will be added to titanium tetrachloride and the resulting pressures determined at temperatures of from 10° C. to 40° C.

Demonstrations were conducted at Fort Benning, Georgia, for the purpose of showing the use of smoke curtains in actual war maneuvers. Altogether five curtains were dropped using a full charge of 980 lbs. of F.M. (titanium tetrachloride) with a Martin Bomber. These tests were as follows:

1. Screening a Company in Attack
2. Screening Battalion in Attack
3. Screening River Crossing
4. Screening River Crossing
5. Screening River Crossing by dropping curtain in three stages at varying altitudes of 1000, 600, and 300 feet. In this case the pilot screened himself in the last two stages of the operation.

Tests Nos. 2, 4 and 5 were declared to be entirely successful.

Tests 1 and 3 were conducted under most adverse wind conditions, and while not entirely unsuccessful, clearly demonstrated the impracticability of attempting to lay a smoke curtain under such extreme weather conditions except with a sufficiently large number of planes to overcome the difficulties arising from these conditions.

Screening Smoke from Airplane Exhaust:

In the production of screening smoke by discharging a liquid smoke material through the aeroplane engine exhaust some difficulty has been experienced due to the corrosive action of the smoke on the plane. To overcome this a plane is being partly rebuilt, substituting ply wood on the fusilage for the fabric and making an all-metal tail assembly. In addition especially designed exhaust manifolds are being added to conduct the smoke to the rear of the tail surfaces.

Experimental 50 lb. H.C. Smoke Candle:

The 50 lb. H.C. smoke candle is similar to the smaller H.C. smoke candles and was developed as the largest smoke producing unit which could be readily handled by one man. In adapting the regular H.C. smoke mixture to this candle it was necessary to make certain changes in order to provide quick means for delivering the full smoke volume from the candle. This was accomplished by using one half pound of a fast burning smoke mixture on top of the regular mixture and using a slower starting mixture. This candle congains about 50 pounds of the smoke mixture and when fired emits a dense white cloud for from twelve to fifteen minutes. The weight of the container in its present state of development is about five pounds.

Development of Lachrymatory Munitions:

Lachrymatory munitions containing C.N. (Chloracetophenone - a tear gas) are being developed for use in the training of troops.

The Army 25# C.N. Drop Bomb:

This bomb, which is for use in mob control and the training of troops, is a non-explosive bomb, the C.N. being thermally dispersed as a smoke cloud.

The bomb used is the old Mk II 25 lb. demolition bomb, which is now obsolete and of which there is a supply available.

The weight of the filling used is 5-1/2 pounds of which 58% is smokeless powder, 40% C.N. and 2% magnesium oxide, which acts as a stabilizer.

The bomb functions on impact, is non-fragmenting and gives off a cloud of lachrymatory smoke for about ten minutes.

Navy Training C.N. Floating Bomb:

This bomb developed for Navy training purposes, is the old H.C. aeroplane screening smoke floating bomb, which has been adapted to the C.N. filling. The weight of the filling used is about 12.5 pounds, of which about 8 pounds is smokeless powder, 4-1/4 pounds C.N. and 1/3 pound magnesium oxide.

The bomb functions on water impact and floating on the water gives off clouds of the tear gas (C.N.) smoke for from 12 to 17 minutes.

Flat-shaped C.N. Candle:

The present C.N. lachrymatory candle is cylindrical in shape, 4 inches in diameter by 2-3/4 inches high, and is consequently not an economical shape for packing and further it is an awkward shape to carry. For these reasons a flat shaped C.N. candle has been developed, using the same container as the H.C.

screening smoke candle. This container is a tin can 5-1/4 inches high with a rectangular cross section 3-5/16 inches by 1-1/2 inches.

The change in the shape of the C.N. candle has necessitated a change in the composition of the C.N. mixture, since the conditions of burning are materially affected by the burning area of the candle and the ratio of the area to the depth. A suitable C.N. mixture for this flat shaped candle has been developed and the manner of loading worked out. For loading the candles the C. N. mixture is first pressed into blocks of suitable sizes, these dipped into molten C. N. (Chloracetophenone) and dropped into the containers. The coating of C.N. thus provided between the C.N. mixture and the container is for the purpose of preventing the burning from spreading down the sides of the mixture and thus causing too rapid burning, which might result in explosion. Details for the large scale loading of these candles have not as yet been worked out.

Investigations of Gas Mask Canister Absorbents:

In connection with the investigations of gas mask canister absorbents, a sample of British activated charcoal and German industrial canisters have been tested.

British Charcoal:

The British charcoal received, which is a steam activated nut charcoal, is about the same quality as the average steam activated nut charcoal now being used in the type 1919 Chemical Warfare Service canister. The total saturated and the retentive adsorption of toluene correspond to our charcoal of the same grade.

German Industrial Canisters:

A number of German canisters for industrial uses have been examined. The nature of the absorbents has been determined as well as the general characteristics of each canister. The canisters are practically identical in mechanical construction with the war canister. The absorbents vary somewhat in their nature and composition according to the compounds against which protection is afforded. However, the two principal absorbents, the charcoal and the alkaline granules are very similar to the same absorbents in the war canister.

The charcoal found in the canisters is a soft friable wood charcoal of approximately 8 to 20 mesh. The moisture content of the charcoal in every canister was somewhat high (14% to 25%). A small amount of zinc and iron was generally found in the charcoal, this having been left after activation. No compounds were found in the charcoal which would be intended to increase the absorption of any gas.

The alkaline granules were compositions consisting of an alkali such as potassium or sodium carbonate impregnated on inert carrier such as infusorial earth. The alkali and moisture content varied considerably. The granules caked to a more or less degree. These granules were used for the absorption of acid vapors.

The third class of absorbents includes special absorbents for particular gases. These absorbents consisted of an inert carrier, as above, and an active material which would absorb a particular gas. For ammonia, acetates of iron and zinc were used; for hydrogen sulphide, a mixture of the oxides of lead, iron, zinc and manganese; and for hydrocyanic acid an alkali such as potassium carbonate mixed with a compound of zinc.

The absorbent fillings of the canisters were as follows:

	Protection Afforded Against	Filling
1.	Organic Vapors	Charcoal.
2.	Acid Vapors Some protection against organic vapors and ammonia.	Charcoal Alkaline Granules
3.	Sulphur Dioxide	Alkaline Granules
4.	Acid and organic vapors, hydrogen sulphide, and ammonia	Alkaline Granules Charcoal
5.	Hydrocyanic acid	Alkaline Granules containing zinc
6.	Cyanmethyl Formate Chlormethyl Formate	Charcoal Alkaline Granules
7.	Ammonia	Carrier impregnated with zinc and iron acetates. Charcoal
8.	Ammonia Hydrogen Sulphide	Carrier impregnated with zinc and iron acetates. Carrier impregnated with oxides of lead, iron, zinc and manganese.

9.	Hydrogen Sulphide Organic Vapors	Carrier impregnated with oxides of lead, iron, zinc and manganese. Charcoal.

None of the absorbents, except the charcoal, compare favorably with American absorbents for similar purposes. This is considerably due to the use of inert carriers.

The special absorbents for ammonia or hydrogen sulfide are slightly different from similar American absorbents, but are very much inferior.

The canisters will afford protection against moderate concentrations of the compounds specified.

Marine Piling Investigation:

This investigation is concerned with the development of methods for the protection of marine piling against marine borers. Test blocks, which have been impregnated with various toxic materials, are prepared and exposed to attacks of the borers in the ocean at Beaufort, North Carolina. An inspection of all test blocks so exposed showed that twenty compounds have given practically perfect protection for two complete seasons.

Arrangements are being made to install impregnated test pieces at several marine borer invested places on the coasts of the country, using the toxic materials which have shown the most promise for impregnation.

Boll Weevil Investigation:

This investigation was undertaken for the purpose of developing some means for the eradication or control of the cotton boll weevil which each year destroys from a quarter to one half of the southern cotton crop.

Several methods of attack have been pursued in this work which is being carried on at Clemson College, South Carolina, and Griffin, Georgia.

(1) Experiments have been undertaken with the idea of finding a poison which the weevil will eat, when dusted or sprayed upon the cotton plant and which would be more effective than calcium arsenate, the poison at present used in the attempt to control the ravages of the boll weevil. So far between 250 and 300 toxic compounds have been tried out, in each case tests with calcium arsenate being made under comparative conditions.

As a result of this work over forty compounds have been found which these preliminary tests indicate to be of equal or greater toxicity than calcium arsenate. Of these about twelve show little or no plant injury. About 15,000 weevils have been used in this work.

No certain conclusions can be drawn from the data so far obtained. Moreover, in this phase of the investigation very little attention is being paid at the present time to the cost of the various poisons used, or to the effect upon the cotton plant. The idea is to determine first by the examination of many substances the various classes of poisons which will kill the weevil. Then it is hoped to find among these classes of substances or from selected poisons, some poison which might prove of practical value.

(2) Another line of investigation was to determine the lethal dose to the boll weevil of various gases, such as hydrocyanic acid, hydrogen sulphide, chlorpicrin, and cyanogen chloride. It was found that the weevil was not killed by any reasonable concentration and time of exposure, although most of these gases paralyzed the weevil after short exposure to high concentrations or longer exposure to low concentrations. Removal of these weevils to fresh air generally revives them. It would appear from this that the weevil stops breathing when exposed to these gases and is able to exist without breathing for a considerable period of time.

(3) Another method of attack has been to try to find some chemical which, in small concentrations, would excite the boll weevil sufficiently to make him fly the idea being that if this were possible the weevils could be caught in fly paper or some other trap, by drawing a suitably covered device over the cotton plants. To this end about seventy-five chemicals have been tried, among them the various war gases which are the most irritating to man. All efforts, however, failed to make the weevil fly. The best compounds found that excited the weevil somewhat, in low concentrations, were formic acid, acetic acid, chlorpicrin, and titanium tetrachloride smoke. It was found, however, that the boll weevil is extremely deliberate in his movements under all agents tried. It responds slowly and can not be blown from the cotton stalk when excited. This line of investigation seems, therefore, to have produced no results of practical value.

Specifications:

The status of specifications for chemicals on December 1, 1924 , is given below:

All fine inorganic and fine organic chemicals in the revised procurement list have been put into one of the six following groups:

M.D. 4-502-U.S.P. - Fine organic U.S.P. 8 items
M.D. 4-502-S.of M. - Fine Organic S.of M. 5 items
M.D. 4-502-Gen. - Fine Organic General 10 items
M.D. 4-501-U.S.P. - Fine Inorganic U.S.P. 8 items
M.D. 4-501-S.of M. - Fine Inorganic S.of M. 43 items
M.D. 4-501-Gen. - Fine Inorganic General 73 items

Of the ninety-six heavy chemical specifications required by the revised procurement list, the technical data for all is 95% complete. Five specifications in approved form have been forwarded (10/24/24) for test approval. It is not planned to write the remainder until these five have been approved.

Of the seven specifications for toxics required, none have been written.

Livens Projector Fuze:

During September a few Bickford time fuze from the Fuse Assembly, Bickford Mk I for Chemical Shell, Livens Projector, were prepared for air burst. When fired during demonstration at Aberdeen Proving Grounds, October 3, 1924, at least one shell prematured. A few tests have been started to ascertain the likelihood of the detonator or fuse and d etonator being driven to the bottom of the well on set back. Tests of the crimp employed in preparing the fuses which were used in demonstration show that the method gives at least as good tenacity as original samples crimped in manufacture.

4" Stokes Mortar Clinometer:

A 4" Stokes mortar clinometer, modified to give barrel elevation and the complementary base plate angle at one setting of the instrument, which was developed previously and tested by the First Gas Regiment, is being prepared for submission for approval. This instrument is graduated in both degrees and mils.

MEDICAL RESEARCH DIVISION

The medical research has included a study of the toxicity of lead tetra ethyl; the treatment of phosphorus burns, and the treatment of acute respiratory diseases with chlorine.

The Toxicity of Lead Tetra Ethyl:

Lead tetra ethyl which is the chemical used in the so-called ethyl gasoline was studied for the purpose of determine its toxicity. As a result it was found that the toxicity of this material as compared to the more toxic war gases is low and that it decomposes at 120° C. It is evident, however, that the manufacture, handling and distribution of lead tetra ethyl involves considerable danger of acute lead poisoning in those instances where considerable material is splashed on the skin and of chronic lead poisoning from the absorption of small amounts by inhalation by the skin or mouth. Tests by the Bureau of Mines appear to show that the exhaust gases of automobiles using ethyl gas are not toxic, the lead tetra ethyl having been decomposed and the lead having been changed to unsoluble forms.

Report on the Treatment of White Phosphorus Burns:

In a number of cases accidentally burned by white phosphorus in the field and in filling plants grêat difficulty was experienced in treating the cases owing to the fact that the phosphorus adhered to the flesh and continued to fume and occasionally burst into flame again. This necessitated the placing of such cases in a continuous bath, and immediately upon removal from the bath the phosphorus would begin to fume and smoulder again. This investigation was started in an attempt to find what agents could be applied to the burns to neutralize the phosphorus following which the burn could be treated as an ordinary heat burn. In the selection of an agent the strong possibility of phosphorus poisoning due to absorption had to be considered.

As a result of this investigation involving tests with a large number of chemicals, it was found that a solution of copper sulphate, between 1% and 3% will stop the fuming and burning of lumps of phosphorus in the tissues, and renders their removal easy by forming a coating of copper phosphide on the phosphorus lumps.

A 1% copper sulphate solution has been recommended as a treatment for white phosphorus burns, and a 1% solution of copper sulphate should be kept on hand at all shell and grenade filling stations, at Stokes mortar batteries when using white phosphorus shells and at first aid stations. Large pads of absorbent cotton should also be at hand. Whenever a phosphorus burn is received a large sponge of absorbent cotton should be saturated with a 1% copper sulphate solution and applied to the burning phosphorus. Within two or three minutes it will be possible to remove the sponge. The copper-coated phosphorus should then be removed by forceps or by irrigation and the case then treated like any other burn.

Treatment of Acute Respiratory Diseases with Chlorine:

The treatment of acute respiratory diseases with chlorine is being continued. Ten horses suffering from equine influenza were treated and all recovered much more promptly than untreated animals would.

BOOKS AND PUBLICATIONS

The following are among the books and pamphlets in the Technical Reference Library, Office of the Chief of Chemical Warfare Service. These publications are available for use of all officers and employees of the Chemical Warfare Service, and may be loaned to any Chemical Warfare Officer outside of Washington upon written request from him. The conditions under which these loans are made outside of the Chemical Warfare Service Office are as follows:

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641 H 217	Alcoholic Fermentation, Harden
	Alloys (Non-Ferrous) Sexton
621.3 J 135	Alternating Currents and A. C. Machinery, D. C. and J. P. Jackson
	American Civil Engineers Pocket Book, Merriman
620.2 B 592	American Highway Engineers' Handbook, Blanchard
355 B 288	American Industries in the War B. M. Baruch
177 B 892	American Social Problems, Burch and Patterson

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937 Or 8	Cavour and the Making of Modern Italy, Orsi
666.3 M 295	Ceramics, Malinovsky
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540.4 B 437	Chemical Lecture Experiments, Benedict
540 B 819	Chemistry of Common Things, Brownlee, Fuller, Hancock and Whitsit
620.2 T 697	Civil Engineers' Pocketbook, Trautwine

Class No.	Name of Publication and Author
667.2 W 332	Color in Relation to Chemical Constitution Watson
347.7[illegible].7 W 679	Commercial and Banking Law, Williston
355 GSS	Communication for All Arms
540.3 T 853	Condensed Chemical Dictionary, The Turner
658 C 127	Course in Modern Production Methods, Business Training Corporation. 6 vols. per set
443.2 B 453	Dictionnaire Militaire, Supplement General
621.31 J 266	Direct Current Machinery, Jansky
551.4 H 652	Earth Features and their Meaning, Hobbs
621.32 F 854	Elec. Lighting and Miscellaneous Application of Electricity, Franklin
546.3 F 38	Elements of Electrical Transmission, Ferguson
621.3 T 481	Elements of Electricity, Timbie
	Engineer Field Manual, 5th Edition Leach
620 H 689	Engineers Manual, Hudson
355.41 G 157	English of Military Communication, The Gano
612.015 H 15[illegible]	Essentials of Chemical Physiology, Halliburton
621.4 H 622	Gas Power, Hirschfield and Ulbricht
	General Metallurgy, Hofman

Class No.	Name of Publication and Author
355 W 886	Giants of the Marne, The A story of Mc-Alexander and his Regiment. Maj. J.W.Woldridge
354.42 L 951	Government of England, Vol. I Lowell
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355 A 1 53	Great War, The
341.1 WPF	Hague Declaration of 1899 Concerning Asphyxiating Gases
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620.2 H 668	Handbook of Chemistry and Physics, 9th Edition Hodgman and Lange
620.2 H 675	Handbook for Heating and Ventilating Engineers Hofman and Haber
547 C 553	Handbook of Organic Analysis, A Clarke
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973 F 547	History of the United States, Fiske
355 C 886	How America Went to War, Vol. 4, The Armies of Industry.
355 C 886	How America Went to War, Vol. 5, The Armies of Industry
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621 M 552	Mechanics of Materials, Merriman
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622	Ore Deposits of Useful Mineral and Rocks, Vol. I & II, Beyschlag Vogt and Krusch
547 C 66	Organic Chemistry for Advanced Students, Cohen
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540 Os 7	Outlines of General Chemistry, Ostwald
551.4 G 862	Physical and Commercial Geography, Gregory and Keller
623.4 H 666	Post War Ordnance
547 C 660	Practical Organic Chemistry, Cohen
621.3143 B 39	Principles of the Transformer, Bedell
	Les Poudres et Explosifs, L Vennin et G Chemeau
544 B 292	Qualitative Analysis, Baskerville and Curtman

Class No.	Name of Publication and Author
	Readers' Guide to Periodical Literature, 1919-21 and 1922
591.12 K 014	Respiratory Exchange of Animals and Man, Krogh
	Scientific American Encyclopedia of Formulae
900 W 459	Short History of World, A H. G. Wells
910 P 537	Soldier's Geography of Europe, Philips
621.18 G 264	Steam Power Plant Engineering, Gebhardt
621.354 M 836	Storage Batteries, Morse
355 A1 53	Supplement to The Great War, Allen
541.3 L 585	System of Physical Chemistry, A 3 Vols. Lewis
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541.9 S 1	Tables of Chemical and Physical Constants, Spielmann-Wheeler
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540 Sa 15	Textbook of Chemistry, 8th Revised Edition, Sadtler and Coblentz
537 St 36	Theory and Calculations of Electric Circuits, Steinmetz
546.3 R 716	Treatise on Chemistry, Vol. 2, Roscoe and Scherlemmer
546.3 R 716	Treatise on Chemistry, Vol. 1, Roscoe and Scherlemmer
	U. S. Artillery Ammunition, Viall
621.3842 B 852	Vacuum Tubes in Wireless Communication, Bucher Telegraph Operation

DIGEST OF TECHNICAL ACTIVITIES

of the

CHEMICAL WARFARE SERVICE

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LACHRYMATORS

(Tear Gases)

1. Introduction.

The lachrymators are the most numerous of all the chemical warfare compounds. They are found in every degree, from those which are merely annoying to those which cause severe irritation and such a copious flow of tears as to result in temporary blindness. Some of them also have an additional toxic effect when breathed in higher concentrations, although at these concentrations there is such intense lachrymation as to be absolutely unbearable. In high concentrations they may also irritate the skin.

Practically all the gases used during the war possessed lachrymatory properties to a greater or less extent. Thus the powerful vesicant mustard gas, the toxic phosgene, and the sneeze gas diphenylchlorarsine, all irritate the eyes enough to cause tears at high concentrations. Chlorpicrin and cyanogen chloride are powerful lachrymators even in low concentrations, but they have been employed in battle primarily for their toxic properties.

Lachrymators were used by the Germans in the World War shortly after the first gas wave attacks and were very effective in incapacitating men until the adoption of gas masks which afforded protection for the eyes. But even though there is no serious difficulty in affording protection against these compounds, their use compels an Army to wear the mask indefinitely, with the expenditure of material far short of that required if the more deadly gases are used. It has been estimated that one good lachrymatory shell will force wearing the mask over an area which would require 500 to 1000 phosgene shell of equal size to produce the same effect.

This harassing value of tear gases has resulted in their use by police for the control of mobs and for dislodging criminals from inaccessible retreats.

2. General Properties of Lachrymators

All of the lachrymators in general use are organic compounds containing one of the halogens - iodine, bromine, or chlorine. In general, those compounds containing iodine usually have the most strongly lachrymatory effect, this effect decreasing through bromine to chlorine. Iodine is, however, comparatively scarce and expensive so that it is desirable that compounds be discovered which will lachrymate effectively without containing this element. Most of the lachrymators used during the War were bromine compounds and many very effective lachrymators were made containing this element. The most effective of the bromine lachrymators developed during the War was brombenzylcyanide. The manufacture of this lachrymator did not, however, get under way in time for use before the end of the War. Even bromine, however, is expensive as compared to chlorine and further, the liquid bromine lachrymators, due to their corrosive action on steel, require special lead, glass or enamel shell linings. It was highly desirable, therefore, that a lachrymator be developed using the relatively cheap and readily available chlorine in place of bromine or iodine. This was accomplished toward the close of the War in the development of chloracetophenone which is very nearly as effective a lachrymator as brombenzylcyanide. This fact indicates that it is not only the halogen which influences the lachrymatory power of a compound, but also the rest of the molecule as well. In the case of the halogenation, however, there is a general rule concerning its influence on the power of lachrymation of a compound. There is no such rule regarding the influence of the rest of the molecule. This must in every case be determined by experiment.

3. Lachrymators used during the War

The principal substances used during the War primarily for their tear producing properties, are given in the following table which also gives the concentration (milligrams per liter of air) necessary to produce lachrymation.

Martonite (80% Bromacetone; 20% Chloracetone)	0.0012
Ethyl Iodocaetate	0.0014
Bromacetone	0.0015
Xylyl Bromide	0.0018
Benzyl Bromide	0.0039
Brommethylethylketone	0.011

Bromacetone

Bromacetone was one of the first lachrymators used during the War. It is a water-clear liquid which turns brown or black on standing. It boils with decomposition at about 126° C. and the vapor pressure of the crude product is 9 mm. at 20° C. Its vapor is not quite five times as dense as air.

Bromacetone is not very stable but traces of water stabilize the product somewhat and the addition of chloracetone seems to have the same effect. It causes lachrymation at

0.0015 mg. per liter (0.21 parts per million) when pure. Its lachrymatory action is very quickly effective. It is claimed to lachrymate at 0.0011 mg. per liter when containing 20% chloracetone (martonite) although the chloracetone is a poorer lachrymator than bromacetone. It is classed as a non-persistent lachrymator. Troops can advance a few hours after the shelling.

Both the charcoal and the soda lime in the gas mask canister stop bromacetone readily.

Martonite

Martonite, so called by the French, is a mixture of 80% bromacetone and 20% chloracetone. It was developed to replace bromacetone for the reason that it could be made without the loss of one-half the bromine as in the case of bromacetone. Martonite is more stable than bromacetone and is a somewhat better lachrymator.

Brommethylethylketone

This lachrymator was prepared as a substitute for bromacetone solely on account of the shortage of acetone. Bromketone, as it is sometimes called, is not as effective a lachrymator as bromacetone.

Ethyliodoacetate

The use of ethyliodoacetate was advocated by the British at a time when the price of bromine seemed prohibitive. Because of the relative price of bromine and iodine under ordinary conditions, it is not likely that it would be commonly used. It is, however, a slightly more effective lachrymator, and is more stable than bromacetone. Ethyliodoacetate boils in air with decomposition at 178-180° C. and has a density of 1.8. It is much less volatile than bromacetone, having a vapor pressure of 0.54 mm. at 20° C.

Benzyl Bromide

Benzyl Bromide was used in the early part of the War, usually mixed with xylyl bromide and often with bromacetone.

Pure Benzyl Bromide is a colorless liquid boiling at 198-199° C. with vapor pressure of 20 mm. at 20° C. It lachrymates at .0039 mg. per liter (0.54 parts per million). The war gas is probably a mixture of mono and dibrom derivatives, boiling at 210°-220° C. and having a density at 20° C. of 1.3.

Xylyl Bromide.

Xylyl Bromide as prepared is practically always a mixture of three isomeric compounds. It is an oil boiling at 212-222° C. with a density of about 1.38. It produces lachrymation at about .0018 mg. per liter (0.2 parts per million). It found its greatest application in the German "T-Stoff", which was a mixture of benzyl and xylyl bromides. "T-Stoff" is a highly persistent material and may last, under favorable conditions, for several days. While it is relatively non-toxic, French troops were rendered unconscious by it during certain bombardments in the Argonne in the summer of 1915.

Brombenzylcyanide

Brombenzylcyanide is much more effective than any of the lachrymators used during the War. Most people can detect it at 0.0015 mg. per liter (0.021 parts per million) and are lachrymated at 0.0003 mg. per liter (0.04 parts per million).

The pure material is a colorless solid melting at 25° C. The crystals soon turn pink owing to slight decomposition, which does not proceed far, however. The crude product melts at 16°-22° C. and the crystals are varying shades of dark brown, often with a marked greenish tinge. The vapor pressure is given as 0.0019 mm. at 0° C. and 0.062 mm. at 40° C.

Brombenzylcyanide is about as toxic as phosgene, but its chief value lies in its lachrymatory power. It is a very persistent lachrymator, having been known to retain considerable lachrymatory power after thirty days exposure in the open. Like the other bromine lachrymators, however, it corrodes most metals and so requires a special lining when loaded into projectiles. Protection against brombenzylcyanide is readily afforded by the Army gas mask.

4. Lachrymators of the Future and their Uses.

It has been pointed out that the lachrymators used during the War were far from satisfactory, due primarily to the fact that they were bromine compounds. Bromine is relatively a scarce and expensive chemical. The lachrymators containing bromine are not very stable and are generally corrosive, thus requiring special linings. Further, the question of protection against lachrymatory gases was never a serious one. During the first part of the War this was amply supplied by goggles. Later, when the Standard Respirator was introduced, it was found that protection was afforded against all lachrymators. Their principal value was, therefore, against unprotected troops and in causing men to wear their masks over long periods of time.

In an attempt to discover a lachrymator which would eliminate the disadvantages of the bromine compounds, experiments were undertaken which led to the study of chloracetophenone as a possibility.

Chloracetophenone is not new to chemical science, for it was first prepared in 1887; but until its use was developed for chemical warfare, it was little more than a laboratory plaything. It was investigated by the British during the War, but was discarded by them due to their failure to disperse it effectively.

It was found to have a lachrymatory power and persistency equal to or slightly better than brombenzylcyanide, and further, it contains the inexpensive halogen chlorine, instead of bromine; is very stable under normal conditions; does not corrode steel and so can be loaded directly in projectiles without any special lining. While these advantages of chloracetophenone over the other lachrymators were known and manufacturing methods had been developed prior to the end of the War, large scale production did not get under way in time for its use at the Front. It is now, however, the only lachrymator seriously considered by the Chemical Warfare Service. It may well be, however, that other lachrymators may be discovered which will in turn result in discarding chloracetophenone.

Chloracetophenone is a colorless crystalline solid, melting at 58°-59° C. and boiling at 245°-247° C. The vapor pressure is about .002 mm. at 0° C., 0.019 mm. at 25° C., and 0.056 mm. at 37° C. Its density is 1.334 at 0° C. and 1.263 at 55° C. It is soluble in benzol and carbon tetrachloride. The pure compound causes lachrymation in the majority of cases at .00031 mg. per liter (.045 parts per million). Protection is secured by the Army gas mask.

Due to the fact that chloracetophenone is a solid at ordinary temperatures and is stable at relatively high temperature, there are a number of possibilities presented for its dispersion as used in the field. It may be melted and cast into projectiles and dispersed by high explosive boosters; it may be dissolved in suitable solvents and sprayed from nozzles by the use of high pressure gas cylinders; or it may be dispersed as a vapor by the use of suitable heating devices.

Of these three methods of dispersion, the second and third have been utilized in the development of a number of effective lachrymatory weapons; the first method, however, that of dispersing the solid lachrymator by explosion, is still in the development stage.

Spraying Chloracetophenone in Solution from Cylinders

For the purpose of spraying solutions of chloracetophenone there was developed a cylinder similar to the toxic gas cylinder Mark I. This cylinder, a photograph of which is shown on the following page, is loaded with about twenty-two pounds of a 10% solution of chloracetophenone dissolved in equal parts of benzene and carbon tetrachloride and charged with carbon dioxide to a pressure of 150 pounds per square inch. In operation the solution is forced out through a suitable nozzle which produces a find spray or mist which is readily carried along by the wind.

In tests made to determine the efficacy of this weapon, cylinders were released and observers were placed downwind from the point of release at various points and a record obtained of the degree of lachrymation as well as its duration. As a result of these tests, it was found that with the simultaneous discharge of four cylinders, time of discharge about one and three-fourths minutes, and wind velocity 13.5 miles per hour, very severe lachrymation was experienced for four minutes at a distance of one thousand yards, width of cloud being about 150 yards at this distance. At a distance of four hundred yards, there was experienced severe burning of the skin in addition to lachrymation.

These cylinders were for use primarily for the training of troops where the tear gas simulates a toxic cloud gas attack. Similar devices based on the same principle and using the same solution have been developed and are in use by police forces for the control of mobs and subjection of criminals.

Dispersion of Chloracetophenone by Heat.

For the dispersion of chloracetophenone by heat there has been developed the so-called chloracetophenone (C.N.) smoke mixture. This mixture consists of an intimate mixture of chloracetophenone, .30 calibre smokeless powder, and magnesium oxide. The smokeless powder on burning generates heat for the volatilization of chloracetophenone, and magnesium oxide serves as a stabilizer for the mixture. The mixture is fired with a special ignition powder, which in turn is ignited by a match head composition.

Various kinds of containers such as grenades, candles, and Stokes mortar shells have been developed for the dispersion of the lachrymatory smoke mixture. The chemical mixture used and methods of heat dispersion used are the same for all containers, but each, of course, serves a special purpose for the distribution of lachrymatory vapors.

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Gas Cylinders Spraying a Solution of Chloracetophenone.

The grenade adopted is the standard light metal hand grenade modified by drilling eight 5/32 inch holes at equal distances apart around the circumference slightly below the top of the grenade body. The holes are covered with adhesive tape and coated with shellac, which is blown off by gas pressure when the grenade functions. The grenade is loaded with the C.N. mixture, a starter of meal powder and an ignition fuze.

The grenade functions in about four seconds after the primer is fired and burns for about 45 seconds producing a dense cloud of chloracetophenone vapors which are strongly lachrymatory. It is non-fragmenting and is no great fire hazard.

The candle, which is a tin can loaded with thirty ounces of the chemical mixture, functions the same as the grenade, except that it is fired in position.

The Stokes mortar shell of the burning type functions in a manner similar to hand grenades. After being fired, the shell on landing gives off lachrymatory vapors which issue through holes provided in the shell.

Chloracetophenone has found an interesting and useful application as a training material in the form of small gelatine capsules, containing a little less than a gram of the lachrymator. These capsules may be placed on an electric hot plate, the heat disintegrates the capsule and vaporizes the chloracetophenone. One capsule will render 1000 cu. ft. of air intolerably lachrymatory in two minutes. These capsules when used in a small room or gassing chamber are very effective in training men in the use of the gas mask.

RESEARCH ACTIVITIES AT EDGEWOOD ARSENAL

The results of investigations carried on at Edgewood Arsenal during the past quarter are summarized in the following paragraphs.

Marine Piling Investigation

Marine borers, mainly limnoria lignorum, and shipworms, cause immense economic loss by their destruction of wooden marine structures. While this fact has been known for centuries, it was forcibly brought to the attention of the American public by the recent invasion of San Francisco bay where property amounting to millions of dollars was destroyed by these pests and the possibility of the recurrence of such an attack at a new location constitutes an ever present menace so long as untreated timber is used, or until definite means for the prevention of such an attack can be found.

The best method of protecting piling against marine borers in the past has been to impregnate the piling with creosote. This is generally recognized as an efficient protection against marine borers for a number of years. The value of creosote is, however, less in warm waters than in cold ones and some creosotes seem more efficient than others.

In an effort to provide some effective means for the preservation and protection of marine piling work was undertaken by the Chemical Warfare Service in cooperation with the Committee on Marine Piling Investigations of the Division of Engineering and Industrial Research of the National Research Council.

The work of the Chemical Warfare Service has been conducted along three lines:

1. Toxicological and physiological tests which were undertaken to determine the poisons most effective against marine borers.
2. Methods for the protection of existing structures.
3. Methods for the protection of new structures.

1. Toxicological Investigations

Toxicological investigations were carried out at Beaufort, North Carolina, during the summers of 1923 and 1924. Laboratory toxicity tests of different compounds were conducted on Limnoria, shipworm embryos, exposed shipworms (Bankia removed from their burrows), and shipworms in wood blocks.

It is of especial note that the order of toxicities of the compounds tested was in general the same for all four series. The decreasing order of resistivity of the organisms was: embryos, exposed shipworm, Limnoria, and shipworm in blocks.

Of the forty-five compounds tested, the following stood out in the order named from all the rest in all round toxic value:

Chlorvinyl arsenious oxide
Phenyl arsenious oxide
Mercuric oxide
Mercuric chloride
Mercuric arsenate
Cuprous cyanide
Cupric orthonitrobenzoate
Cuprous chloride
Mercuric anilinate
Mercuric benzoate
Crystal violet

It has been definitely shown that several of the compounds are many times as toxic as creosote to marine wood boring organisms.

2. Prevention of Attack on Existing Structures

In accordance with the procedure outlined by the inventors, a test was carried out at Beaufort, North Carolina, July 1, 1923, of a method of generating chlorine by the electroysis of sea water, and it is sufficient to state here that there was no evidence of the extremely beneficial effects claimed by the sponsors of this process.

Evidence of the toxic effect of metallic copper and compounds formed by the action of sea water on metallic copper seemed definite enough to warrant the trial of copper studded test pieces. Colonel Atwood of the National Research Council, found that when some of the test blocks which were already attacked by teredine borers were wrapped with copper wire, not only was there no further attack, but the borers already in the block were killed.

It was hoped that, if the exigencies of the situation demanded, the surface of the piles already in the water could be covered with copper slugs or shot by some such means as an air pressure gun. This work would, of course, necessitate the use of a diver, and the expense would undoubtedly be too great, except in the most desperate case, as the single cost of the necessary cleaning of the barnacles, slime, and other marine growths from the pile would be prohibitive.

3. Protection of New Structures

In the investigation to develop means for the protection of new structures, a number of toxic substances were used to impregnate sections of railroad ties at Edgewood Arsenal, which were then exposed to the attack of marine borers in the harbor at Beaufort, North Carolina.

Some experimental work was conducted to determine the best method of impregnation for given substances, and four adaptations of standard methods were selected. Experiments were conducted to develop suitable impregnating mediums for different solid toxics. Satisfactory impregnation was secured in practically all cases.

The data from the service tests at Beaufort indicate that certain toxics, when used as impregnants, give definite protection against marine borers for a short period of time. How lasting this protection will be, it is impossible to state on the basis of tests made to date, but when the service test data are studied in conjunction with the specific toxicity data, there is certainly basis for the presumption that several of the materials used in the service tests will probably protect for thirty years or more. In fact, the results of the investigation of the San Francisco Bay Marine Piling Committee, as published in their Third Annual Progress Report (5), show that protection for a period of from 15 to 20 years can be secured by proper creosote impregnation and this narrows the problem of protection of new structures to the point of finding a material which will give protection for a longer period than creosote, or of finding a cheaper material than creosote, which will give equal protection, or of finding a material cheaper than creosote which will give protection for a longer time.

There is no doubt that the addition of a specific toxic to creosote will give protection for a longer period than creosote alone.

It is quite probable that with the use of some cheaper vehicle than creosote, several of the specific toxics found, when used in this vehicle, will give protection equal to creosote for less cost.

It is possible that when all the data are available, one or more materials will be found which will give protection for a longer period than will creosote, and at less cost.

Conclusions

1. All of the impregnated pieces used gave much better protection against marine borer attack than unimpregnated pieces.

2. The addition of 5 per cent of specific toxics, such as diphenylarsenious oxide, diphenylaminearsenious oxide, phenylarsenious oxide, etc., to creosote for impregnation purposes would seem to afford definite protection for piling against marine borers.

3. While the length of exposure was not sufficient to justify too optimistic conclusions, it is believed that piling so impregnated will stand up for a longer period than straight creosote impregnated piling.

4. While several compounds of undoubted toxicity have been found, the choice of the best all around toxic for impregnation work will eventually depend upon the comparative economy of material and process cost in introducing the same.

5. The cost of the carrier for the toxic will probably prove the determining factor in the choice of the best all around agent. Economically, the carriers used are as follows, in order of cheapness:

a. Water
b. Fuel oil
c. Benzol (figuring recovery)
d. Ammonia
e. Creosote

6. If a method can be perfected for using toxic dyes in water solution which will obtain the desired depth of impregnation, and which are fast to sea water, they will probably prove the most economical of the compounds used.

7. It is believed that most of the impregnation results can be duplicated on large scale apparatus sufficiently well for practical purposes.

8. The toxicity results indicate that Limnoria can be used as a criteria for the specific toxicity of any compound on all the types of marine borers studied.

Boll Weevil Investigation

Congress appropriated $25,000.00 for investigations to be undertaken toward the eradication of the cotton boll weevil. Plans for this work have been formulated and five chemists are now at work in the South carrying on toxicity tests to determine the most effective poisons to be used.

The Development of a Hot Wire Anemometer for the Instantaneous Measurement of Fluctuations in Wind Velocity.

The development of a hot wire anemometer for the instantaneous measurement of fluctuations in wind velocity was undertaken in connection with the study of the travel of smoke and gas clouds. In this study considerable interest attaches to the velocity of the wind, because of its effect upon the rate of travel, height, shape and general behavior of such clouds. It is common experience that no wind travels at a constant rate for continued periods, but changes its velocity more or less frequently. The effects of this gustiness of the wind upon smoke or gas clouds is but little known, because up to the present time no accurate method of determining rapid changes in wind velocity has been available.

The instruments most commonly employed for wind velocity measurements are averaging instruments, such as the vane or Robinson cup-anemometer, which indicate distance traveled, not velocity. These results are accurate to a reasonable degree, but they afford no measure of the gustiness of the wind, but only of general tendency of average increase or decrease of distance traveled in unit time.

For use in the study of gas cloud travel, an instrument capable of actual velocity measurement and of following the velocity changes of the wind instantaneously is highly desirable.

From the nature of this demand, it is readily seen that an instrument deriving its actuating energy from the wind is unlikely to meet this requirement. Instruments like the Robinson cup and vane anemometer seldom give instantaneous velocity, and never for a long enough time to provide a record because of the accumulation or dissipation of energy in the moving parts of the instrument.

Instruments which, like the Pitot tube, balance a hydrostatic pressure against the kinetic pressure of the wind are free from this error but at lower velocities (below 12 miles an hour) develop so slight a hydrostatic pressure that their reading or recording is hardly feasible.

The hot wire anemometer is based on the fact that the electrical resistance of most metals and alloys varies with the temperature and this rate of change is linear or nearly so. Further the cooling of heated metals is increased by the wind blowing on them. Thus the hot wire anemometer derives no energy from the wind but measures the rate of energy loss from the hot wire due to the cooling action of the wind upon it and hence measures the velocity of the wind causing the change in the rate of loss. For this reason the hot wire anemometer offers a solution of the problem and it is with the study and adaptation of this principle to use in the field that this development is concerned.

The first experiments were based on the work of King. A heated platinum wire exposed to variable winds requires a variable current to maintain the wire at a constant temperature and resistance, and the variation in current is a measure of the changes of wind velocity. These experiments were abandoned in favor of the method of Huguenard, Magnan, and Planiol. According to this method current at a constant potential is supplied and the decrease in resistance of the hot wire when exposed to the wind, i.e., the increase in current, is a measure of the wind velocity. Rapid changes in wind velocities over a range of 0-25 miles per hour were successfully indicated and tentative recommendations for a recording instrument have been turned over to the Signal Corps, who plan to construct one of these instruments.

The Development of the H.C. Smoke Grenade

A grenade containing a smoke mixture which evolves a cloud of white screening smoke for about one minute has been developed for the use of troops. The container is the standard K.J. or W.P. light metal grenade body, modified by drilling twenty-four 5/32" holes near the top and covering these holes with strips of gummed paper. The firing mechanism is the bouchon assembly with the W.P. detonating thimble sawed off and sealed with a celluloid disk. Four grams of the starter mixture is placed in the detonating thimble. The grenade is loaded with either one of two mixtures, 300 grams of E-1 Mixture (zinc powder 32,98%, hexachlorethane 36.88%, sodium chlorate 22.23%, magnesium carbonate 7.91%) or 280 grams of mixture I-5 (zinc powder 38.03%, hexachlorethane 45.78%, and ammonium perchlorate 16.19%). In preparing these smoke mixtures, the ingredients are mixed dry for a short time, then 10-15% carbon tetrachloride is added, and the mixing is continued for twenty-five minutes.

A number of smoke mixtures were studied, using zinc and hexachlorethane as a base, using various cooling agents, and comparing the volume, density, color, temperature, and acidity of the smokes. Surveillance tests showed that there is a certain amount of deterioration in the adopted smoke mixture due to the absorption of moisture. However, the deterioration is not felt to be serious within a year.

Although the finished grenade as described is not entirely successful from a stability standpoint, it is felt that should a better grenade be desired, little difficulty would be experienced in the development of such a grenade, in view of the experience gained in the present investigation.

Travel of Smoke. Cloud

Two field tests were conducted during June. These were made to test the relative effectiveness of white phosphorus when burned in pans and B.M. candle smokes. The B.M. candle smoke was one-third to one-fourth as effective as the white phosphorus smoke.

Black Smoke Mixtures

Considerable work has been done checking up results obtained by Prof. Demetrio Helbig's mixture for developing a black smoke. Prof. Helbig states that carbon tetrachloride and the aromatic hydrocarbons react at a high temperature, liberating carbon and gaseous hydrochloric acid.

Several experiments were conducted using a mixture of benzene and carbon tetrachloride, and attempting to combine them in their theoretical proportions. The liquids were absorbed in a combustible absorbent mixture composed of sawdust, potassium nitrate, and sulphur. The combustible mixture was used to produce sufficient heat to cause the following reaction:

$$3\,CCl_4 + 2\,C_6H_6 = 15\,C + 12\,HCl$$

Several experiments were also tried in which fuel oil was substituted for the benzene.

Results obtained by the use of both benzene and fuel oil were very poor. The resulting clouds obtained were very thin, did not hang together, the color was brown rather than black, and in all cases were greatly inferior to those obtained from ixture using zinc, hexachlorethane, anthracene, and potassium perchlorate.

While results obtained from theuse of carbon tetrachloride and the liquid hydrocarbons were poor, results obtained from the use of solid hydrocarbons and a solid chlorinating agent in reactions analogous to those employed by Prof. Helbig gave promise of satisfaction.

Generation of Smoke by Means of Aeroplane Exhaust Gases

The apparatus for producing smoke screens from aeroplane exhausts was installed on a Martin Bomber from Quantico, Virginia. This installation was tested and gave a satisfactory smoke screen

Sprinkling Smoke from Aeroplane

The smoke screen equipment removed from the Martin bomber which was wrecked on Staten Island last fall has been returned to Edgewood Arsenal and reconstructed in a stationary position in order to determine the required pressures necessary to give rates of flow of liquids at different velocities equal to variations in speeds of the plane for each size of nozzle proposed for use.

Compressed air and water are being used in place of carbon dioxide and F.M. in these calibration tests on account of their greater availability. About 100 tests were run with water speeds of from 60-120 miles per hour with nozzles of 7/16 inch, 17/32 inch, 5/8 inch, and 3/4 inch, diameter. Curves are being drawn from the data obtained. A few experiments will now be made with titanium tetrachloride.

In addition to these tests, the smoke screen apparatus was removed from the D.H. plane for modifications. An additional outlet pipe has been welded to the forward and under side of the cylinder and conducted downward and backward in an effort to lead the column of liquid out of the slip stream of the plane. It is also believed the coefficient of friction can be lowered materially by shortening the length of the pipe used heretofore which ran the full length of the fusilage. This will reduce the required pressure or permit a greater control of the pressure factor. This modified apparatus was tried out and a satisfactory curtain was dropped, although the curtain was shorter than was expected from the amount of F.M. in the container.

Fundamental Study of Charcoal

Any complete study of charcoal with reference to its ultimate use in the gas mask must include a knowledge of the resistance to air flow of charcoals of various mesh, activity and with different methods of packing.

An investigation has been undertaken to determine the resistance of charcoal to the passage of air using 6-8, 14-16, and 24-30 mesh charcoal in 2.5, 5 and 10 cm. depths with air velocities of 125, 250, 500 and 1,000 cm/minute. The air flow was carefully measured on a calibrated wet meter. The pressure drop was observed on a vertical manometer using a magnifying glass with a cross hair. Using the latter, a difference of .02 inch could be read with accuracy. Considerable deviation was observed between check determinations. For instance, four observations of the resistance of a 2.5 cm. depth of 24 to 30 mesh charcoal of 28 minute activity at an air velocity of 125 cm./min. varied between .32 and .49. It is probable that these deviations are due to differences in the packing of the charcoal. It is therefore necessary to make a large number of determinations to reduce the probable error of the average resistance of each mesh and depth.

Soda Lime from Czecho Slovakia

A sample of soda lime from Czecho Slovakia has been tested against phosgene. On the standard test the service time was 7 minutes at 95% and 10 minutes at 90% efficiency. Both the activity and capacity for the absorption of phosgene by this material is much lower than that of the Army pink soda lime.

In hardness, the Czecho Slovakian soda lime compares favorably with pink soda lime.

Livens Projector Exploder

An investigation has been undertaken for the purpose of devising means of firing 500 Livens projector shells simultaneously. Tests on firing 500 or more squibbs with manually operated exploder using the graded series parallel connection gave evidence of the possibility of this means of solving the problem. A preliminary set, constructed of materials on hand and weighing ninety pounds fired the equivalent of 750 squibbs; the energy input being well within that developed by a man.

An improved model of the experimental exploder weighing 45 lbs., 8 oz. was constructed. In a test it fired 550 squibbs in approximately 0.03 seconds. This time lag is believed to be negligible and an improved model is being prepared.

Surveillance on Chemical Warfare Munitions

Tests have been made on the following munitions during the past three months.

C.N. Grenades

The surveillance of C.N. Grenades at 60° C. has been discontinued due to failure of grenades as reported in last Digest. The 50°C. surveillance tests are, however, being continued. Results obtained with grenades fired at the end of six, seven and eight months respectively, are given below. It will be noted that the burning time of these grenades gradually increased until the eighth month when the burning time decreased - at the end of five months burning time was 40 seconds.

6 months (June 12, 1924)

#1 functioned satisfactorily, burning time 52 sec., lachrymation fair.

#2 functioned satisfactorily, burning time 49 sec., lachrymation fair.

7 months (July 12, 1924)

Two grenades were assembled and fired. Both functioned satisfactorily, one burning for 1 min. 5 sec., and the other burning 1 min.

8 months (August 12, 1924)

One grenade was assembled and fired, and functioned with a burning time of 45 seconds.

BOOKS AND PUBLICATIONS

The following are among the books and pamphlets in the Technical Reference Library, Office of the Chief of Chemical Warfare Service. These publications are available for use of all officers and employees of the Chemical Warfare Service, and may be loaned to any Chemical Warfare Officer outside of Washington upon written request from him. The conditions under which these loans are made outside of the Chemical Warfare Service Office are as follows:

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547 Al 53	Allies' Map of the Western Front, Y.M.C.A.
944 H 388	Alsace-Lorraine under German Rule, Hazen
621.3 K 32	Alternating Current Electrical Engineering, Kemp
540 H 132	American Chemistry, Hale
920 C 297	American Men of Science, Cattell & Brimhall
661.2 D 518	American Sulphuric Acid Practice, De Wolf and Larison, 1st Edition
900 B 74	Ancient Times, Breasted
541.37 H 13	Applications of Electrolysis in Chemical Industry, The Hale

Class No.	Name of Publication
	Applied Colloid Chemistry, General Theory, Wilder D. Bancroft.
	Applied Mechanics, Rankine
	Artillery Firing, W.P.D., General Staff
	Association of British Chemical Manufacturers
641 F 829	Bacteriological & Enzyma Chemistry, Fowler
	Behind the Scenes with the Kaiser, Von Larisch
662.2 Sm 52	Bombs and Hand Grenades, Captain Bertram Smith
920 P 258	Captains of Industry, Part I & II, Parton
547 W 528	Carbon Compounds, Weston
540 T 454	Chemical Discovery & Invention, Tilden
	Chemiker Kalender, Bd., 1923
	Chemists' Year Book, Atack
540 Sa 15	Chemistry of Familiar Things, Sadtler
540 K 121	Chemistry and its Relation to Daily Life, Kahlenber and Hart
541.345 T 219	Chemistry of Colloids, The Taylor
676 Su 83	Chemistry of Pulp and Paper Making, Sutermeister
540 N 878	College Textbook of Chemistry, Noyes
541.3452 As 27	Colloid Chemistry, Alexander
667.2 W 332	Colour in Relation to Chemical Constitution, Watson

Class No.	Name of Publication
546.3 F 915	Corrosion of Iron and Steel, The Friend
547.1 W 672	Cyanogen Compounds, Williams
745 B 314	Design in Theory and Practice, Batchelder
355 D 738	Development Division, C.W.S.
540.3 T 398	Dictionary of Applied Chemistry, (5 Vols.) Thorpe
443.2 B 453	Dictionnaire Militaire, 2 Vols.
667.2 P 419	Dyes and Dyeing Pellew
537 S 28	Electrical Engineering, Shaw
	Electrometallurgy, Kershaw
621.3 F 854	Elements of Electrical Engineering, Franklin and Esty
542.48 C 561	Elements of Fractional Distillation, 1st Edition Clark Shere Robinson
920 H 249	Eminent Chemists of our Time Harrow
	Engineers Transit Book, Nat. Bank Book Co.
540.4 T 398	Essays in Historical Chemistry, Thorpe
662.2 B 264	Explosives, Barnett
641 P 718	Fermentations, Plimmer
530 M 621	First Course in Physics Milliken & Gale
443.2 W 643	French-English Military Technical Dictionary, Willcox

Class No.	Name of Publication
621 W 879	Gages and Gaging Systems, Woodworth
621.4 N 792	Gas Engine Ignition, Norris, Winning and Weaver
540 B 581	General Chemistry, Theoretical and Applied Blake.
550 G 275	Geology, Geike
	Graphical & Mechanical Computation, Lipka
945 W 155	Greater Italy, Wallace
620.2 H 668	Handbook of Chemistry and Physics (9th Edition, Hodgman
	Handbook of Modern Explosives, Eissler
	Higher Mathematics for Students of Chemistry & Physics (2 vols.) Mellor
353 M 349	How Americans are Governed, Marriot
678 C 27	India-Rubber Laboratory Practice, Caspari
541.3 W 152	Introduction to Physical Chemistry, Walker
355 B 64	Inventions of the Great War, A. Russell Bond
543.9 L 59	Laboratory Companion to Fats & Oils Industries, Lewkowitsch
973 M 776	Leading Facts of American History
920 D 228	Life of Woodrow Wilson, The Josephus Daniels

Class No.	Name of Publication
900 V 638	Maintenance of Peace, The S. C. Vestal
	Manufacture of Artillery Ammunition, Alford
	Manufacture of Organic Dyestuffs Wahl-Attack
	Metallography, Desch
543.6 O 5	Microscopic Analysis of Metal. Osmond and Stead
940 Sc 16	Modern and Contemporary European History, Schapiro.
667.2 P 419	Natural Organic Coloring Matters, Perkin & Everest
546 W 495	New Ideas on Inorganic Chemistry, Werner
443.3 M 499	Nuovo Dizionaire Inglese Italiano, Melzi
	Ordnance & Gunnery, Tschapat
631 C 355	Organic Agricultural Chemistry, Chamberlain
547 B 279	Organic Medicinal Chemicals, Barrow-Cliff and Carr
540 K 121	Outlines of Chemistry, Kahlenberg
546 P 931	Per-Acids and their Salts, Price
	Pharmaceutical Arithmetic, Sturner
541.35 S 49	Photo Chemistry, Sheppard
770 D 448	Photography for Students of Physics and Chemistry Dorr
541.3 R 545	Physical Chemistry of the Proteins, The Robertson

Class No.	Name of Publication
535.5 R 644	Polariscope in the Chemical Laboratory, The Rolfe
547 G 228	Practical Methods of Organic Chemistry, Gatterman
547 C 66	Practical Organic Chemistry for Advanced Students Cohen
546 Os 7	Principles of Inorganic Chemistry, Ostwald
633.7 H 396	Plant Alkaloids, Henry
678 W 561	Plantation Rubber & Testing of Rubber, Whitney
544 N 874	Qualitative Chemical Analysis of Inorganic Substances, Noyes
547 R 418	Richter's Organic Chemistry, 2 Vols. Smith
613.1 B 162	Sanitary and Applied Chemistry; Bailey
973 C 362	Students History of United States Channing
	Sturmtruppen und Flammenwerfer, Theune
546.3 H 13	Synthetic Use of Metals, Hale
355 G33	Tactical Principles & Decisions, Vol. 1.
546 F-C 315	Textbook of Inorganic Chemistry, Vol. V. "Carbon and its Allies", Cavan
667 W 885	Textiles, Woolman and McGowan
541.36 Sa 14	Thermochemistry and Thermodynamics Sachur

Class No.	Name of Publication
615.11 R 284	U. S. Dispensatory, 20th Edition, Remington and Wood
621.3842 Z 45	Wireless Telegraphy Zenneck
660 Sm 55	Zinc Industry, The Smith

LANTERN SLIDES

Lantern slides are in the Technical Division, Office of the Chief of Chemical Warfare Service, and are available for loan on request. Among these are the following:

Title	Number
Gas Mask, McBride	3793
Gas Mask, British, One of the later types, with nose clip	3101 NYC
Gas Mask, British, P.H. Side view	3103 NYC
Gas Mask, British, P.H. Helmet. Front view	3106 NYC
Gas Mask, British Type H Helmet	3107 NYC
Gas Mask, French A.R.S.	7816 NYC
Gas Mask, French Tissot Artillery. Back view	7802 NYC
Gas Mask, Russian	7703 NYC
Gas Masks developed since 1918	3795
Gas Masks, Various types developed previous to Armistice	3739
Gas Mask Canister, Sectional view, Model 1919	682
Gas Mask Drill. U.S.Marines in France. Lined up for gas mask drill and inspection.	2143 SC
Gas Mask Drill: Side carrier This is the latest set of slides showing the approved method of adjusting the carrier and mask.	3316-3335 in
Gas Mask Drill: Side carrier. To sling the mask, 1st position.	3316
Gas Mask Drill: Side carrier. To sling the mask, 2nd position	3317
Gas Mask Drill: Side carrier. To sling the mask, 3rd position	3318
Gas Mask Drill: Side carrier. Mask in carrying position, full pack.	3319
Gas Mask Drill: Side carrier. Adjusting the mask to the face. Helmet with strap under chin. Opening flap and knocking off helmet.	3320
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Gas Mask Drill: Side carrier. Taking the face piece out of the satchel, showing the proper method of grasping the face piece.	3322
Gas Mask Drill: Side carrier. Bringing up face piece. Chin thrust out preparatory to putting on mask.	3323
Gas Mask Drill: Side carrier. Digging the chin into the face piece and passing the harness over the head.	3324
Gas Mask Drill: Side carrier. Clearing the face piece of gas by closing the outlet valve with right hand and breathing out, the exhaled air passing out around the edges of the face piece.	3325
Gas Mask Drill: Side carrier. Passing the flap of the satchel around the breathing tube and fastening on outer snap fastener.	3326

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The above list will be continued in future issues of this Digest.

WAR DEPARTMENT
OFFICE CHIEF CHEMICAL WARFARE SERVICE
WASHINGTON, D. C.

SEP 27
UNITED STATES A

106-14

reply refer to

Sept. 26, 1924.

MEMORANDUM FOR Commandant Army War College, Washington Bks., D.C.

A copy of the Digest of Technical Activities of the Chemical Warfare Service, dated June 30, 1924, was recently mailed you. It has been found that there are several serious errors in this publication, and it is requested that it be sent back in the enclosed envelop for correction, after which it will be promptly returned to you.

For the Chief, Chemical Warfare Service:

WILLIAM N. PORTER,
Major, C.W.S.
Executive Officer.

Returned 9/27/24

SEP 24 106-14

UNITED STATES

UNCLASSIFIED

~~CONFIDENTIAL~~

DIGEST OF TECHNICAL ACTIVITIES

OF THE

CHEMICAL WARFARE SERVICE

JUNE 30, 1924

TECHINCAL DIVISION
Chemical Warfare Service
Washington, D. C.

Rec'd The A.W.C. Sept.23,1924.

THE SMOKE CURTAIN

DIGEST OF ACTIVITIES
OF THE
CHEMICAL WARFARE SERVICE
JUNE 30, 1924.

Vol. 1 Number II

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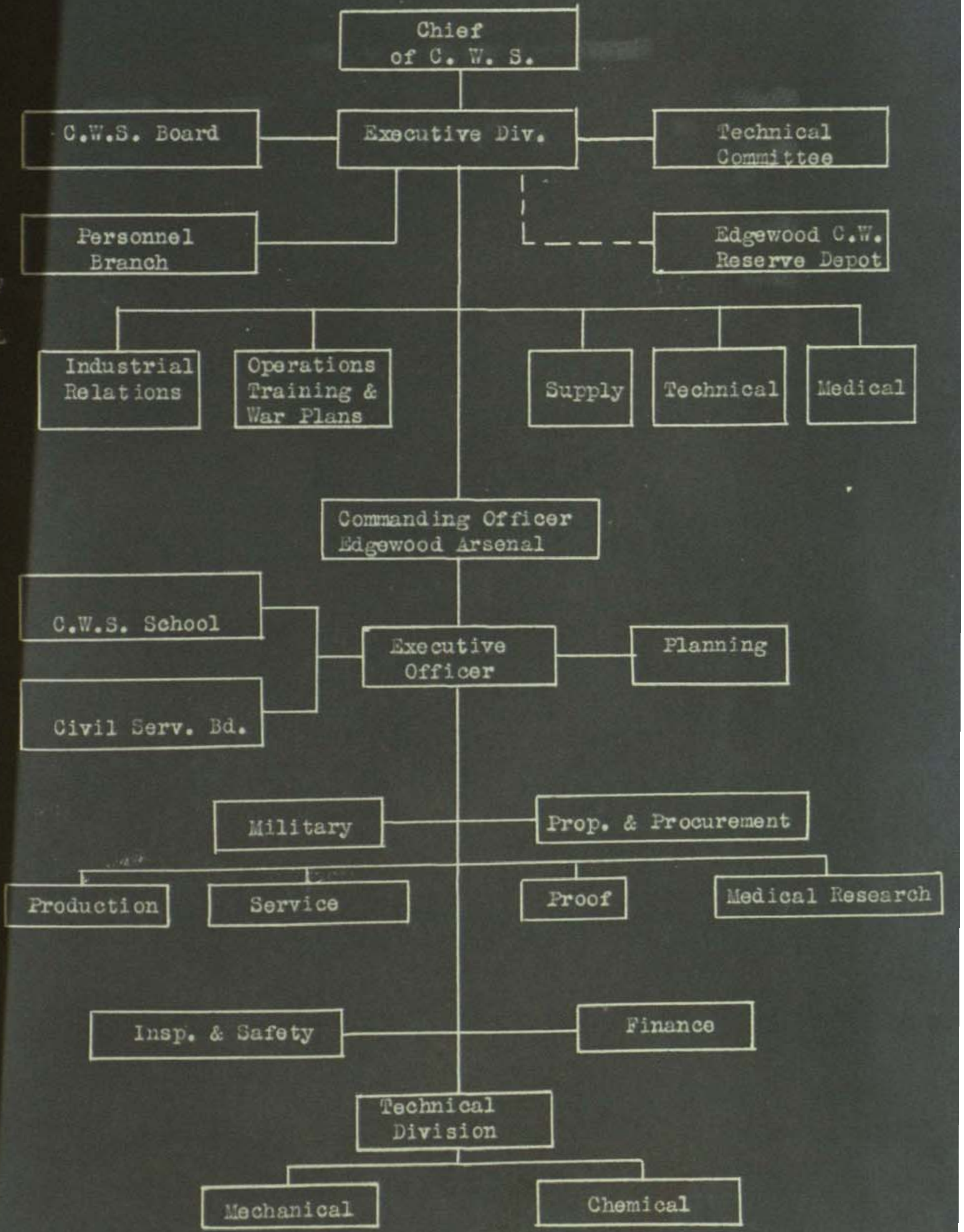
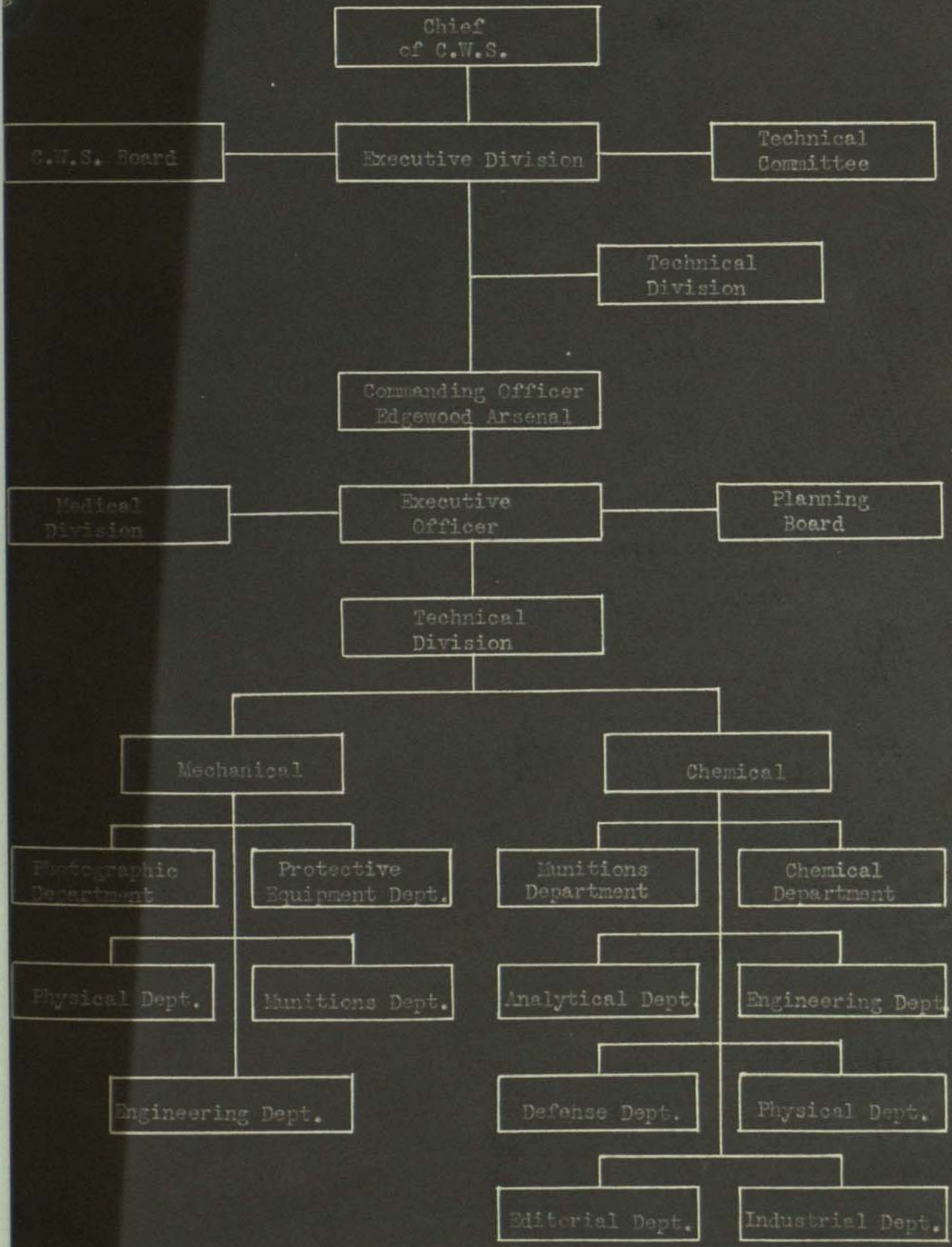


Organization of Research and Development Activities.



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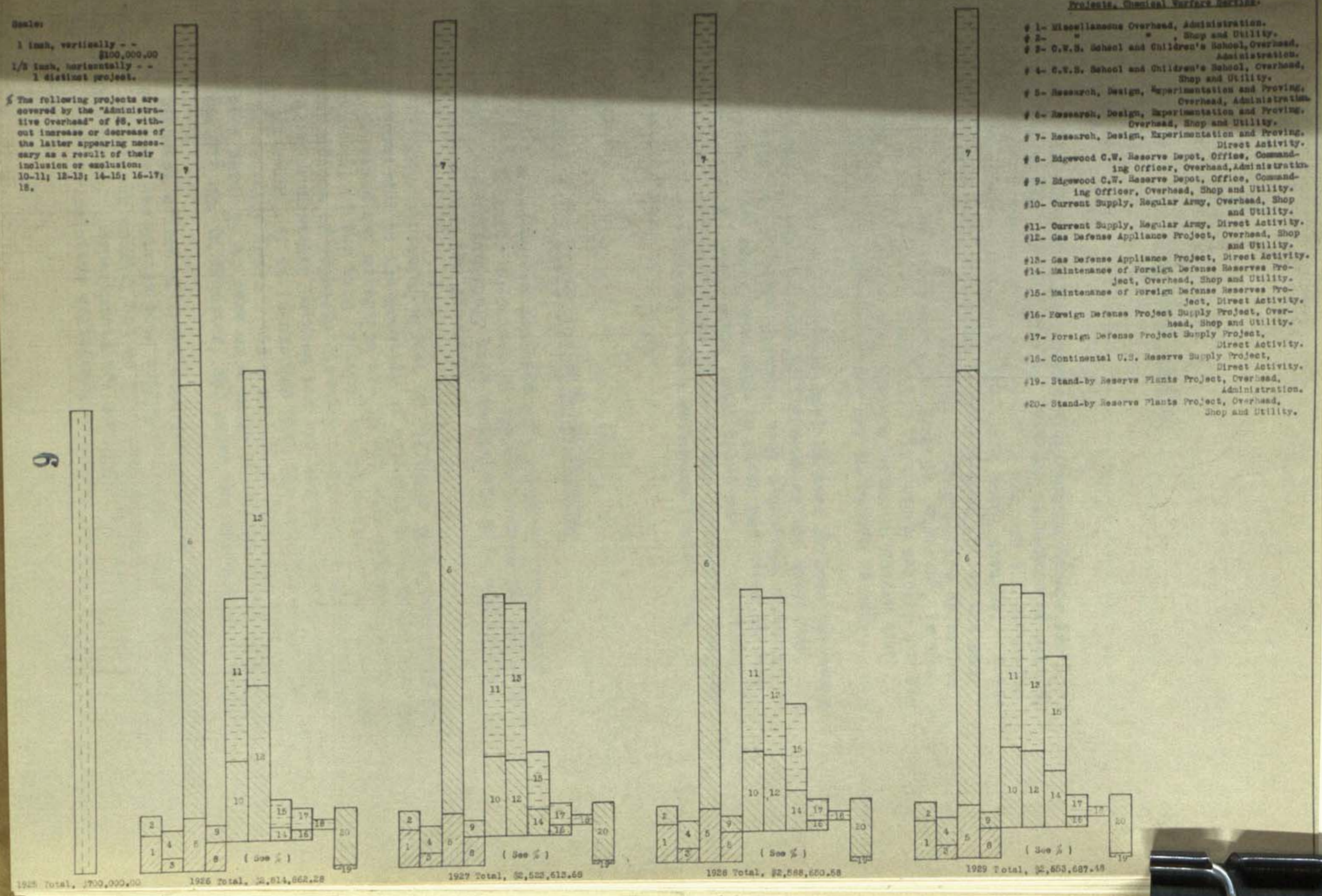

1925 Total, $700,000.00

1926 Total, $2,814,862.28

1927 Total, $2,522,613.68

1928 Total, $2,588,650.58

1929 Total, $2,653,687.48

Scale:

1 inch, vertically - - $100,000.00

1/3 inch, horizontally - - 1 distinct project.

§ The following projects are covered by the "Administrative Overhead" of #8, without increase or decrease of the latter appearing necessary as a result of their inclusion or exclusion: 10-11; 12-13; 14-15; 16-17; 18.

Projects, Chemical Warfare Service.

1- Miscellaneous Overhead, Administration.
2- " " , Shop and Utility.
3- C.W.S. School and Children's School, Overhead, Administration.
4- C.W.S. School and Children's School, Overhead, Shop and Utility.
5- Research, Design, Experimentation and Proving. Overhead, Administration.
6- Research, Design, Experimentation and Proving. Overhead, Shop and Utility.
7- Research, Design, Experimentation and Proving. Direct Activity.
8- Edgewood C.W. Reserve Depot, Office, Commanding Officer, Overhead, Administration.
9- Edgewood C.W. Reserve Depot, Office, Commanding Officer, Overhead, Shop and Utility.
#10- Current Supply, Regular Army, Overhead, Shop and Utility.
#11- Current Supply, Regular Army, Direct Activity.
#12- Gas Defense Appliance Project, Overhead, Shop and Utility.
#13- Gas Defense Appliance Project, Direct Activity.
#14- Maintenance of Foreign Defense Reserves Project, Overhead, Shop and Utility.
#15- Maintenance of Foreign Defense Reserves Project, Direct Activity.
#16- Foreign Defense Project Supply Project, Overhead, Shop and Utility.
#17- Foreign Defense Project Supply Project, Direct Activity.
#18- Continental U.S. Reserve Supply Project, Direct Activity.
#19- Stand-by Reserve Plants Project, Overhead, Administration.
#20- Stand-by Reserve Plants Project, Overhead, Shop and Utility.

Screening Smokes.

1. Introduction.

The masking of movements of attacking troops is probably as old as the art of warfare. Taking advantage of natural cover or darkness to surprise the enemy or to conceal the direction of an attack, was fundamental knowledge, even among savages. Artificial means of this kind date back to at least as far as the use of the wooden horse at the siege of Troy. Shakespeare describes artificial masking of the advance of an army in "Macbeth", in the advance through Birnam wood to Dunsinane, "Let every soldier hew him down a bough and bear't before him, thereby shall we shadow the numbers of our host, and make discovery err in report of us".

Smoke screens had been used to more or less advantage in minor naval operations at least as far back as the civil war, when blockade runners, to evade pursuit, took advantage of dense black smoke produced by using wood high in pitch and resin as fuel for the boilers, but no large scale intelligent use of screening smokes was made by military forces prior to the World War, when its importance, both as an offensive and a defensive factor, was definitely established.

2. Theoretical.

A. Definition and Properties of Smoke Screens.

A smoke screen consists of a cloud of very minute liquid or solid particles suspended in the air between the observer and the object in a sufficiently high concentration to completely obscure the object from the observer.

The screening effect of different smoke materials is probably proportional to the quantity of material between the eye and the object, provided the materials are in the same relative state of sub-division, and, if the term "volume" be substituted for "quantity", the screening effect is probably directly proportional to the total volume of all the particles between the eye and the object, regardless of the material, if it is assumed that the material is in the same state of sub-division*. As a matter of fact, the bulk of visible particles which go to make up a smoke cloud are of the order of from 10^{-4} to 10^{-5} cm. in diameter, and under the average field condi-

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*The blinding effect of light superimposed upon the eye by reflection from white clouds has always been supposed to make white smokes more effective than black smokes; but no quantitative data have been available on this point. Experiments are now under way which will determine quantitatively the relative efficiency of white, black, and intermediate colored smokes.

tions, the particles could be considered of the same degree of subdivision, without the probability of very great error.

It should be pointed out that the particles of material in the smoke cloud are usually different in chemical composition from the original compound in that they have combined with one or more of the constituents of the air. Thus in the case of phosphorus; phosphorus pentoxide is formed first and then phosphoric acid, or in other words, one pound of phosphorus combines with the oxygen and water vapor from the air to produce 3.16 pounds of phosphoris acid, and this phosphoric acid takes up still more water vapor to make a dilute solution of phosphoric acid in the form of minute droplets, which particles or droplets of dilute phosphoric acid are the actual screening material. Now the same number of the same sized droplets of a dilute solution of sulphuric acid, or of any other solution which produces a white, or nearly white, smoke*, will probably give obscurance equal to that given by the phosphoric acid droplets, but the initial amount of SO_3, or oleum, necessary for the production of sulphuric acid solution droplets, is greater than the initial amount of phosphorus required to produce the same bulk of phosphoric acid droplets.

It does not necessarily matter whether or not the particles absorb, reflect, or refract the light, so long as the object is screened, but it is believed that by far the greatest factor is the actual blocking of the light rays by the particles in line with the object.

It follows from the above that if there is a sufficient volume of smoke particles between the eye and the object to obscure the object, it makes practically no difference whether this volume of particles is highly concentrated in a comparatively small depth, or is spread out along the entire distance between the eye and the object. This has been borne out by experimental data, except that these data indicate that possibly greater obscurance is obtained by spreading the same volume of particles over a greater depth than by confining them in comparatively narrow limits.

In the case of practically all substances being considered for military smoke screens, the particles of actual smoke producing material are liquid. In the case of destroyer smoke screens used by the Navy, the actual smoke producing material is probably a combination of liquid particles of oil and moisture and solid particles of finely divided carbon.

*See note on preceding page.

B. Cloud Travel.

Inasmuch as smoke is carried with the wind, in order to screen any objective for a given period of time, it is necessary to continuously generate smoke from a source which may be either a point or a front, for the desired length of time. It naturally follows that it is necessary to understand the fundamental mathematics of smoke cloud travel. Observations of a great many clouds indicate that the resultant of the upper boundary of a smoke cloud is a straight line for at least the first 600 yards of its travel and the available data on longer clouds indicate that this straight line effect continues for practically the life of the cloud. It is true that there is a small initial rise in the first few yards, due to the initial thermal effect of smoke generation, but what evidence there is seems to prove that this effect is dissipated before the cloud has traveled a hundred yards. It is also true that the smoke cloud travels at approximately the same speed as the wind, and that the resultants of the lateral edges of the cloud may be considered straight lines. In other words, the cloud spreads more or less uniformly both upwards and sideways as it travels along. The main causes of this spread are the turbulence of the atmosphere and the character of the terrain. The turbulence of the atmosphere seems to be a function of the wind velocity and it has been shown that for any given wind velocity the rise per minute of the cloud is equal to a constant times the square root of the wind velocity in miles per hour, or $H = K \ V$. This constant is really made up ot two variables and a constant, the variables both being functions of the wind velocity; one, called the "gustiness" factpr, is obtained by dividing the average wind velocity by the maximum variation of the velocity and adding one, and the other is an arbitrary factor based on the changes in direction of the wind during the generation of the smoke cloud. If the wind is fairly steady both in velocity and direction, K is in the neighborhood of 10, and H in yards per minute $= 10 \ V$.

Outside of the general effect on K, the laterial spread is of importance only in the case of frontal screens. That is, screens in which the direction of the wind is either from the observer to the object, or vice versa. The lateral spread of the cloud at any given distance from the source, provided the wind is fairly uniform in direction, is approximately equal to twice the vertical rise, or the lateral spread in yards per minute $= 2H = 20 \ V$.

While so far there is no direct evidence to prove it, general observation seems to indicate that there is no gradual decrease of concentration towards the edge of a smoke cloud - rather, there is a sharp transition from a high concentration in the cloud, to a zero concentration of the smoke just outside the cloud. This is based on the fact that clouds in general show sharp, distinct edges and that a person near a cloud in a steady wind can be either in the cloud or just outside it. These, and other observations, seem to indicate that at a given distance from the source, the average concentration of smoke throughout a cloud generated from a single source is fairly uniform, regardless of whether the sample is taken near the edge, in the middle, or near the top of the cloud, provided, of course, that the distance from the source is the same. It is hoped in the near future to definitely prove or disprove this assumption by actual analysis of samples. It is evident from the foregoing that the decrease in concentration or density of a smoke cloud is proportional to the square of the distance or $C = \frac{K}{D^2}$, where C is the concentration, K, a constant, and D, the distance from the source in yards.

In addition to the concentration data desired above, it is hoped that analysis of samples of various smoke materials will give an exact idea of the amounts of water vapor that are taken up from the air by various smoke agents under varying conditions.

C. Properties of Ideal Smoke Producing Material.

The ideal agent for screening smokes should produce a maximum volume of actual screening material for a minimum original weight. Its characteristics should be such that the rate of smoke production could be readily controlled and little or no heat should be evolved in the formation of the final obscuring product. It should be non-toxic and non-irritating. It is obvious that it should be readily available and commercially economical, and should not be dangerous to handle.

If it were possible and practical, probably the ideal smoke screen would be one in which the cloud was manufactured by the catalytic change of the water vapor in the air to particulate droplets, especially if a mobile catalyst could be devised which could perform this phenomenon in any particularly desired area or locality. Failing this, if a method could be devised for the catalytic oxidation and synthesis of sulphur to minute droplets of a dilute solution of sulphuric acid, using the oxygen and water vapor of the air, it would probably be a more economical and practical smoke than white phosphorus.

The possible atomization of water into minute droplets of between 10^{-4} and 10^{-5} cm. in diameter by forcing through a nozzle or by any other means, might produce screens very economically and efficiently.

3. Methods of Smoke Dispersion.

A. Classes of Dispersion.

There are three general classes of dispersion, all of which are used to some extent in the production of screening smokes.

1. Explosive
2. Thermal
3. Pressure

In all of these methods of dispersion chemical or physical change is necessary before the final obscuring product is formed.

1. Explosive:

This method includes the dispersion of smoke by artillery shell, Stokes mortars, Livens projectors, hand and rifle grenades, and drop bombs. The smoke material is loaded in the projectile and dispersed by an explosive charge set off by means of a time or impact fuse.

2. Thermal:

In this class is included the production of smoke screens by means of candles, airplane exhaust, smoke boxes, the stacks of destroyers, etc. The general principle is that the original material is converted by means of heat into a form whereby it acts with the constituents of the air chemically and physically to produce the final obscuring product.

3. Pressure:

This method of smoke production includes the use of oleum, titanium tetrachloride, and tin tetrachloride, released from cylinders, the Navy smoke funnel, and similar appliances. In most cases the agent is placed in the cylinder under pressure and upon being released through an atomizing nozzle, passes through the vapor phase and is condensed in the form of small particles which react with the constituents of the air to a greater or less degree, depending upon the specific properties of the material. In the case of the Navy smoke funnel type, two materials are stored in cylinders under pressure and released simultaneously to combine chemically to form a compound which reacts with the constituents of the air to form the final obscuring product.

4. Present Materials considered for Screening Smokes.

The following are the main materials considered for smoke production, including a brief description of each:

A. White Phosphorus.

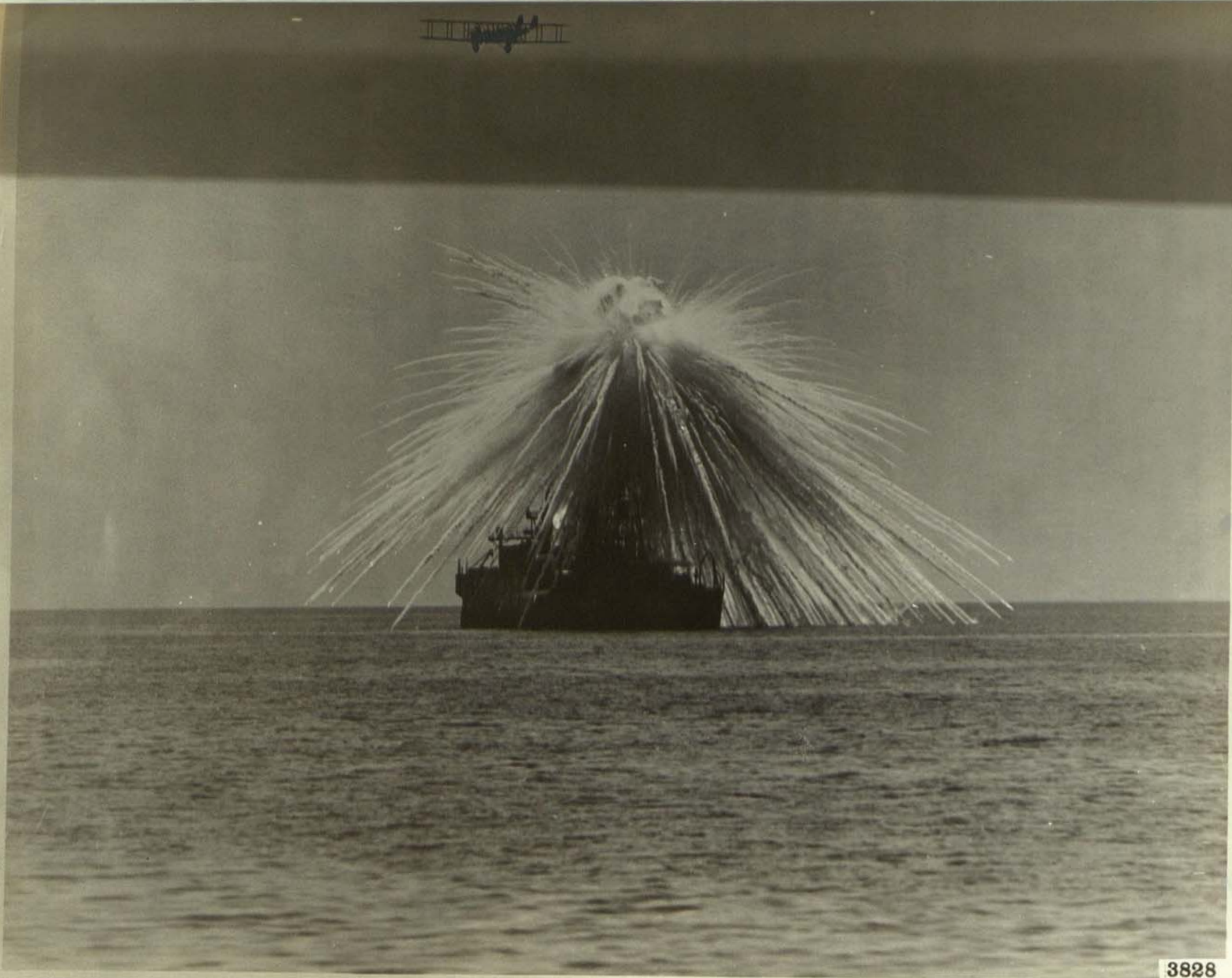
White phosphorus is a solid, melting at 44°C., and boiling at 290°C., which oxidizes upon contact with air at ordinary temperatures, or upon burning in air, to form phosphorus pentoxide, which takes up water vapor to form phosphoric acid, and this phosphoric acid absorbs still more water vapor from the air to form a dilute solution of phosphoric acid. One pound of phosphorus produces 3.16 lbs. of phosphoric acid. It is commercially available in large quantities and is comparatively reasonable in price. It is used in shell, Stokes bombs, grenades, drop bombs, and attempts are being made to use it in a candle. It is not corrosive when sealed in iron or steel containers, andthe smoke produced under field conditions is not injurious to men or equipment.

B. Sulphur Trioxide and Oleum.

Oleum is a solution of sulphur trioxide in sulphuric acid. Sulphur trioxide exists in two forms, the ordinary stable one which would be used for Chemical Warfare work being the beta modification which melts at 50°C. The sulphyr trioxide reacts with the water vapor in the air to produce fine droplets of sulphuric acid which combines with still more water vapor to form droplets of a dilute solution of sulphuric acid, which is the ultimate screening material. Neither sulphur trioxide nor oleum is harmful to man in ordinary concentrations, although they are somewhat irritating, and both are readily vailable on a large scale commercially, can be stored in iron or steel containers, and are economical in price. The only use for pure sulphur trioxide is in shell or bombs, but oleum can also be used as a spray in the exhaust of aeroplanes (although it is quite injurious to the present aeroplane fabric), in tanks and destroyers, and possibly may be used in aeroplane curtains.

C. Titanium Tetrachloride.

This material is a liquid boiling at 136°C., which, when released under pressure through a nozzle, forms a hydrate, $TiCl_4.5H_2O$, with the water vapor in the air, which, upon further reaction with moisture, breaks up into titanium hydroxide and hydrochloric acid. Under conditions of high humidity this hydrochloric acid condenses with water to form ninute droplets of dilute hydrochloric acid solution. Titanium tetrachloride smokes dissipate more quickly than either phosphorus or oleum smokes, even under conditions of high humidity, possibly due to the difference in vapor pressure of solutions of hydrochloric acid as compared to phosphoric acid or sulphuric acid. The smoke produced is not injurious to man under ordinary conditions, and is only slightly irritating. The liquid titanium tetrachloride is corrosive to fabrics and the human skin, and is highly injurious to untreated aeroplane fabric.



BURST OF PHOSPHORUS AIRPLANE DROP BOMBS

Titanium tetrachloride is not now available in large quantities commercially and is comparatively expensive. While the smoke is considerably inferior to white phosphorus or oleum in shell and bombs, it is used at present in the aeroplane exhaust smoke and the aeroplane curtain because it is the most desirable for that purpose.

D. Silicon Tetrachloride, Ammonia, and Water.

The proportions which give the best results are 2 of silicon tetrachloride to 1 of ammonia by weight. This smoke is generated from a smoke funnel. One cylinder is charged with silicon tetrachloride containing about 10% carbon dioxide under a maximum pressure of 550 pounds per square inch at 55°C. The other cylinder contains liquid ammonia. Upon discharging the cylinders the silicon tetrachloride and the ammonia react to form ammonium chloride, which probably takes up water vapor from the air to form the screening product. The smoke produced is harmless and stable. Ammonia is now commercially available in large quantities, and silicon tetrachloride could readily be obtained in large quantities if there were sufficient demand. It is used with the smoke funnel and smoke knapsack.

E. B.M. Mixture and H.C. Mixture.

The B.M. mixture was:

Zinc	35.4%
Carbon tetrachloride	41.6%
Ammonium chloride	5.4%
Sodium chlorate	9.3%
Magnesium carbonate	8.3%

This mixture proved unstable on storage and the present H.C. mixture was evolved. The main difference in this mixture is that solid hexachlorethane is used in place of the liquid carbon tetrachloride as the chlorine carrier. This mixture is stable on storage. The smoke produced is the product of the zinc chloride with the water vapor in the air. The product is harmless and is not irritating in low concentrations, but causes coughing and throat irritation as the concentration increases. The mixture is safe and easily handled, but the cost is comparatively high, although either the H.C. or the B.M. mixture could be supplied on a large scale basis. In case of war, when long time storage would not be necessary, the B.M. mixture might prove more economical.

These mixtures are used in candles, the 4" Stokes mortar shell, burning type, and the H.C. grenades.

F. Crude Oil.

A dense, dark smoke screen can be set up by destroyers by spraying oil below the stack with an insufficient supply of air. The smoke itself probably consists of particles of carbon and some tarry and oily matter, augmented by films of condensed water vapor. This method of smoke production cuts down the speed of the destroyer and fouls the boiler tubes, but it is probably one of the most economical methods for the production of naval screens by destroyers. The smoke is harmless, but soils everything with which it comes in contact. The smoke producing material is always available, being part of the fuel supply necessary for the propulsion of the vessel. At the present time no feasible method of using crude oil screens on land has been found, and its use is limited to large scale naval screens.

G. Other Materials.

The above materials are the main sources of smoke production now being considered. The disadvantages of such materials as tin tetrachloride, chlor sulphonic acid, ammonia, and hydrochloric acid, the British Type S mixture, etc., are such that no real use will be made of them unless some new development in the method of their use be discovered.

H. Summary.

Crude oil, oleum, and phosphorus will give maximum obscuring power at minimum cost, in the order named. For obscuring power for a given weight of material, the order is just reversed, and when it is remembered that the use of smoke at the front depends upon the total cost of the weapon, its use, its efficiency, its transportability and other factors, as well as the original cost of the smoke agent, it is likely that phosphorus, sulphur trioxide or oleum, and crude oil will be the three smoke agents of general use, except in the case of aeroplane distribution.

5. Tactical Use of Smoke.

A. General.

According to both the British and U.S. Gas Manuals, smoke screens may be employed with one or more of the following objects in view:

1. 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.

2. As a feint to draw the 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.

3. 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.

4. In flat or open country to conceal formation of guns and troops, and to screen roads, forming up places, and lines of advance. To blind the flashes of a battery in action, and to hamper observation from the air.

5. 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 aeroplanes or kite balloon observation.

In all of these cases except 3, three screen should be totally obscuring. When it is desired to simulate gas, it is much better to have just sufficient smoke to be distinctly visible to the enemy as it drifts down upon him. It should be mentioned, however, that smoke is an aid to advancing troops, even when not totally obscuring, as it cuts down the visibility of the target and so renders enemy rifle fire less effective.

Briefly stated, the essentials of a smoke screen are that it must give the desired obscuring effect for the total front or object to be screened from all enemy points of observation for the desired duration of the screen, with minimum impedance to one's own observation, artillery fire, and general communications.

This necessitates a thorough knowledge of all phases of the situation by the gas officer, who must determine whether these conditions can be met by one of the material on hand under the prevailing weather conditions. Knowing the kind and quantity of smoke agents on hand, and the weather conditions, he should be able to determine how large and how effective a screen can be established at a given locality, and how long it can be maintained. It naturally follows that he must make the choice of method for establishing and maintaining the screen and according to the situation, decide whether artillery, Stokes, Livens, candles, aeroplanes, or other devices should be used.

B. Aeroplane Possibilities.

The development of the aeroplane exhaust and curtain smokes since the war has opened up new possibilities in putting down much more effective screens at points that were hitherto more or less inaccessible for good screens and a study of aeroplane smoke tactics constitutes a field in itself.

C. Naval Possibilities.

Especially is this so in Naval warfare, where previously screens had to be maintained by the use of an excessive amount of smoke for a very long period to enable destroyers to attack successfully. By use of aeroplanes, effective and economical screens can be established for any desired sea area, and the screen can be originated comparatively close to the target or object instead of five miles or more away, as was previously necessary. In addition to screening torpedo attacks by destroyers, these screens can be used to block out part of the enemy fleet, enabling a concentration of fire on almost any desired number of enemy ships at a cost of very little material, and the probability of loss of aeroplanes would be much less than the probability of loss of one or more destroyers engaged in setting up such a screen.

RESEARCH ACTIVITIES AT EDGEWOOD ARSENAL

The research carried on at Edgewood Arsenal during the past quarter has been concerned with the following studies and investigations:

Development of Chemical Agents useful in Gas Warfare.
Studies of the chemical properties of standard chemical warfare agents and of improvement in methods of manufacture.

Investigations of new compounds.

Studies of the theory of toxicity.

Development of Offensive Equipment useful in Gas Warfare.
Development of projectors and projectiles for both land and air forces.

Studies of Materials and Methods for laying down Smoke Screens.
Investigation of smoke candles and smoke candle mixtures.

Smoke Generation by Airplane.
 Airplane Exhaust Smoke.
 Smoke Curtains.

Surveillance tests to determine the stability of Chemical Warfare Munitions.

Development of the use of Chemical Warfare Agents in the Field and at Sea.

Studies of the travel of Smoke Clouds.

Development of Defensive Equipment and Supplies.
Gas Mask Investigations.
 Filters
 Absorbents
 Storage Tests

Effect of Chemical Warfare Agents on Chemical Plant Equipment.

Preparation of Specifications

Investigations of War Gases as Insecticides.

Ship Bottom Paint Investigation

Studies of the Curative Value of Toxic Agents

The foregoing list of investigations shows the character of the research being conducted at Edgewood. Many of these investigations, of course, require a considerable periodof time for the attainment of positive results; so that there is often little to report for many of the problems at the end of a three month period. There are, however, quite a number of investigations which have reported progress of considerable interest. The results of these investigations are summarized in the following paragraphs.

Fundamental Study of Screening Smokes

In connection with the fundamental study of screening smokes, experimental work has been undertaken to establish the relation between the obscuring power of smokes when dispersed in a closed experimental chamber to the obscuring power of smokes when dispersed in the field. From the results obtained so far, it has been found that the empirical factor for converting ounces per thousand square feet necessary for obscuring in the smoke chamber to the corresponding figure for out of doors is about 0.4. This factor has been found to hold good for both B.M. and W.P. smokes. While it is desirable to check this factor by the use of a third smoke, preferably a colored smoke, it is considered justifiable to accept this factor tentatively and make chamber runs on a number of different kinds of smokes during which the effects of different methods of generation may also be tested. Some work has, therefore, been carried out on the design of a suitable generator for a thermal generation of smoke clouds.

Generation of Sulphur Trioxide in Place

An attempt has been made to develop a smoke generator which evolves sulphur trioxide (an excellent screening smoke material) efficiently, when phosphorus penta sulphide is burned or when phosphorus and sulphur are burned together. It was thought sulphur dioxide formed during the burning of sulphur might be converted to sulphur trioxide by the catalytic action of phosphorus pentoxide in the presence of air. It was found, however, that for high concentrations of sulphur dioxide, such as would be required for an effective smoke generator, the percentage conversion of sulphur trioxide was very low. This makes it appear that the generation of sulphur trioxide in place is not practical and work on this project has been suspended for the time being.

Construction of Smoke Apparatus for Airplanes

The exhaust manifolds were removed from a D.H. plane in order to weld the supplementary exhaust pipe in place as an additional safeguard against the escape of F.M. fumes during operation, which endangers both the pilot and operator.

The F.M. feed lines leading to the exhaust amnifolds of the plane were also removed and cleared of obstructions resulting from the accumulation of the hydrolysis products of F.M.

Safety valves were placed in the pressure gauge lines of both the Martin Bomber and the D.H. in order to minimize the danger resulting from a bursted gauge. The gauge traps were also replaced, and were filled with chlorinated paraffin instead of the oil and mercury as formerly used.

The valves on the carbon dioxide cylinders were overhauled in an effort to bring about a more rapid discharge of CO_2. The orifices of the valves were increased from 1/8 inch to 5/16 inch, and the valve seat changed from flat to taper.

A conference was held at McCook Field between a representative of the Chemical Warfare Service, and the Air Service for the purpose of establishing a better understanding and closer relationship between the Engineering Division of the Air Service, and the Chemical Warfare Service. As a result of this trip, an especially constructed tail assembly for a D.H. plane was promised and also especially constructed manifolds if required.

Navy Lachrymator Drop Bomb

This bomb which is loaded with a lachrymator, smokeless powder and a stabilizer is a floating bomb of the burning type to be used for Navy training purposes.

Tests of this bomb were carried out in a barrel (approximately 65 gallons capacity) of water at 16°C. A comparison of these tests with those conducted in the river water at 0°C. during Februrary showed that there was very little difference in burning time between summer and winter conditions. The burning time for full volume being within a few seconds after ignition to about 12 minutes.

It is considered that this bomb is now in its final stage of completion.

Surveillance on Chemical Warfare Munitions.

Since Chemical Warfare munitions have been in use only since the recent war, no considerable experiende has been gained as to their stability on storage or their effectiveness on use after such storage. It is, therefore, necessary to conduct extended surveillance tests to determine the characteristics of Chemical Warfare munitions after standing and to eventually formulate basic principles for the safe and effective mixing of Chemical Warfare agents with other materials.

Lachrymatory grenades have been held in storage at 50°C, and 60°C. to determine how long they may be so held before becoming ineffective.

50°C. Test.

At the end of five months (May 12, 1924) one grenade was taken from the lot being held at 50°C. and fired. It functioned satisfactorily giving a burning time of 40 seconds.

60°C. Test.

It was found on examination of the lot being held at 60°C. that practically all of the grenades in this lot had deteriorated to the point where the mixes would not ignite. All of the grenades gave off a distinct acid odor when opened. In many cases the cork stoppers had been badly attacked by the acid. The results of 18 grenades when fired were as follows:

a. Only two grenades ignited and burned. The first burned for two minutes; the second for three minutes ten seconds. In both cases the lachrymatory power of the cloud was very poor.

b. In eleven grenades the starter functioned satisfactorily but the mis failed to ignite.

c. In five cases the starter failed to function.

d. New starter was then poured on the sixteen grenades that failed. In every case the new starter functioned properly but the mix failed to ignite.

These tests are extremly severe and in spite of the results obtained this grenade is satisfactory for issue.

Lachrymatory 4" Stokes Mortar Shell

One shell kept at room temperature twenty-one months was fired from the gun. It failed to function through deterioration of the starter. Subsequent examination of the starter showed it to be insentive to flame, probably due to contamination with the lachrymator. The starter will be replaced and the shell tested statically at an early date.

H. C. Smoke 4 " Stokes Mortar Shell

One shell kept at room temperature one and one half years was fired from the gun and functioned normally.

SPECIFICATIONS

Specifications for all chemical wafare material was being prepared, 342 having been written of the total of 542.

MEDICAL RESEARCH

Among the various researches being carried on by the Medical Division, the experimentation undertaken to determine the curative value of various toxics has resulted in exceptionally important developments and has opened up a large number of exceedingly interesting possibilities. Among the developments to date which have resulted in positive results is the use of chlorine as a therapeutic agent in respiratory diseases, both for human beings and animals. A brief statement showing the effectiveness of this treatment is given here.

The Use of Chlorine as a Therapeutic Agent in Certain Respiratory Diseases

Employees in plants producing or using chlorine have long been supposed to be relatively free from respiratory diseases. This was emphasized during the war when the chlorine plant at Edgewood Arsenal was produding to capacity, especially with reference to the epidemic of influenza. It was stated that no cases occurred among its operatives while every other division on the Arsenal had its full quota. During the rush of work at that time this aroused only passing comment but, with the establishment of the Medical Research Division in 1922, interest in the possible therapeutic utility of war gases led to the beginnings of real work along these lines.

This work was guided by the physiological concentration limits for chlorine air mixture, which had already been established. These are as follows:

	Mg. per liter
Odor plainly perceived	0.01
Irritation of throat in 3 minutes	0.048
Toleration for a few seconds	0.3
Lethal, dogs, 30 minutes	3.0

From these data it will be seen that the concentrations which can be easily breathed are far below the danger point. With these data as a basis it was then necessary to ascertain the bactericidal properties of these low concentrations before human experimentation was justifiable.

To this end the concentration of chlorine in air required to kill various organisms growing in various cultures was studied. As a result of extensive experimentation of this nature and subsequent treatment of volunteers having colds and other respiratory diseases it was found that concentrations of chlorine of .013 to .015 mg./l. gave satisfactory bactericidal action and could be readily breathed without discomfort.

In treating cases at Edgewood Arsenal only such patients as were suffering from conditions in which the causal organisms are located on the surface of the respiratory passages were accepted; no selection was made as to the stage of the disease, but all patients who asked for treatment were taken and they steadily increased in number as time demonstrated the efficacy of the method. The majority were cases of simple coryza. In order of frequency there followed acute bronchitis, acute laryngitis and pharyngitis, chronic rhinitis; chronic bronchitis, influenza, whooping cough, and chronic laryngitis. Tables I and II show the number of cases of each disease treated, and the results obtained at Edgewood Arsenal and in the Office of the Chief of Chemical Warfare Service, respectively.

TABLE I

CASES TREATED AT EDGEWOOD ARSENAL

Total cases treated. Number of cured, improved and not improved with percent of each.

Diagnosis	Number of cases	Cured		Improved		No change	
		No.	%	No.	%	No.	%
Coryza	388	288	74.2	91	23.5	9	2.3
Ac. Laryngitis and Pharyngitis	127	99	78.0	24	19.0	4	3.1
Acute Bronchitis	241	192	80.0	47	19.5	2	0.5
Chronic rhinitis	106	33	31.1	41	38.6	32	30.2
Chronic bronchitis	47	34	72.13	12	25.5	1	2.1
Chronic laryngitis	2	2	100.0				
Whooping cough	9	8	88.8	1	11.1		
Influenza	11	9	81.8	2	18.1		
Totals	931	665	71.4	218	23.4	48	5.1

TABLE II

CASES TREATED IN THE CHAMBER IN THE OFFICE OF CHIEF OF CHEMICAL WARFARE SERVICE

Showing cases treated, number treated, cured, improved, and not improved, with percentages in each case.

Diagnosis	Number cases	No. treatments	Cured		Improved		Not improved		Unknown
			No.	%	No.	%	No.	%	
Asthma	26	134	2	9	8	34	13	57	3
Acute Bronchitis	118	380	54	52	45	42	7	6	12
Chron. Bronchitis	50	250	21	47	17	34	9	19	3
Bronchiectasis	2	5							
Catarrh	56	201	1	2	31	71	11	27	13
Coryza	465	862	234	55	170	40	19	5	42
Chronic colds	51	173	20	49	14	34	7	17	10
Hay Fever	16	38	0		2	13	13	87	1
Laryngitis	19	44	3	25	8	66	1	9	7
Pharyngitis	11	34	1	11	7	78	1	11	1
Psoriasis	2	5	2						
Chronic rhinitis	22	90	3	13	8	39	10	48	1
Sinus Involvement	17	63			10	68	5	34	2
Whooping cough	45	231	19	47	19	47	2	6	5
Totals	900	2510	360		369		100		101

While the results of the treatment obtained in the chamber in the Office of the Chief of Chemical Warfare Service are not so flattering as those published in Table I, yet considering the nature of the cases, the chronicity of the diseases and the fact that time allowanse prevented any individual treatments, it is believed these results are highly satisfactory.

Accurate records not having been kept of patients treated in the chamber at the Capitol Building and elsewhere of which there were over eleven hundred, these are not included.

In conducting the work in Washington, no attempt was made to make physical examinations, nor were any laboratory tests utilized. In all cases the patients came with their own diagnosis; the results of treatment were obtained from them.

It was early recognized that the success of the treatment depended largely upon three important factors, as follows:

First: The introduction of a sufficient amount of chlorine gas of a concentration capable of producing therapeutic results.

Second: The maintaining of this concentration constant throughout the period of treatment.

Third: Each period of treatment to consume at least one hour.

A portable apparatus releasing gaseous chlorine in suitable amounts from small cylinders through a measuring device was devised by the Chemical Warfare Service and is a modification of an apparatus used by this Service during the war for the purpose of administering oxygen to those severely affected with lung irritating gases. This equipment has been used with marked success in administering chlorine gas as follows:

(a) In the chambers established in the Capitol Building in Washington where many Senators, Representatives and other Government officials were treated successfully for colds and other respiratory diseases.

(b) In the Office of the Attending Surgeon, Washington, where several hundred patients were treated, including the President of the United States.

(c) In the Office of the Chief of Chemical Warfare Service, where over a thousand persons have received treatment for respiratory diseases of different kinds.

(d) In private homes where the treatment was administered to those not able to visit the chambers established for the purpose of giving the treatment.

The apparatus is so constructed that the amount of chlorine gas to be administered can be seen before it is permitted to be released. The gas is ejected continuously and automatically in suitable amounts through a glass tube leading into the chamber thus assuring a constant and safe concentration throughout the entire period of treatment. The apparatus is simple in construction, safe, durable, easy to operate, inexpensive, and readily transportable. By using pure chlorine gas obtained from the cylinders, it is a unit in itself and independent of any outside influences.

When in use, the apparatus is placed on a shelf on the outside of the chamber, and the gas permitted to seep into the interior slowly, continuously and automatically through a 5/16 inch glass tube, one end of which is attached to the apparatus, the other or free end within the chamber three feet above the floor and directly over a ten inch revolving fan where the gas is taken up by the draft produced by the fan and distributed equally throughout the chamber.

The use of this apparatus to introduce chlorine gas has proven efficacious and satisfactory in every respect. By placing the apparatus on the outside of the chamber it is not necessary for the operator to enter, while, by the continuous and automatic distribution of the gas, its constancy is assured at all times. Likewise, its regulation consumes little time on the part of the operator.

Conclusions

1. Inhalations of chlorine at a concentration of approximately .015 mg. per liter for one or more hours have a distinctly curative value for common colds, influenza, whooping cough, and other respiratory diseases in which the infecting organisms are located on the surface of the mucous membranes of the respiratory passages.

2. The application of this method to army needs, especially with regard to camp epidemics, is obvious.

3. The outlook for control of meningitis, diptheria, and influenza epidemics and the treatment of carriers by this method is bright.

4. It is very important that the gas be given in sufficient strength. If too weak, it will not produce the desired effects. There is practically no danger whatever in any reasonable dose.

Electrical apparatuses are on the market for generating the chlorine directly by connecting the apparatus with the electric light system. No such apparatus has been tested in this office, or, so far as is known, by anyone in the Service.

The Chemical Warfare Service makes no direct recommendation of any particular apparatus; in fact, any apparatus that will furnish a known quantity of gas and will allow a steady flow into the chamber will produce results.

The Treatment of Equine Influenza with Chlorine

During the month of February, 1924, there occurred an outbreak of influenza among the horses at Fort Hoyle, Maryland, which was effectively broken up by treating the animals with chlorine gas.

The initial cases (2) were discovered on February 8th, but were considered to be of sporadic character until February 11th, when eleven others were found with symptoms of influenza. On February 14th, a total of forty-one cases were on the register. At this point treatment with chlorine gas was commenced and on the following day the total of animals on the register had reached forty-five. On this date, however, twenty-one of the cases of the preceding day had apparently recovered following a single treatment with the gas. None of these cases displayed symptoms for a period of longer than five days prior to apparent recovery, many for lesser periods. A second treatment dropped the total of animals of this type from twenty-one to seven. These seven received further treatment and within a period of twelve days from the date of original discovery of cases other than the first two, no cases whatsoever remained.

Recovery without intervention following the course of the disease would in no case, we believe, have occurred as rapidly; nor can the uniform results obtained, as manifested by the improved condition of the animals and the prompt disappearance of symptoms, be explained in any other manner than as being due to the effect of the treatment.

BOOKS AND PUBLICATIONS

The following are among the books and pamphlets in the Technical Reference Library, Office of the Chief of Chemical Warfare Service. These publications are available for use of all officers and employees of the Chemical Warfare Service, and may be loaned to any Chemical Warfare Officer outside of Washington upon written request from him. The conditions under which these loans are made outside of the Chemical Warfare Service Office are as follows:

Written request should be made by the officer desiring the use of any publication, giving the class number, title and name of author. Upon receipt of this information, the publication will be loaned for a period of two weeks. A card is sent with the publication, which must be signed and returned to the library immediately upon receipt. When the publication is returned to the library the receipt will be returned to the borrower. No publications can be withheld from the library for a period greater than two weeks without special permission.

Class No.	Name of Publication
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973 C 654	Building the Nation, Coffin
543.39 J 578	Catalysis and its Industrial Applications, Jobling
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540.2 H 116	Chemical Reactions and their Equations, Hack
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543.1 Sh 55	Chemistry of Food and Nutrition, Sherman
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377 G 671	Dominant Ideas, Gore
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341.1 Sa 99	Experiments in International Administration Sayre

Class No.	Name of Publication
662.2 B 264	Explosives, Matches and Pyrotechny, Barnett
355 H 932	Fleets at War, Hurd
941.3	Frontier of Germany, Sara Wambaugh Menace of Migratory Peoples, Dr. Edw. A. Ross. Two Practical Steps to the Restoration of Our Commerce & World Peace - A Survey of Present Day Europe, E. A. Feling.
551.93 R 148	Gases of the Atmosphere, Ramsey
662.2 D 927	Handbook of Explosives, Du Pont de Nemours
	High Explosives, Colver
355 Ad 53	Historical Backgrounds of the Great War Adkins
370 P 166	History of Education, Painter
355 B 851	History of the War, Vol. 1 to 16 Nelson
355 S 156	History of the World War, Vol. II, Simonds
355 H 165	History of World War (10 Vols) Literary Digest
546.3 D 454	Intermetallic Compounds, Desch
920 H 384 Vol. 1 missing	Life and Letters of Walter H. Page, 2 Vols.
551.5 M 599	Meterology, Milham
541.341 F 493	Osmotice Pressure, Findlay
533 H 884	Physics of the Air, Humphreys

Class No.	Name of Publication
541.9 L 236	Physikalisch-Chemische Tabellen, Landolt, Bornstein, Roth
	Practical Shell Forging, Bower
815 W 699	President Wilson's State Papers and Addresses, Wilson
327 M 784	Principles of American Diplomacy, Moore
621.3 L 438	Principles of Alternating Current Machinery, Lawrence
541.37 A 151	Principles of Applied Electro-Chemistry, Allmand
667.2 F 86	Principles of Dyeing, Fraps
370.15 J 237	Psychology (briefer course) James
547 Ar 69	Quantitative Laws in Biological Chemistry, Sante Arrhenius
297 St 64	Rising Tide of Color, The
947 R 122	Russia, its Trade and Commerce, Raffalovich
541.3411 G 862	Short Introduction to the Theory of Electrolytic Dissociation, Gregory
535.84 B 219	Spectroscopy, Baly
541.9 Y 87	Stoichiometry, Young
355 So 49	Strategic Camouflage - S.J.Solomon
541.9 M 1	Tables Annuelles, International de Constants, 4 vols.
541.9 K 182	Tables of Chemical and Physical Constants, Kaye and Laby
355 G SS	Tactical Principles and Decisions, The School of the Line, Vol. II

Class No.	Name of Publication
609 W 858	Teaching of Science, The, Woodhull
665.4 H 186	Technical Examination of Crude Petroleum Products and Natural Gases. 1st Edition, 2nd Impression, Hamor and Padgett
541.37 L 492	Textbook of Electro-Chemistry, LeBlanc
546 F-L 723	Textbook of Inorganic Chemistry, Vol. IV, "Aluminum and its Congeners including the Rare Earth Metals," Little
546 F-F 915	Textbook of Inorganic Chemistry, VOL. IX, "Cobalt, Nickel and the Elements of the Platinum Group", Frient
530 D 843	Textbook of Physics, Duff
540 T 454	Textbooks on Science (Chemical Philosophy), Tilden
536.7 P 258	Textbook of Thermodynamics, A Partington
541.36 T 381	Thermochemistry, Thomsen
621.3 St 36	Theoretical Elements of Elec. Eng. Steinmetz
541.3411 J 717	Theory of Electrolytic Dissociation, Jones
541.39 F 915	Theory of Valency, The Friend
973 D 929	Uncle Sam's Modern Miracles, Du Puy
973 C 777	United States as a World Power, Coolidge
355 M 787	United States Official Pictures of World War 1 set

Class No.	Name of Publication.
623.4 C 725	United States Rifle and Machine Guns, Colvin and Viall
	Viscosity of Liquids, Dunstan
355 C 691	War Against War, The Collins
341.1 B 446	War and Private Property, Bentwich
662 Or 2	War Department Document 947, Military Explosives
355 W 699	Woodrow Wilson and the War, Gale
355 C 475	World Crisis, 2 Vols. 1 set
355 Sp 31	World War Issues and Ideals, Speare and Norris

LANTERN SLIDES

Lantern slides are in the Technical Division, Office of the Chief of Chemical Warfare Service, and are available for loan on request. Among these are the following.

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Edgewood Arsenal: Airplane view showing Classified Magazines.	2930
Edgewood Arsenal: Airplane view of Headquarters.	2932
Edgewood Arsenal: Airplane view showing Mfg. Area.	2929
Edgewood Arsenal: Airplane view showing south edge Mfg. Area; Barracks area and Bachelor's Quarters.	2931
Edgewood Arsenal: Alcohol Storage Tanks.	2866
Edgewood Arsenal: Bush River Dock.	2852
Edgewood Arsenal: Bush River Power Plant.	2856
Edgewood Arsenal: Chemical Laboratory.	2780
Edgewood Arsenal; Chemical Laboratory, Interior.	60219
Edgewood Arsenal: Chemical Laboratory, Interior.	60223
Edgewood Arsenal: Chlorine Mfg. Plant.	2983
Edgewood Arsenal: Chloropicrin Plant Interior.	60473
Edgewood Arsenal: Carbon Dioxide Generating Bldg. and scrubber towers of Phosgene Plant.	2711

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Edgewood Arsenal: Drop Bomb Tower.	3179
Edgewood Arsenal: Enlisted Men's Barracks.	3173
Edgewood Arsenal: Entrance to Arsenal.	3145
Edgewood Arsenal: Exhaust Purification Towers and Sulphur Chloride Plant.	2714
Edgewood Arsenal: Enlisted Men's Barracks.	3174
Edgewood Arsenal: Gas Mask Mfg. Plant.	3124
Edgewood Arsenal: General View of Mfg. Area near Phosgene Plant.	2713
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Extermination of Rats. Releasing gas in rat holes in walls.	037-D
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Gas Mask. Interior of 1919 Model.	3008,3009
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Gas Mask. R.F.K.	1501 NYC
Gas Mask. K.T. Adjusted on so ldi er withpack	1505 NYC
Gas Mask. K.T. Front view, Besse eye-piece.	1509
Gas Mask. K.T. $\frac{3}{4}$ front view.	1511 NYC
Gas Mask. Negro Type.	1529 NYC
Gas Mask. K.T.M.	1530 NYC

The above list will be continued in future issues of this digest.

THE ARMY WAR COLLEGE
APR 18 1924
106-14
UNITED STATES ARMY

April 14, 1924.

MEMORANDUM for Commandant, Army War College, Washington Barracks, D.C.

1. There is enclosed herewith copy of the first number of Digest of Activities of the Chemical Warfare Service which it is planned to issue every three months. In case the information contained is not of particular interest to you, it is requested that you inform the office of the Chief of Chemical Warfare Service, in order that we may make the issue as small as possible.

For the Chief of Chemical Warfare Service:

~~CONFIDENTIAL~~ UNCLASSIFIED

C. E. BRIGHAM,
Lt. Col., Chemical Warfare Service,
Executive Officer.

Encl (1)
Digest

Rec'd. The Army War College APR 17 1924

AWC 106-14 1st Ind. N-aem

The Army War College, Washington Barracks, D.C., April 21, 1924. -- To Chief of Chemical Warfare Service.

The above mentioned Digest is of interest to The Army War College.

For the Commandant:

HENRY GIBBINS,
Executive Officer.

~~CONFIDENTIAL~~

UNCLASSIFIED

DIGEST OF ACTIVITIES

of the

CHEMICAL WARFARE SERVICE

March 31, 1924

Technical Division
Chemical Warfare Service
Washington, D.C.

DIGEST OF ACTIVITIES
of the
CHEMICAL WARFARE SERVICE

March 31, 1924.

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VOLUME I. NUMBER I.

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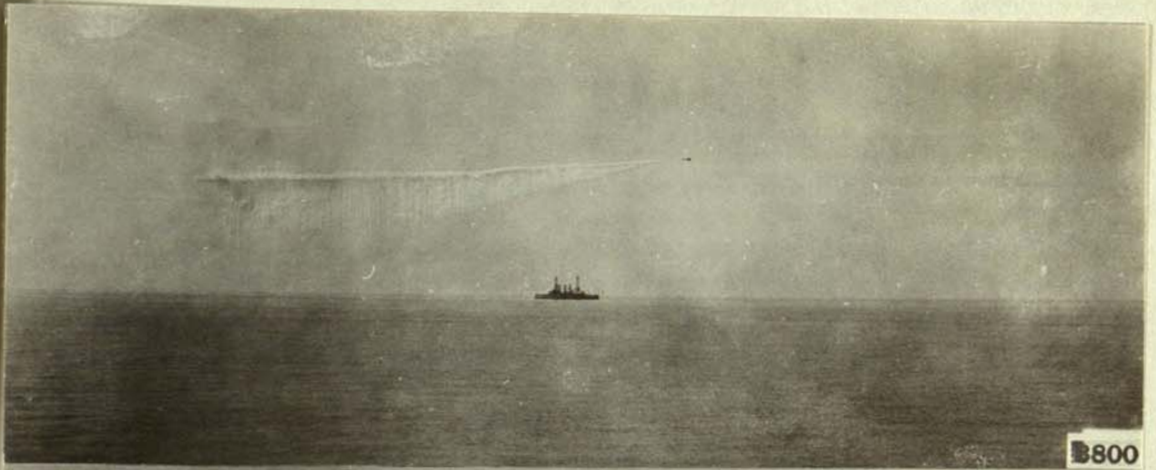

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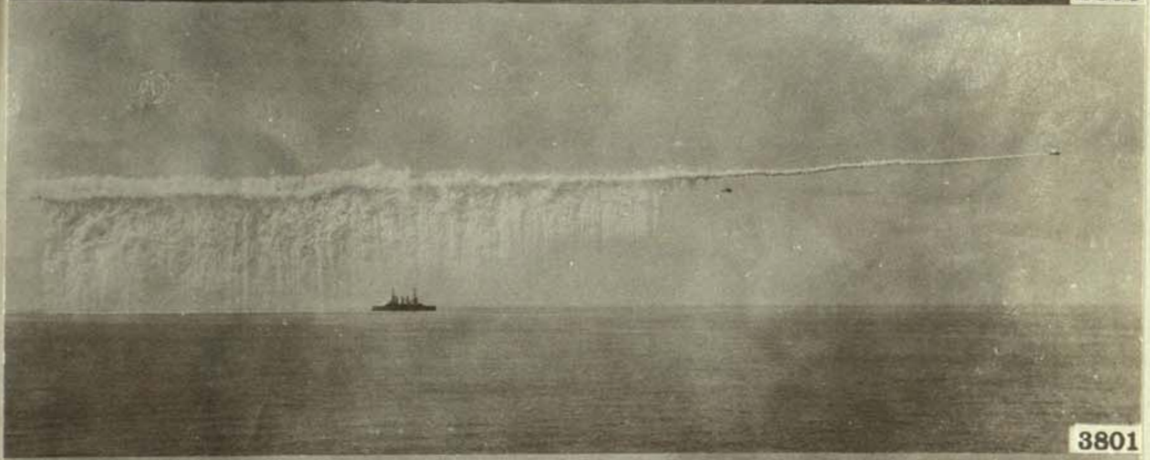

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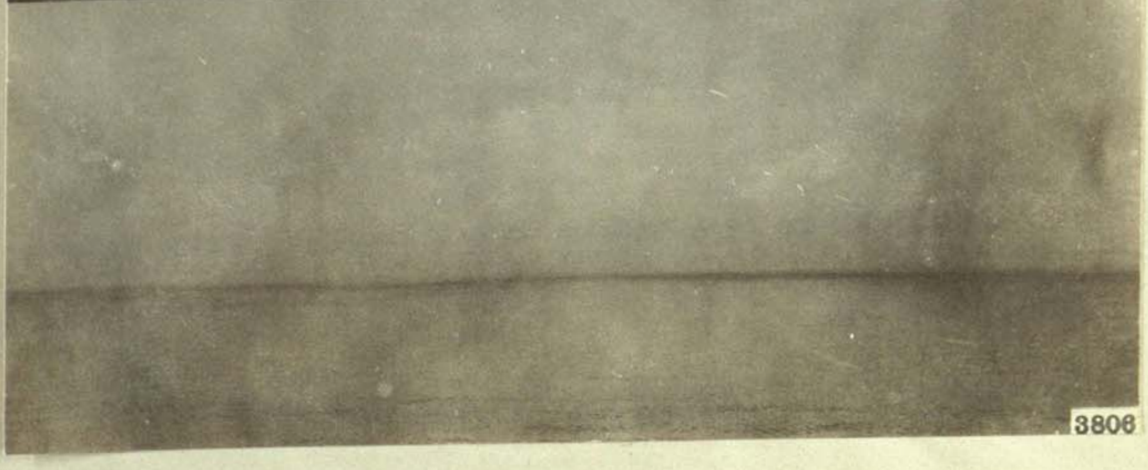


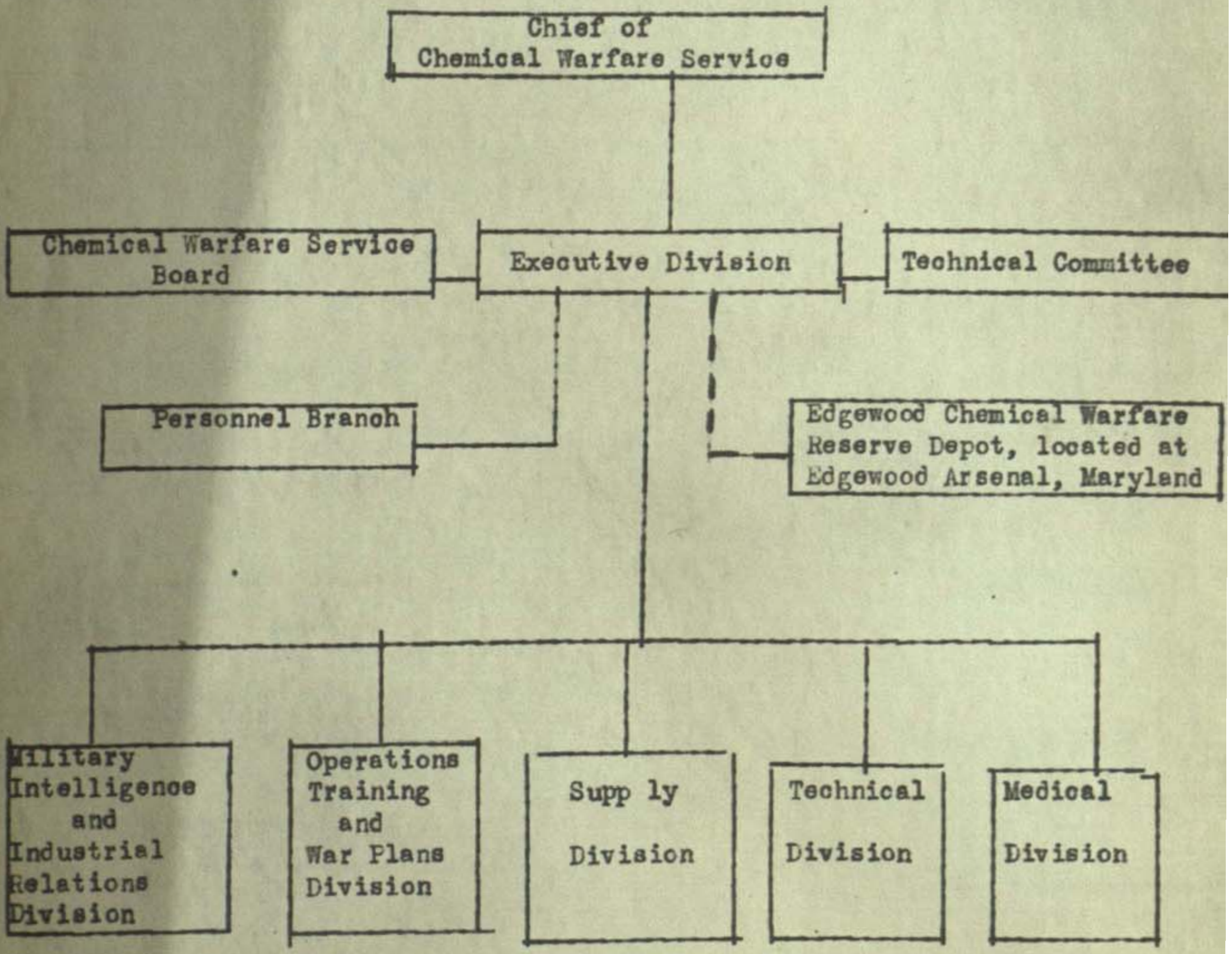
3806

Smoke Curtain laid by aeroplane.
Last picture shows effect 15 minutes

EXECUTIVE ORGANIZATION CHART

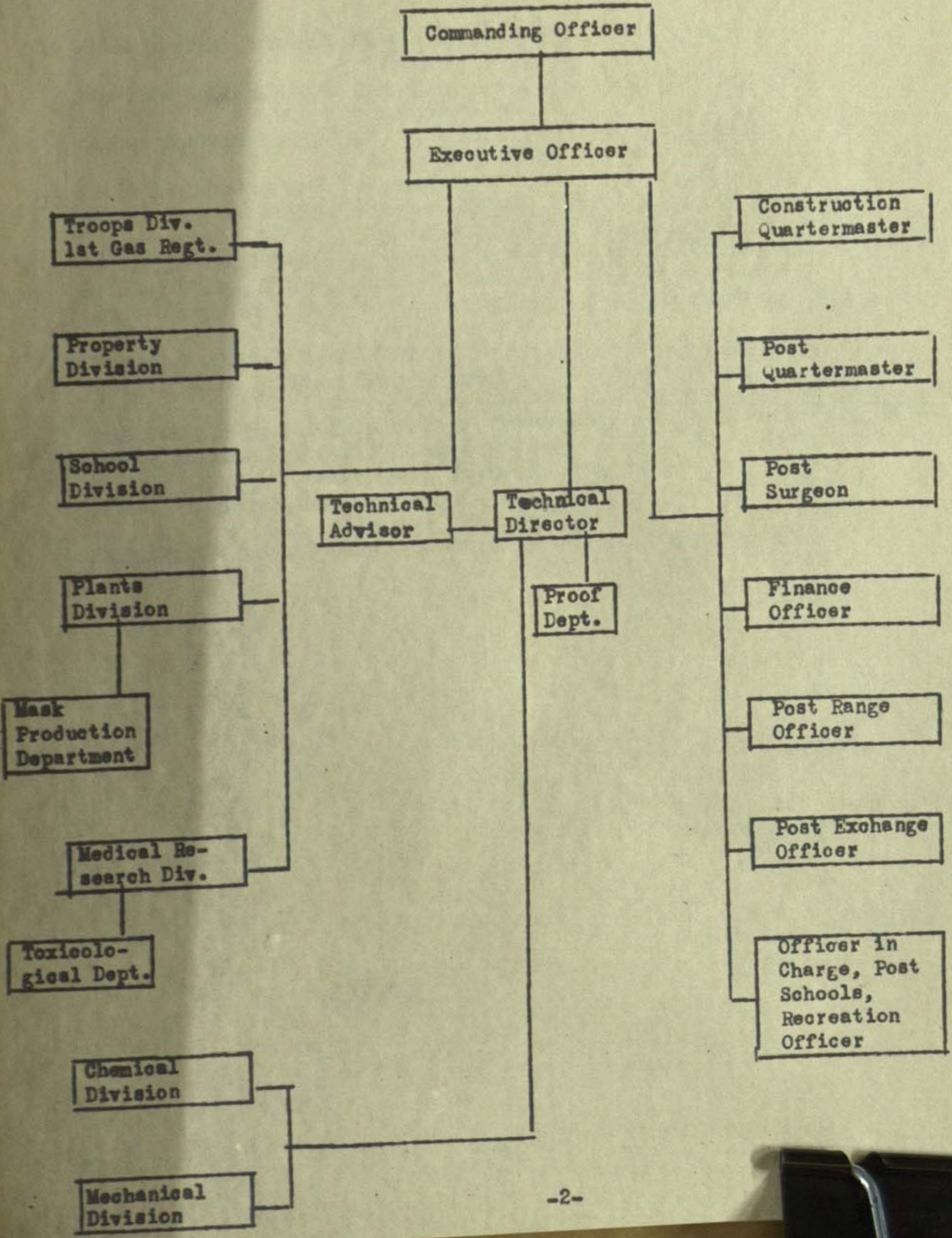
CHEMICAL WARFARE SERVICE

I. Office of the
Chief of Chemical Warfare Service
Washington, D. C.



II. Edgewood Arsenal, Maryland

Reorganization of the Arsenal is now under way. The new organization will be published when completed.



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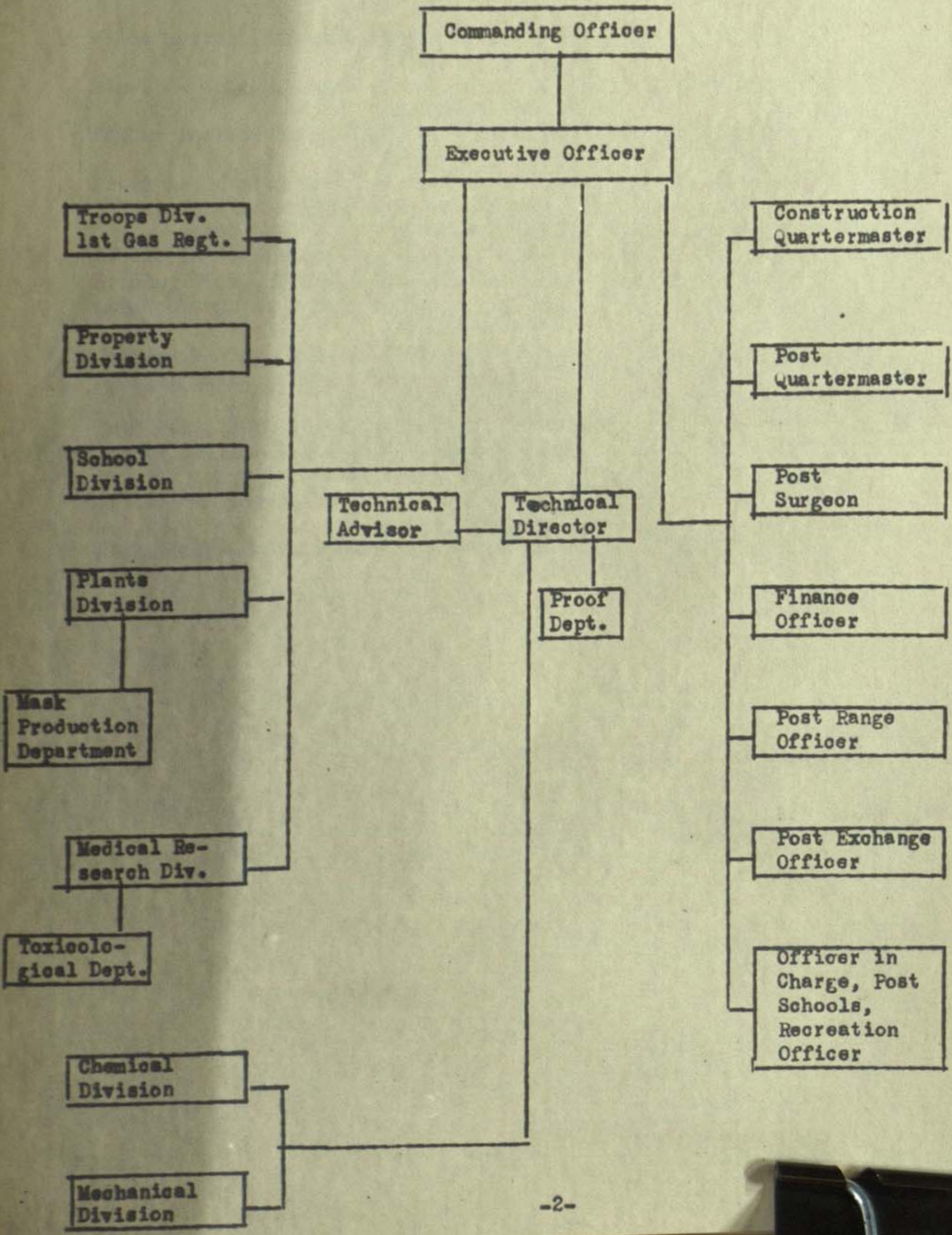

CHEMICAL WARFARE SERVICE COMMITTEE

(Consulting Scientists)

Wilder Dwight Bancroft, Dept. of Chemistry, Cornell University,
Ithaca, New York.
Elmer P. Kohler, Dept. of Organic Chemistry, Harvard University,
Cambridge, Mass.
Arthur Beckett Lamb, Dept. of Chemistry, Harvard University,
Cambridge, Mass.
Frank M. Dorsey, Nela Research Laboratory, Cleveland, Ohio.
Warren Kendall Lewis, Dept. of Chemical Engineering, Massachusetts
Institute of Technology, Cambridge, Mass.
Leslie T. Sutherland, Sutherland Industrial Research Co., New York City.
Bradley Dewey, Dewey & Almy Chemical Co., Cambridge, Mass.
Louis Cleveland Jones, National Aniline & Chemical Company, Inc.,
New York City.
Charles L. Reese, E. I. Du Pont de Nemours & Co., Wilmington, Del.
William Hultz Walker, Division of Industrial Coöperation and Research,
Massachusetts Institute of Technology, Cambridge, Mass.
Reid Hunt, Dept. of Pharmacology, Harvard Medical School, Boston, Mass.
Arthur Solomon Loevenhart, Dept. of Pharmacology, University of
Wisconsin, Madison, Wisconsin.
Charles H. Herty, Editor, Journal of Industrial and Engineering
Chemistry, New York City.
Harrison E. Howe, National Research Council, Washington, D.C.

CHEMICAL WARFARE SERVICE

Office Directory

Chief of Chemical Warfare Service . . . . Brig.Gen.Amos A.Fries

Executive Division

Function: Promulgation and execution of general policies of the Chief of Chemical Warfare Service and of the War Department, and the supervision, coordination, and administration connected therewith.

Executive Officer . . . . .Lt.Col.Claude E.Brigham

Assistant Executive Officer . . . . . . .Major William N. Porter

Chief Clerk . . . . .Mr. K. L. Osborn

Personnel Branch

Function: Supervision and administration of matters pertaining to commissioned, reserve, enlisted, and civilian personnel; personnel records; classification.

Chief . . . . .Capt.Geoffrey Marshall

Chemical Warfare Service Board

Function: Action on all matters referred to it by the Executive Division. Primarily outlining of broad policies and shaping them in definite form for the approval of the Chief of Chemical Warfare Service.

Executive Officer, Office of the Chief of Chemical Warfare Service
Assistant Executive Officer, Office of the Chief of Chemical Warfare Service
Chief of Operations, Training and War Plans Division, Office of the Chief of Chemical Warfare Service
Chief of Technical Division, Office of the Chief of Chemical Warfare Service
Chief of Supply Division, Office of the Chief of Chemical Warfare Service
Commanding Officer, Edgewood Arsenal, Maryland
Technical Director, Edgewood Arsenal, Maryland
Assistant Commandant, Chemical Warfare School
Commanding Officer, First Gas Regiment

Technical Committee

Function: Consideration of all technical questions concerning equipment and supplies for the Chemical Warfare Service.

Commanding Officer, Edgewood Arsenal
Technical Director, Edgewood Arsenal
Technical Advisor, Edgewood Arsenal
Chief, Technical Division, Office of the Chief of Chemical Warfare Service.
Assistant Chief, Technical Division, Office of the Chief of Chemical Warfare Service.
Chief, Operations and War Plans Division, Office of the Chief of Chemical Warfare Service.
Chief, Medical Division, Office of the Chief of Chemical Warfare Service (consulting member)
Representatives of various branches:

Ordnance Department	Major B.W.Simpson
Cavalry	Major J.B.Coulter
Field Artillery	Major J.W.Anderson
Coast Artillery	Captain Aaron Bradshaw,Jr.
Infantry	Major W.R.Scott
Air Service	Captain R.L.Walsh
Engineer Corps	1st Lt. C.E.Burlin
Signal Corps	Captain Fred P. Andrews
Quartermaster Department	Captain J.M.Ward
General Staff	Major C.A.Schimelfenig
Navy Department	Lt. Comdr. T.S.Wilkinson

Military Intelligence and Industrial Relations Division

Function: Collection and dissemination of military information of Chemical Warfare Service; maintenance of relations with chemical industries; educational institutions, Government bureaus, Military Intelligence Department, and maintenance of records on location of technical personnel and manufacturing facilities; procurement planning.

Chief	1st Lt. H.W.Rowan
Consulting Chemist	G.A.Rankin

Operations, Training and War Plans Division

Function: Supervision of training of the Army in chemical warfare;,training of Chemical Warfare Troops and the supervision of publications pertaining thereto; preparation of Tables of Organization.

Chief . . . . Major R. F. Maddux
Assistant Chief . . . . Capt. E. C. Wallington

Supply Division

Function: All matters pertaining to procurement and supply of munitions and equipment; transportation;disbursement of funds; settlement of claims; disposition of surplus supplies; war requirements; estimates.

Chief . . . . Major A. L. Rockwood
Assistant Chief . . . . Capt. G. F. Unmacht
Contract and Finance Clerk. . . . . . . Mr. C. C. Coombs

Technical Division

Function: Supervision of experimental and development work of the Chemical Warfare Service; preparation of all technical data pertaining to service; technical reports; maintenance of technical records.

Chief . . . . Major C. R. Alley
Assistant Chief . . . .
Consulting Engineer . . . . Dr. G. S. Maxwell
Librarian . . . . Mrs. L. R. Maxwell

Medical Division

Function: Medical advisor of the Chief of Chemical Warfare Service; investigation of physiological effects of chemical warfare agents on human life; preparation and supervision of medical-chemical warfare reports and statistics; liaison with the Army and Navy Medical Departments, the Public Health Service, and Veterans Bureau

Chief . . . . Lt. Col. H. L. Gilchrist

Edgewood Arsenal

Commanding Officer	Colonel C. W. Exton
Executive Officer	Major J. W. Lyon
Technical Director	Major Fred Seydel
Technical Advisor.	Dr. J. E. Mills
Commanding Officer, 1st Gas Regt..	Major Wm. A. Copthorne
Chief, Property Division	Major A. M. Heritage
Asst. Commandant, Chemical Warfare School	Major R. C. Ditto
Chief, Plants Division	Major C. E. T. Lull
Chief, Medical Research Division .	Lt. Col. E. B. Vedder
Chief, Chemical Division	Mr. J. F. W. Schulze
Chief, Mechanical Division	1st Lt. L. M. McBride
Chief, Proof Department.	1st Lt. Howard Stokes
Secretary, C. W. School.	Major J. A. Baird
Finance Officer	Captain C. R. Insley
Quartermaster.	1st Lt. E. E. Hagan

Edgewood Chemical Warfare Depot

Commanding Officer	Major A. M. Heritage

SOME INTERESTING STATISTICS OF THE CHEMICAL WARFARE SERVICE.

	Amount	Strength of the Army	Per Capita Army Cost of C.W.S.	National Census of 1920	Per Capita National Cost of Chemical Warfare Service	
Fiscal Year 1921 (Reappropriation)	$2,000,000	174,313	$11.48	105,710,620	Less than one and nine-tenth cents. ($.01891)	Includes amounts spent on C.W.S. training by Navy.
Fiscal Year 1922	1,350,000	144,148	9.37	105,710,620	Less than one and six-tenths cents. ($.01522)	
Fiscal Year 1923	600,000	137,000	4.37	105.710,620	Less than one and four-tenths cents. ($.01323)	
Fiscal Year 1924	700,000	137,000	5.10	105,710,620	Less than seven-tenths of a cent ($.00666)	
Fiscal Year 1925 (From final estimates).	700,000	137,000	5.10	105,710,620	Less than seven-tenths of a cent ($.00662)	

PROJECT PROGRAM FOR FISCAL YEAR 1924

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	A 1.2	Lewisite - Effectiveness as Warfare Agent
	A 2a	Toxic Smoke, Fundamental Study of
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	A 4.3-6b	Picric Acid - Manufacture of
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	B 1.3-1	Stokes Mortar, 3" - Shell adapted to smoke
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	B 2.1	Artillery Shell (Gas Shell)
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	B 2.2a	Smoke Shell - Comparison of 75 mm. with Maximum and Minimum Boosters, White Phosphorus Filling
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	B 3.2-2	Bomb, Chemical, 25-lb., Persistent Type
	B 3.2-3	Bomb, Chemical, 25-lb., Lachrymator, Burning Type

	B 3.3	Smoke Bombs
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	B 3.4	Incendiary Bombs
	B 3.4-1	Bomb, Incendiary, 40-lb., Mark II, Mark I
	B 3.4-3	Bomb, Incendiary, 8-oz., Baby
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	B 4.1-1a.1	Candle, Hexachlorethane, 50-lb.
	B 4.1-1b	Candle, Chloracetophenone - Alter the shape of
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	B 4.1-2b	Candle, Diphenylaminechlorarsine, 50-lb.
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	B 4.2-3	Cylinder, Mark I - Modification of
	B 4.2-5	Cylinder, Chloracetophenone
	B 4.2-5a	Means of Distributing Brombenzylcyanide
	B 4.3	Ship Screens
	B 4.5	Special Methods of Distribution of Toxics
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	C 2	Persistence of Substances in Field
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	C 4	Information on the Use of Gas in the World War
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	D 1.1-5	Charcoal and Absorbents
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	F-94	Smoke Screens for Large Areas
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	F-96	Bombing of Battleships

Heretofore the Chemical Warfare Service has made up its Project Program from ideas which have originated during the preceding year and suggestions from the using services obtained before its preparation, adding to the program new projects as the need for them became apparent. Hereafter it is planned to prepare a tentative program in the manner stated, furnishing a copy to each of the services interested and requesting suggestions thereon for the preparation of the final Project Program.

THE GAS MASK*

The evolution of the gas mask, from the first crude Cotton Hyposulfite Soda Glycerine Pads, made by the women of England and France, in response to Lord Kitchener's S.O.S. call, following the German Chemical Surprise at Ypres, April 22, 1915, to the latest developments in the Navy Diaphragm, Submarine, Binocular and Gasoline masks, made by the Chemical Warfare Service at Edgewood Arsenal in 1923, is an interesting story resembling the long drawn out battle between armor and projectile, as applied to chemical agents and protective equipment.

BRITISH MASKS

Black Veil Respirator

The primitive English type of cotton pads, impregnated with chemicals was superseded in May, 1915, by a similar and slightly more effective contrivance, called the Black Veil Respirator, which was worked out by Dr. Haldane and certain other prominent chemists.

Hypo-Helmet

The next step in mask development produced the Hypo-Helmet, a kind of flannel hood, impregnated with the same solution as the cotton pad, and having a celluloid film eyepiece. The idea of covering the whole head was suggested by a Canadian sergeant, "who had seen a German pulling a bag over his head during a gas attack." This idea was carried to England by Captain MacPherson of the Newfoundland Corps, and satisfactory tests having been made in the Anti-Gas Laboratories (May, 1915) two and a half million (2,500,000) of the Hypo-Helmet masks were manufactured from June to September, 1915.

The P. Helmet or Tube Helmet

The British, as early as July, 1915, discovered and reported that the Germans intended using phosgene against Essines Ridge Sector in December, 1915, and as the Hypo-Helmet afforded no protection against the phosgene chlorine mixture, it was deemed necessary to soak this helmet in a solution of sodium phenolate containing glycerine. To prevent the deterioration of the alkali of the mask by the CO_2 of the expired air, an expiratory valve or tube was added, and as the new chemical solution, which afforded protection against 300 parts of phosgene to a million parts of air, attacked flannel, two layers of

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*Much of the historical part of this article is condensed from the book "Chemical Warfare", by Fries and West, and "The Riddle of the Rhine", by Lefebure.

flannelette were used. This new type was called the P. Helmet or Tube Helmet, and in this form it countered the enemy phosgene attack in December, 1915.

The P.H. Helmet

Later, further protection was afforded by the addition of hexamethylenetetramine, suggested by Russian, resulting in the P.H. Helmet which increased the protection to 1,000 p.p.m. The magnitude of the task of furnishing protection against gas can be judged from the fact that two and a half million (2,500,000) Hypo Helmets, nine million (9,000,000) P-Helmets, and fourteen million (14,000,000) P.H. Helmets were issued.

The P.H.G. Helmet

To counter the lachrymatory compounds of the enemy, goggles with rims of rubber sponge, were added, thus the P.H.G. Helmet came into existence. During 1916-1917 more than one and a half million (1,500,000) were issued.

Box Respirator

The increasing concentration of gas from cylinder attacks and the introduction of shell with such gases as chlorpicrin and superpalite made imperative the production of a better protective device, and the wonderful British polyvalent respirator of the canister type with nose clip and mouth piece was produced. This was probably the result of experience with the oxygen apparatus in mine rescue work, and was developed in England under the direction of Lieutenant Colonel Harrison and Major Lambert after innumerable experiments. The respirator consisted of a canister attached to the face piece by a flexible tube, and the face piece was secured by tape or elastic bands which fitted over the head. The face piece was made of twenty-four thicknesses of muslin cloth soaked in a solution of sodium zincate and hexamine, and covered only the chin, mouth and nose; this necessitated the issue with each respirator of a pair of goggles, made of sponge rubber pads and glass eyepieces, for protection of the eyes. When the mask was adjusted, all breathing had to be done through a mouth piece of rubber attached to a metal tube, as the nose was closed by means of the clips (wire springs, with rubber jaws covered with gauze.) An expiratory rubber valve and an elbow tube was connected to the under side of the face piece, the elbow tube being also connected to the canister by a corrugated rubber tubing. This arrangement insured the passing of all air breathed through the canister. The canister was large and heavy and was filled with granules of charcoal, soda lime and potassium permanganate. The Box Respirator, in spite of its nose clip and mouth piece, and lack of ventilation in the face piece, was the best protection afforded against gas from February, 1916, to August, 1916, when it was replaced by the S.B.R.

The S.B.R.

As the Box Respirator did not afford protection against lachrymators, and in addition was uncomfortable, heavy and cumbersome, a small box respirator was devised, in which the face piece, made of rubber cloth, covered the whole face. This was equipped with a rubber mouth piece, nose clip, and eye pieces made of a composition of celluloid. A corrugated flexible rubber tube joined the canister to the face piece through an elbow tube, to which was attached the mouth piece; the outlet valve was also attached to the elbow tube. An important feature of the elbow tube was the baffle, which prevented the saliva from running down into the chemicals and causing deterioration.

The canister, only about half the size of the Box Respirator canister, contained the same chemicals with a smoke attachment for filtering out the smokes and toxic solids. This was easily detached from the canister and often lost, which resulted in incorporating the smoke attachments and chemical granules into one canister called the N.C., or New Carbon container. Later much filtering material was added to the canister to increase the efficiency in filtering out solid particles. Over sixteen million (16,000,000) of the S.B.R. were issued before the Armistice and at one time over a quarter of a million of the S.B.R. were produced weekly. Altogether over fifty million (50,000,000) masks and respirators of different kinds were manufactured by the British Anti-Gas Department for their own and the Allied Armies. (See "The Riddle of the Rhine", page 122.)

FRENCH MASKS

The M-2 Mask

The early protection of the French Army against gas was obtained by means of a mask consisting of a number of layers of muslin impregnated with greasene and complexene (twenty layers of each.) The mask fitted the face tightly with no outlet valve, the exhaled air escaping through the fabric.

The eyepieces were made of special non-dimming celluloid. A flap of weather-proof fabric protected the mask and absorbent chemicals from deterioration.

The Tissot Mask

The Tissot mask was the next step in French protective development. This mask, while resembling the British Box Respirator (canister and rubber face piece) lacked the mouth piece and nose clip, making it more comfortable. The canister was filled with a highly hygroscopic chemical absorbent, about 70% being sodium hydroxide. The use of caustic soda in the canister was made possible by the inter-mixing of steel wool with granules of caustic, a layer of absorbent vegetable charcoal being placed on top. It was shaped like a rectangular prism, 8" x $6\frac{1}{2}$", and was carried against the body, connected to the face piece with flexible rubber tubing. The design was superior, but the mask was too delicate and complicated. The rubber was easily torn and the box added much weight to the soldier's pack

The A.R.S. Mask

The A.R.S. Mask, closely resembling the German mask, is one of the latest types of French protective development. It is a frame mask made from well rubberized balloon material, lined with oiled or waxed linen, fitted with a screwed-on drum. The eye pieces, of cellophone, are fastened by metal rings in rubber goggles, sewed in the mask. A metal mouth ring, placed somewhat higher than in the German mask, is tied in the mask with tape. An inlet valve of mica, and an outlet valve of rubber are placed in the mouth ring. On the inside of the mask, in front of the valves, a baffle is sewed in, whereby the inhaled air is forced to pass in front of the eyepieces to prevent dimming and, at the same time, condensed vapor is prevented from entering the valves. The mask has two head straps, one elastic, one across the top of the head, and one in the back; these are joined by an elastic as in M-2. The drum made of metal and similar in shape to the German drum, fits in the mouth ring by means of a thread. It is made tight by a rubber ring. The thread differs from the German mask, making an interchange of canisters impossible.

GERMAN MASKS

The Cartridge Mask

To protect her men against their own use of phosgene, Germany had already adopted the cartridge mask in the autumn of 1915, which was conclusive evidence of Germany's plan for further use of gas. She evidently held up the use of phosgene until her own protection against it was completely developed.

The cartridge mask consisted of an impermeable fabric helmet, the cartridge or filtering box being attached in the form of a snout. The face piece of leather, treated with oils to make it soft and pliable, and impervious to gas, was roughly shaped to the face by seams at the chin. A circular steel plate three inches in diameter was set into the face piece, opposite the wearer's nose and mouth, with a threaded socket into which the drum containing the absorbents was screwed. A rubber gasket secured a gas-tight joint between the drum and face piece. There were no valves, both inhaled and exhaled air passing through the canister. The eyepieces, with metal rims and leather washers, were in two parts: (a) a permanent exterior sheet of cellon, and (b) an inner removable disc - an anti-dimming device.

The canister, a short thick cylinder (10 cm. x 5 cm.) slightly tapered, with a threaded protrusion or neck, was screwed in the neck. Within were three layers of absorbents of unequal thickness, separated by discs of fine metal screen wire. The 1915 canister contained some such material as powdered pumice stone saturated with a solution of potash to protect against organic irritants and phosgene. The three layer drum was introduced in 1916. The middle layer consisted of granulated charcoal. This went through all sorts of changes as substances with acid properties (chlorine) fell into disuse and chlorpicrin gained in importance in gas warfare. In 1917 the layer of charcoal was increased and in 1918 the other layers were done away with altogether and the entire three sets were filled with "A" charcoal. The capacity of absorption of "A" charcoal was never equalled by any foreign production.

ITALIAN AND RUSSIAN MASKS

The Italians used a mask similar to the French M-2 until 1918, when it was discarded for the British Small Respirator.

The Russian mask consisted of a box canister filled with chemicals, attached directly to the face piece. The head piece covered the entire head and had no mouth piece or nose clip. It offered a very low degree of protection.

The canister included a bottom screen, springs, and wire screen between the three layers, being closed by a perforated bottom. Top layer of absorbents, cotton, central layer charcoal (a little finer than in the German), lower layer, soda lime mixed with charcoal and zinc oxide, and moistened with glycerine.

AMERICAN MASK

When America entered the war, Professor George A. Hulett of Princeton University, Professor Ames of Johns Hopkins, and Major James R. Church of the United States Army Medical Department, were sent to England, France and the Western Front to investigate and report on mask development. After careful study of the three types of Allied masks (P.H. Helmet, M-2, and S.B.R.) it was found that the S.B.R. offered the greatest development and was adopted as the American Standard. The first 25,000 were built along lines of the S.B.R., hastily assembled without definite specifications and accurate knowledge; and, of course, proved to be poorly constructed and inefficient. They were never used, and the First Division was equipped with British masks.

The Training Mask

After more accurate information was obtained as to the method of manufacture by the British, a so-called Training Mask, used only for training, was issued, while designs and specifications of an unimproved gas mask for large scale manufacturing were being completed.

The C.E. Mask (Corrected English)

The C.E. Mask appeared in October, 1917, with its impermeable fabric face piece, longer and wider flutter valve, wider mouth piece, eye lenses held in place by a coiled spring, and its canister of activated cocoanut charcoal. 1,684,000 of this type were produced.

The R.F.K. (Richardson, Fleury, Kops) Mask

The R.F.K. Mask, incorporating some minor changes ("spun in" aluminum eyepieces) and a change in the binder frame, superseded the C.E. mask. From February, 1918, to November 11, 1918, 3,080,000 of the R.F.K. masks were produced, monthly output being 500,000.

The A.T. Mask (Akron Tissot)

In the summer of 1918 orders were received by the Gas Defense Production Division to increase the comfort and reduce the resistance of the R.F.K. mask. This necessitated the development of a new type face piece, and the French Tissot, having no nose clip or mouth piece, was recognized as the most efficient design for experiment. Parallel designs, one of rubber and one of fabric, were started simultaneously, resulting in the A.T. mask. The A.T. mask had for its distinctive features a moulded rubber stockinette covered facepiece, with sponge rubber chin rest and self-centering adjustable head harness. Incoming air from the corrugated rubber tube passed through an angle tube somewhat similar but distinctly superior to the old style masks. Production of this mask started in June, 1918, the total being about 197,000.

The K.T. Mask (Kops Tissot)

Similar in principle to the A.T. mask, but different in construction was the K.T. mask. The R.F.K. binder frame was used in this mask, but the material was a vulcanized fabric of semi-flexible construction, complicated by sewing operations. There was no angle tube. The incoming air entered from the corrugated rubber tubing through a simple metal orifice; a flutter valve was attached to a similar but smaller exit about an inch below the inlet. A butterfly shaped deflector of rubber functioned instead of the "Y" shaped clarifying tube. An elastic chin strap took the place of the rubber chin rest. Production started in September, 1918. 337,000 were made before the Armistice.

These Tissot masks had the advantage over the R.F.K. that there was no nose clip nor mouth piece. The non-dimming eyepieces were a decided improvement. The disadvantages of the K.T. mask facepiece (which became brittle and stiff, and hard to manipulate) and the possibility of reversing the position of the eye lenses of the A.T. mask (bulging in instead of out) were eliminated and the best features of both masks combined in the 1919 Model American mask.

American Mask, Standard 1919.

The face piece is struck out as a single flat piece from a special rubber compound which comes in sheets, one side covered with stockinette, a single seam under the chin (made gas proof with rubber cement) producing the proper shape to fit the face. This face piece, as punched out, contains two elliptically shaped holes, in which the eyepieces are inserted. The oval or circular eyepiece openings (smaller than the eyepiece) are stretched to give the necessary bulge to keep the cloth and metal away from the face and make a snug fit at the temple. The eyepieces are triplex glass in metal frames with rubber gaskets. The rings are pressed home so there is no possibility of pulling them out. The harness has three straps on each side, enforced when stitched on the face piece. Two lead from directly over the eyes, pressing the cloth against temples, and the lower strap, just above the chin, insures gas tightness in that vicinity. All six straps are brought together around a pad 2½" x 3½" at back of head, making the harness much more comfortable. The straps are fastened by means of buckles, and are, therefore, capable of perfect adjustment. The 24-inch angle tube, containing outlet valve and the connection to the corrugated tube connecting with the canister is the same as the latest model of the R.F.K. mask. Connected to the angle tube on inside of face piece is a butterfly baffle of rubber, so arranged that the incoming air is thrown upward and over the eyepieces keeping them clear in spite of exertion and temperature, except at 25° below zero F. or lower.

Canister

Radically different from the R.F.K. and earlier types, the canister is eight inches long with two inlet valves at the top and protected by a tin cover instead of the single inlet valve at bottom. These valves are 5/8" in diameter and are made up of square flat valves on the end of a short rubber tube fitted over a short metal tube. These valves, though delicate, work satisfactorily, and while not vital, help to keep the eyepieces from being fogged and the dead air space from being increased by that held in the inlet tube. The canister consisted of two parts - an outer solid, and an inner perforated tin casing. The inner perforated casing is fitted with a filter of wool felt 3/16" in thickness so that no air can get into the chemical without passing through the filter. The air coming through the inlet valves at the top circulates through all parts of the filter, through the perforations of tin, into the charcoal and soda granules. The chemicals are packed around a wedge-shaped tube extending about two-thirds the length of the can. The wedge made of perforated tin is enlarged and circular, passes through the top of the can to connect with the corrugated tube. It is covered with a thin cloth to keep dust from the chemicals from entering through the tube to the lungs. The cans are filled from the bottom and are subjected to two mechanical jarring operations to settle the chemicals thoroughly, before the spring which holds them in place is added. The outer tin can protecting the inlet valves has two openings on each side, but none at the ends of canister. The mixture used in the American canister during the last nine months of the war contained 60% of 6 to 14 mesh cocoanut shell charcoal, and 40% of 8 to 14 mesh soda lime permanganate granules, commonly called war gas absorbent mixture, which was considered superior to that used by any foreign country. A new combination found even more efficient which was to have been put into production, was a mixture of 75% special impregnated cocoanut charcoal and 25% soda lime containing no permanganate.

The carrier is a simple canvas case about 12" x 15" with two straps, one passing over the right shoulder and the other around the body. The flap, closing the case, opens outward. It does not interfere with pack or with anything in front of the body. It has been tried out by the Infantry, Cavalry, Artillery, and Chemical Warfare Troops and adopted as eminently satisfactory.

All Purpose Canister

While the standard 1919 Army and Navy mask was effective in combatting all known war gases, it was found insufficient to protect against the deadly carbon monoxide, ammonia and acid gases, which so often occur, through accidents and fire, on shipboard, in mines, and in refrigerating and ice plants. To meet this imperative need, the All-Purpose canister mask was developed.

Special Canisters

The Research Division of the Chemical Warfare Service, after many experiments and diligent investigations, was successful in discovering a chemical combination called Hopcalite, which when placed in the canister, catalytically changes the deadly carbon monoxide to carbon dioxide, which can be breathed to the extent of 20 to 30% without harmful results. The discovery of Silica Gel, which gives protection against ammonia gas, solved the serious problem of entering ammonia laden atmosphere to repair leaky valves which so often occur in refrigerating, food preserving and ice plants.

While the All-Purpose gas mask protects against carbon monoxide, ammonia, organic vapors and acid gases, it does not furnish oxygen as in the oxygen breathing apparatus, and if the oxygen content is below 13% in the air where the mask is worn, the oxygen breathing apparatus, or the hose mask, must be worn.

Gasoline Mask

The gasoline mask consists of the regulation face piece Mark I with an Atmos check valve attached at the end of the 27% flexible hose. To the opposite stem of the valve is attached a 50-foot length of wire-bound non-collapsible garden hose, with a 6" funnel inserted in its end. The carrier is similar in principle to the Carrier Mark II, but with the rear canister compartment portion omitted, the rear of the face piece compartment being box-seamed, with a slit left at the upper corner thereof for the passage of the 50-foot hose; near which, within the carrier, are a pair of strap loops secured by "Lift-the-Dot" fasteners which snugly encircle both hose on opposite sides of the check-valve, thereby preventing any pull by the 50-foot hose on the flexible hose or on the face piece. If necessary, the latter may be disassembled from the carrier by unfastening these straps, pulling the check-valve forward, and disconnecting the 50-foot hose therefrom.

This service has recently manufactured some hose masks for the Air Service, for use in connection with gasoline tanks in the Panama Canal Zone. The Air Service has gasoline storage tanks of about forty thousand gallons capacity, where it is necessary to enter underground pits where the control valves are located. These pits contain a high concentration of gasoline fumes, against which the ordinary mask gives inadequate protection. It is also necessary at times to enter the empty tank for inspection and repaird, in which case these hose masks will be used.

Binocular Mask

The Navy Department required a mask which could be used on board ship for the operation of range finding instruments, binoculars, etc., and this service has developed a face piece with the lenses so arranged that the gas mask can be satisfactorily used with the above mentioned instruments.

Navy Diaphragm Mask

The final design of diaphragm mask has been completed and adopted for a Navy order which is now in course of production. The Diaphragm feature of this mask is now made with a one-piece aluminum die casting, with a screwed-in diaphragm holder of aluminum. This mask has an enlarged flutter valve neck, in order to fit the peculiar design of the flutter stem.

Submarine Mask

The design of submarine mask has been completed and tested. The submarine masks consists of a drum type canister attached directly to the face piece, similar to the German type of mask, and gives protection only against gases occurring on board submarines, including carbon monoxide.

GAS MASK DEVELOPMENT

Fundamentals of Charcoal Absorption:

The Bureau of Mines is cooperating with the Chemical Warfare Service in developing a more highly activated and retentive charcoal in order to reduce the size of the canister.

The absorption of chlorpicrin by charcoals of varying "activity" at various rates of flow has been investigated.

Apparatus for the measurement of the total absorption and the retentive absorption of gases has been set up. The absorption and retentivity of toluene by the charcoals activated in studying the manufacture of charcoal will be determined. The same data will be obtained on the charcoals used in studying chlorpicrin absorption. This will help to tie together data obtained by a standard static method with that of chlorpicrin absorption obtained dynamically. It will also show whether or not the size of particles has any influence on the total or retentive absorption.

In addition to increasing general knowledge of properties of activated charcoal, these investigations will give some of the necessary data for a redesign of the canister.

Manufacture of Charcoal:

The latest work on manufacture of charcoal has consisted in making runs on the activation of Jeddo anthracite coal. The highest activation so far obtained has been eighteen minutes against the accelerated chlorpicrin test.

Data from reports on the work done at Astoria, Long Island, during the war are being collected as a means of determining the best design for a rotary furnace. Letters asking for descriptive literature on the properties of various high temperature metals have been sent out in order to decide upon the proper material from which to construct the furnace under consideration.

Work on the activation of cocoanut charcoal has been continued in order to get the activation unit in good shape and to develop operating practices. It has been found that about 1 g. of water per hour for each gram of charcoal gives the best results. The temperature of activation and the length of activation must vary with the initial apparent density of the material used.

The work done by the Bureau of Mines at Pittsburgh, Pennsylvania, on the preparation and activation of carbon from coal is being studied. The laboratory set up has been put together duplicating the arrangement of the Bureau of Mines report.

Impregnated Charcoal:

A charcoal impregnated with copper sulfate has been developed which compares favorably with the charcoal impregnated with copper nitrate.

When the amount of copper put into a charcoal exceeds a certain value, which probably depends somewhat on the activity of the charcoal, the absorption of cyanogen chloride is less than that for charcoals carrying a lower copper content. This optimum copper content for cyanogen chloride absorption is less than 10%. However, even a heavier impregnation increases absorption as compared with the base charcoal. Too heavy an impregnation tends to clog the pores which decreases the rate of diffusion, and consequently, the absorption of cyanogen chloride.

Gas Masks:

Careful consideration was given to the exact details of the causes of gassing of Chemical Warfare Service personnel during a field demonstration on December 11, 1923. Recommendations were made directed toward the perfection of facepiece fittings in the Regiment. Additional recommendations will be made regarding fittings by troops at other stations.

In accordance with instructions from the Chief of Chemical Warfare Service, Mechanical Division Progress Report 416 has been compiled covering detailed description of the forty-one gas masks developed during the war and since that time.

Binocular Mask:

Mask for use by Navy with range finding and other optical instruments has been satisfactorily developed.

In order that the lenses may fit within the eye socket of the wearer and thereby permit of the proper use of the various precision optical instruments on ship board, a satisfactory redesign of the eyepiece was accomplished, wherein eleven of the twelve components heretofore used have been eliminated, resulting in a one-piece assembly of maximum compactness and corresponding efficiency.

The deflector, which is a one-piece tube cast integral with the angle tube body, is 100% efficient at -6 deg. F. which eliminates the necessity for the use of anti-dim compound with its attendant detrimental results with optical instruments.

In order to overcome interference of the mask with certain of the instruments, the chin rest was eliminated and the angle tube to face piece assembly performed in a reverse manner, with the former projecting inward in lieu of outward.

An eyepiece bridge forming jig was designed for the Binocular Mask assembly. One hundred of these masks were made up and delivered at Baltimore on December 31, 1923, for transshipment to the Norfolk Navy Yard to be delivered to the fleet for test during its winter maneuvers.

Navy Submarine Mask

In preparation for an order for 35,000 NS Mark I masks, the angle tube was redesigned for die-casting in lieu of sand-casting. The inverted flutter stem principle of the ND Mark I angle tube was applied thereto, thus shortening the flutter valve extension 1-7/8" or 66% of its length. New drawings and specifications have been prepared.

The caustic pumice which was used in the Public Health Service canister was found to be too coarse for use in the submarine canister. A mixture of the fine and coarse material and an increase in the volume of the caustic pumice filling from 180 cc. to 210 cc. gave a satisfactory filling.

A container which followed the design of the experimental model has been received and found to give satisfactory protection when filled.

Head Wound Mask:

Model A of Head Wound Mask was constructed by inserting regulation eyepieces, angle tubes, deflector, etc., in the front of an HP Helmet-like mask with a regulation stockinette covered rubber front. The rear was of [illegible]K fabric to facilitate gathering with a drawstring about the neck. Additional models will permit of additional gathering of the entire mask by drawstrings, thereby reducing dead-air space to a minimum while maintaining ample size for adjustment over a turban bandage.

Gas Mask Facepiece:

It has been found that in the German mask, the facepiece of leather treated with oils to make it soft and pliable and impervious to gas, is still in excellent condition while the rubber mask of same age is practically worthless.

Rubber readily absorbs mustard gas, and is of short life in the tropics. Experiments have shown that under ordinary atmospheric conditions in the tropics, rubber in gas masks becomes practically worthless after eight or ten months.

Cotton linters felt impregnated with rubber from rubber latex solution produces a tough fibrous material not unlike leather in general physical characteristics. The impregnated cotton linters felt is being tested as a base in making up materials that would be satisfactory to take the place of the rubber facepieces. To give high resistance against gas it has been considered necessary to further impregnate the cotton linter-rubber pad with materials to fill up the pores of the treated material. The resistance of this material against mustard vapor was greater than that of the rubber facepiece.

Other impregnating agents along the line of rubber substitutes and waterproofing compounds are being tried.

Leather impregnated with a carnauba wax-castor oil mixture was penetrated by chlorpicrin vapor in four hours at 25° C. Leather impregnated with the oil-wax mixture is too stiff for facepiece material. Greater flexibility can be obtained by using a softer and thinner leather. However, the point to which the thickness of the leather can be reduced will be determined by its resistance to chlorpicrin.

Two samples of artificial leather known on the market as "Textileather" were tested against chlorpicrin and mustard vapors. Neither sample gave any protection against chlorpicrin and only three hours against mustard vapor at 25° C.

Gutta Percha has the physical advantage that it can be molded into any form at the temperature of hot water.

One sheet .04 inches thick was penetrated by saturated chlorpicrin at 25° C. in four hours. This is good protection considering the thickness of the sample. A sample .07 inches thick gave twenty-four hours protection against mustard as compared with sixteen hours for rubber .08 inches thick.

Samples of vegetable parchment have been tested against chlorpicrin and mustard vapors. Two samples showed equally high resistance against gas. Samples were not penetrated by saturated chlorpicrin up to twenty hours or saturated mustard vapor up to five days when tests were discontinued.

Vegetable parchment is waterproof in the sense that it will hold water without allowing it to drop from the under surface. Water permeates every fiber of the parchment without decreasing the toughness. When dried not under tension the parchment wrinkles. Vegetable parchment redried after being wet offers the same high resistance against gas as the original material.

Both "Amyloid" and varnish coatings are flexible enough so that sharp creasing does not crack the surface and alter the resistance to gas. Vegetable parchment coated with spar varnish was tried out as a diaphragm in the audible mask. The voice was transmitted clearly and the diaphragm seemed satisfactory in every respect.

It may be possible to find application for the parchment in the facepiece. During the parchmentizing process when the sheets are coated with the gelatinous colloid it is possible to ply up the sheets and press them together between rolls so that they cannot be separated by an ordinary means. It should be possible to go a step further and have the pressed sheets take the form of a mask. While one sheet of the parchment can be torn fairly readily, the plied up material should be very tough. The chief difficulty with a mask molded from the material would be in getting it to fit properly.

Facepiece Aging Tests:

Specifications for storage rooms for gas masks in Hawaii, Philippines and Panama have been completed, approved and forwarded. Accelerated aging tests in carbon dioxide are being made at Edgewood Arsenal.

A new lot of 1919 facepiece samples has been prepared for aging tests. Accelerated aging tests on three samples of 1919 facepiece material have been completed. The samples comprised one lot of Goodrich, which was received in partial shipments in August and September, 1921; one lot of Goodyear received from March to July, 1923; and one lot of Goodyear received in October, 1923. It was noted that the ultimate strength and elongation were low on all samples, a marked falling off being noted in the older samples. The aging followed the normal curve.

Kapoc Jackets:

Models A and B of kapoc Navy life jackets were constructed and delivered to Commanding Officer, Naval Unit, Edgewood Arsenal, for transmittal to the Navy Department.

Model A consisted of a carrier Mark II with harness omitted, assembled within the interlining of the jacket in a position corresponding to its normal one, beneath the left arm. The flap was slightly modified, and adapted to be secured by means of lift-the-dot fasteners, to the adjacent portion of the jacket. The kapoc removed to facilitate this location of the carrier was inserted within the jacket linings about its neck, beneath the collar.

Model B consisted of a flap-like pocket of grey Kapoc jacket material attached beneath the left armhole by stitching the bottom and rear sides to the outside of the jacket so that the contour corresponded to that of Carrier Mark II. The diagonally opposite corner was provided with tapes adapted to be tied after insertion of the carrier within the jacket. This design is considered the more advantageous on account of its enabling the wearer to insert or remove the regulation carrier even though over-board; also it simplifies stowage of jackets and masks.

STOKES MORTAR

One standard barrel was reinforced with steel clamps in the first reduction of the section forward from the breach, and has been used for experimental firings.

The Stokes mortar barrel equipped with a relief valve in the breech to allow the use of a shell with reduced clearance has been tried out. The valve was then redesigned and ten additional rounds were fired using variable weights of propellants and with pressures up to 4760 pounds. No difficulty from fouling has been encountered since redesign. On the basis of the few rounds fired some indication of increasing the range is given. The average range for two rounds fired with service charge and at an elevation of 45° was 1140 yards. This is not taken as conclusive evidence, however, due to the erratic results obtained with Hivel powder.

Further firings with increased charges up to the point of bulging the gun gave satisfactory functioning of this valve. While this device gives every promise of functioning satisfactorily in so far as giving a smoother flight to the shell, a greater range, and a decided increase in the volume of the shell capacity, and though it is recommended for use with the mobile, its adoption as an improvement of the present Stokes is not advocated, due to the fact that the Stokes used as a trench mortar would at times be set up in both mud and water which would enter the ports and defeat the aims of the device.

Working drawings for a proposed light mortar (Bradford), with recoil mechanism, have been completed. These were submitted to the Ordnance Department for comment in the light of their experience with gun design, and the comments together with a design of their own and several other designs, are now under consideration at Edgewood Arsenal. Experiments have been made to determine the size of oil ports and shape of throttling bars required by the Bradford design.

The recoil mechanism consists of an oil chamber and piston with ports for the passage of oil, to take up the recoil, and a spring for counter-recoil.

This mechanism, with the present barrel, was tested at various times, with pressures up to 10,000 lbs. The pressure on the base plate with the present gun is about 70,000 lbs., while with the new gun it is expected that it will be about 30,000 lbs., which will allow material reduction in weight of base plate. During the firings numerous modifications and replacements were made. Port areas and throttle profiles were changed. Due to the fact that on recuperation on some rounds the inertia of the forward moving barrel caused the piece to move forward from its emplacement; tie rods were added to prevent this motion. These rods further removed a portion of the bending moment on the piston rod. The recuperation of present mechanism was extremely rapid but has been overcome.

Shell:

Forged shell have been made from 4.7 shrapnel forgings, twenty rounds with double service pressure were fired with no failures. In firing forty-two experimental rounds, it was found:

(a) That the seamless steel shell lacks ductility. Normalizing the steel, eliminates this objection.

(b) That the normalized shell successfully withstood the pressure of any firings to date.

(c) That with the smooth type seamless shell, greater clearance between shell and barrel is required. A maximum outside diameter of 4.170" is now being used with apparent success.

(d) That the American smoke shell Mark I reinforced by shrinking a 1-1/4" band on the base of the body and turning to the guide diameter withstands successfully greatly increased gun pressures when concrete filled. The limit has not yet been determined.

(e) That increasing the charge and pressure beyond a certain point for each propellant, results in reduction, or at least no increase, in range. The cause has not been definitely established.

In September and October it was found that about 1700 yards was the maximum range obtainable with tumbling shell and powder furnished. Picatinny Arsenal is endeavoring to develop better powder, but it is believed that it will be necessary to obtain true flight in order to increase the range.

At Edgewood Arsenal the attempt to increase the range of the mortar is now confined to experiments with stabilizers and with the ogival head until the development of a slower burning powder by Picatinny Arsenal.

A detailed study of results obtained on stabilizer firing to date is being made. It appears that three main features contribute to the non-uniformity of flight observed with a given type of stabilizer. These features are:

(1) The "hop" of the shell as it leaves the muzzle, which is caused by the large shell clearance and the recess back of the front guide, in addition to factors normally associated with projectile "hop".

(2) The failure of the stabilizer while within the bore.

(3) The propellant, that is Hivel No. 2, is somewhat erratic in its ballistic properties. Considerable evidence in the form of wide variations in range with equal charge bears out this supposition. The mechanism being that due to a varying rate of burning that excessive turbulence with consequent resonance effects in chamber cause a deformation of the stabilizer.

A project is being written up for the development of a practice shell for the 4" Stokes Mortar to be used in training of troops in the handling of Chemical Warfare Service weapons and munitions.

Stokes Mortar Cart:

Detailed drawings for the Stokes mortar cart are nearly completed, and the carts for test at Fort Benning are now being manufactured.

The carts have standard Ford wheels and machine gun cart shafts, in order to standardize the parts as far as possible with easily obtained material.

3" STOKES MORTAR SMOKE SHELL, BURNING TYPE, EXPERIMENTAL

Several 3" Stokes shell were loaded by pressing into the shell a hot plastic mixture of C.N. and .30 caliber smokeless powder.

It was found that when loaded by this method, mixtures containing 30% or more of C.N. burned too slowly, while those containing only 28% C.N. exploded in fifteen seconds.

An attempt will be made to secure a satisfactory shell by molding blocks of C.N. and smokeless powder to a size which will fit the shell loosely, dipping these blocks in molten C.N., and then inserting the block in the shell.

It has also been found that the full charge of black powder contained in the Mark VI fuse, because of the smaller void space in the 3" shell, is too severe and therefore interfers with the proper functioning of the starter applied to the 3" Stokes. By reducing the charge of black powder in the Mark VI fuse to five grams, proper functioning of the starter is obtained.

CYLINDERS

Five portable chemical cylinders Mark I were modified by having the bottom head cut out and reassembled with the head convex instead of concave as viewed from the bottom end. The head was then gas butt welded to the body of the cylinder. These cylinders were tested hydrostatically to ascertain safe working pressure. It was found that the cylinders would stand applied pressure of 775 lbs. per square inch before the metal began to distort. At approximately 950 lbs. per square inch the cylinders began to bulge along the sides and they would eventually rupture before 1250 lbs. pressure had been applied.

A total of thirty cylinders have been reconditioned in the above manner and tested to destruction, and in no case did the welded joint fail. It is planned to recondition an additional fifty cylinders for further tests and observations before closing this project.

The three types of valves for the cylinder, the Mark III, the McBride and the Bradford, having been modified so as to allow approximately the same flow of gas, were tested to determine the best type to prevent leakage. The Mark III valve has a rigid steel shank fitting on the conical steel seat. In the Bradford valve the end of the shank is swivelled, and the McBride valve is similar except that the seal is formed of soft metal fitting against a ring shaped seat. A fourth valve has been proposed by Major F. S. Seydel similar to the McBride valve but doing away with the rotational friction between the valve and its seat, which it is thought may reduce the chance of leakage and increase the life of the valve. One of these valves has been manufactured and will be tested with the others.

LIVENS PROJECTOR

Three springs were made from Novo crucible cast steel selected grade FF for watch springs, for use in a modified spring exploder. These were hardened and the draw temperatures varied. With the first spring drawn at 900° F. two squibs were fired through 250 ohms resistance. This spring fired 99 out of 100 squibs in field test. The second spring drawn at 850° F. fired two squibs through 280 ohms and in the field fired 107 out of 198 squibs. The third spring drawn at 450° F. with the two ends drawn at 1055° F. broke while winding to place in the spring retainer. It is apparent that the maximum capacity which can be attained with this spring will be with the spring drawn somewhere between 450° F. and 850° F. The lower the draw temperature, the greater the strength. The limit placed on this strength will, however, be that with which sufficient endurance can be obtained. The normal endurance life of spring steel decreases rapidly with fiber stress above a definite limiting value. This can best be determined by firing springs to destruction.

C. N. CANDLES

Experiments were conducted to adapt the C.N. .30 calibre smokeless powder mixture to the 2 lb. H.C. candle container. Dry mixtures of C.N. and .30 calibre smokeless powder did not give satisfactory results in this container. Fairly satisfactory results were obtained when these dry mixtures were moistened with acetone and the resulting small lumps allowed to dry before being packed into the candle, but this method of loading was discontinued on account of the difficulty of drying the mixture.

An attempt was made to produce a plastic mixture which could be packed into the container in small lumps. On account of the small amount of mixture which could be packed in the candles and the length of time required for preparing the mixture, this method was considered impractical and was abandoned.

The standard C.N. candle mixture burned too slowly in this type of container. Very good results were obtained by making the orifice of the candle smaller and using a mixture composed of 31% C.N. and 69% .30 calibre smokeless powder. Work is being continued using smaller amounts of C.N.

Very satisfactory candles have been obtained by melting C.N., adding magnesium oxide and warming, then adding .30 calibre powder and mixing thoroughly. The plastic mass is then placed in a mold so the cake will fit the H.C. candle. The cake removed from the mold when cooled, immersed to within one half inch from the top in molten C.N. The block is then placed in the container with the uncoated end up and starter poured over the exposed end of the block. This method requires dies for pressing the mixture and a mechanical method of mixing large quantities. The fact that the mixture sets quickly, even in elevated temperatures makes the manufacture of the mixer a difficult one.

In view of the fact that one of the biggest items of cost in loading C.N. candles is the cost of mixing by hand, the problem of a mechanical mixer has received considerable attention.

A small mixer, with a water jacket was tried out, using steam instead of water in the jacket. Several methods were tried with this machine, but without success.

A careful survey of catalogs was made and several patent journals were read. Complete specifications for two patents covering machines which look promising have been ordered.

W. P. CANDLES

One hundred eleven 2 lb. double seamed candles were White Phosphorus filled, hot water tested to 60° C. and subjected to an endurance test to determine the resistance of the double seamed joints against spreading.

Of these eleven were tested for twenty-four hours, receiving 448,000 jolts each. The final hot water test showed that nine of the candles had withstood the test while two candles were leaking , due to the candles having come in contact with a nail head in the bottom of the tray during the bolting test. The remaining one hundred candles were tested in hot water to 60° C., and then jolted for one hour, receiving 20,400 jolts each. No leaks developed after the final hot water test. The container is now considered to be satisfactory.

50 lb. D.M. Candles

Two experimental 50 lb. D.M. candles have been tested. One candle was loaded with 21 lbs. of smokeless powder and 15 lbs. D.M. This candle burned over a period of 12 minutes 50 seconds, and gave off a uniform volume of canary yellow smoke. However, subsequent examination showed that 6 lbs. of D. M. had not been evolved.

The second candle was loaded with 20 lbs. of ammonium nitrate-charcoal fuel and 14 lbs. of D.M. This candle gave off a cloud of D.M. smoke for 11 minutes. The fuel continued to burn for an additional 5 minutes, showing that a considerable excess of fuel had been used. The color of the smoke varied from canary yellow at first to white and finally to brown. It is not known definitely to what extent decomposition can be judged by color, but in the past color has been considered as giving a rough idea of decomposition.

Both of the candles tested were covered with a 1/4 inch layer of asbestos to prevent excessive loss of heat by radiation.

Two additional experimental candles are being constructed. One will have the fuel container made longer so as to hold about one-third more powder. Twenty gauge instead of fourteen gauge metal will be used in the construction of this candle in order to reduce the weight of the container. The second candle being constructed is a duplicate of those already tested and will be loaded with ammonium nitrate-charcoal fuel.

H. C. SMOKE MIXTURE

Some of the blue powder zinc on hand at Edgewood Arsenal has become hard and lumpy due to oxidation in storage. An investigation is being conducted to determine whether this zinc can be used to produce satisfactory smoke candles. Results to date indicate that it will be possible to make good candles from this zinc by drying, grinding, meshing, and reducing the usual amount of zinc oxide used in the formula to allow for the higher oxide content of the blue powder.

If a zinc containing a higher percentage of zinc oxide is found to be satisfactory for smoke candles, it is possible that in the future some money can be saved by changing the specifications on zinc in regard to oxide content.

50 lb. H. C. CANDLES

After preliminary tests on various smoke mixtures in the 2 lb. H.C. candles, two 50 lb. 6" x 6" x 18" candles were tested in November of 1923. A 17" can was made next and tested satisfactorily, except that the starter had to be changed to give less violent results and one or two minor changes in the mixture and container were found desirable. Full volume of smoke cloud 12½ minutes, total time of burning 14½ minutes.

Three 50 lb. H.C. smoke candles of the same design but of different materials were then made and tested. The same proportion of smoke outlet to horizontal cross-section as in the 2 lb. H.C. smoke candle was used. In all cases the burning was too fast and the cloud dissipated rapidly.

Candles with various mixtures were next tested with the ratio of smoke outlet to horizontal cross-section reduced, and results were much better than those previously obtained. It is hoped to control the burning time and keep a higher percentage of smoke producing materials in the mixture.

RED PHOSPHORUS CANDLES

This new project was started on account of the danger in the use of white phosphorus. Red phosphorus is non-poisonous and offers no danger of fire. It is apparently converted to white phosphorus in burning. Mixtures of red phosphorus and various oxidizing agents were tried in 2 lb. H.C. smoke candle container with encouraging results. A mixture of 25% sodium nitrate and 75% red phosphorus was found too sensitive. Sensitivity is decreased by 20% glycerine added.

A comparison of the obscuring power of a red phosphorus candle (glycerine 16.6%, red phosphorus 62.5%, sodium nitrate 20.9%) and the H.C. candle has been made. The results were considerably in favor of the red phosphorus candle, but the experiment will be repeated for more conclusive data.

MANUFACTURE OF MUNITIONS FOR MILITIA BUREAU

Six thousand seven hundred twenty assembled C.N. candles called for on the order have been delivered to the Plants Division for painting.

Loading and assembling 9660 H.C. smoke candles is approximately 50% complete.

The loading of 1791 C.N. rifle grenades and 1790 C.N. hand grenades called for on this order has been completed, all of these grenades having been delivered to the Plants Division for painting in January.

SURVEILLANCE OF CHEMICAL WARFARE MUNITIONS

(a) Two H.C. candles assembled with 37-B-10 starter (zinc, antimony, and potassium perchlorate as used in the H.C. candle Mark I), and one candle with the bound modified match-head starter in contact with the smoke mixture (as used in the H.C. Stokes shell) were tested after fifteen months storage, and functioned normally.

(b) Two candles loaded with service H.C. smoke mixture were fired after two years storage, and found to function normally when the old 57-B-14 starter had been replaced by the 37-B-10 starter.

(c) After being in an oven for one month, one C.N. grenade from those being held at 60° C. and one from those being held at 50° C. were fired. Both grenades functioned in a normal manner.

(d) Surveillance tests are being continued on the following additional munitions:

Shell, 4" Stokes mortar, Smoke Mark I, M-1, H.C. Burning Type, Experimental
Shell, 4" Stokes mortar, Smoke Mark I, M-1, C.N. Burning Type, Experimental
Aluminum Ophorite
Grenade, Rifle C.N.
Grenade, Training
Grenade, Rifle for Toxic Smoke
Bomb, Smoke 8 oz. (Baby Smoke Bomb)
Bomb, Incendiary, 8 oz. (Baby Incendiary Bomb)
H.C. Smoke Candle (Starters and Binders)
Candle, C.N.

AVIATION MATERIEL

Spraying Devices:

A number of tests with the experimental spraying apparatus on a Martin bomber at Aberdeen Proving Ground, using F.M., have fairly well established the following points:

1. When liquid F.M. is atomized by allowing it to run out of a pipe at an angle to the slip stream of an aeroplane it produces only about one-sixth as much smoke as when vaporized in the engine exhausts.

2. When F.M. is sprayed as a rain from an aeroplane it produces a screen about 500 to 600 feet deep when sprayed at the rate of 1½ gallons per second from a plane traveling about 85 miles per hour or 125 feet per second.

3. Considerable detailed data with regard to apparatus requirements, pressures necessary for discharge, methods of handling, etc., were obtained and used as a basis for the design of a larger spraying apparatus.

Apparatus was designed, constructed and installed on two aeroplanes at Aberdeen Proving Ground to be used in bombardment tests against battleships. A test of one apparatus at Aberdeen, using F.M., gave an excellent screen across the wind over a mile long and about 600 feet deep, which offered obscurence for about ten minutes in a wind of about 5 miles per hour. With higher wind the life of the cloud will probably be shorter. Arrangements were made to operate this apparatus in bombardment tests.

Smoke Screen laid by Aeroplane during Bombing of Battleships New Jersey and the Virginia, September Fifth

"Flying into the wind which was blowing about two miles per hour, the aeroplane, at an elevation of from 500 to 600 feet, began laying the smoke screen at 9:30 A.M.

"The sky was entirely overcast at that hour and the light was entirely uniform without shadows. The plane, approaching from a distance of about 3/4 of a mile, left in its wake a tiny tapering cloud, which descending in ragged jagged rifts of broken streaks of smoke, became diffused in a cumulous mass of cloud, forming a veritable curtain. There was a gradual settling, and at the expiration of fifteen minutes the whole mass had spread to a sufficient uniformity to completly obscure both battleships.

"Ultimately, the screen drifting with the wind, passed the battleship, and from stern to bow the entire ship stood silhouetted against the sky. The complete concealment lasted about ten minutes, the battleship becoming visible only when the cloud had drifted past. It required about twenty-five minutes for the cloud to drift about a mile, showing that the wind velocity was exceptionally low, and also demonstrating that under that condition this type of screen will prove most effective." (Report of observer)

It should be noted in this connection that the screen in this case was not laid in the manner in which it would be used tactically, but in a way calculated to show it to advantage to the observers present. In actual warfare on the sea it would in most cases be laid from a higher altitude for the purpose of screening the approach of bombing planes from the observation of ships, rather than for the purpose of screening one ship from another. The test, however, was sufficient to demonstrate its effectiveness for this purpose.

BOMBING OF BATTLESHIPS

Extrusion tubes of various lengths were loaded with tetryl to be used for proof test of bombs by the Ordnance Department. This test showed that an extrusion would not provide for burst above water and demonstrated the need of a super-sensitive primer detonator assembly for water impact. Therefore, the project to use chemical bombs in the bombing of the New Jersey and the Virginia had to be given up.

FUNDAMENTAL STUDY OF SCREENING SMOKE

Recent work has consisted in making several duplicate runs of 200 gram charges of white phosphorus, counting smoke particles, and obtaining data on H.C. smoke clouds and gray smoke clouds (produced by mixing naphthalene with H.C. smoke mixture). The latter data was used to test out a formula developed for calculating the point of disappearance of the non-luminous target from the absorption (or penetration) of light measurement. In general it has been found that the agreement of the calculated and observed distance of disappearance of the target are good. In the case of white phosphorus the agreement is excellent. It is believed that this formula will be very valuable since it will allow us to calculate the distance at which the target will disappear with lower concentrations of smoke such as are used in the field. Concentration of smoke is of importance since it has been found that with charges of 50 to 400 grams of white phosphorus a higher obscuring power per unit weight is shown by the lower concentration.

It has also been found that over the range tested, this variation of obscuring power with concentration is regular, i.e., the relationship between T.O.P. and concentration can be expressed by an empirical formula.

As yet no entirely satisfactory method of measuring the reflection of light by smoke has been found. The methods suggested for use in place of the non-luminous target measurement have not proved practical. However, by a more accurate control of operating conditions and by changing the target used, it has been found possible to obtain much better checks with the non-luminous target than were formerly obtained.

FUNDAMENTAL STUDY OF TOXIC SMOKE

The apparatus for the counting of smoke particles at the concentration laboratory has been modified by the substitution of a sampling line about one inch in diameter for the previous line of 1/4 inch glass tubing. Since the length of this tubing was about fourteen feet it appeared probable that the particulate number might have been reduced by the particles sticking to the walls of the narrow tube. Several runs were then made during which the two sampling systems were alternated in order to get a comparison of the results with the small and the large tubes. Although these runs justified the reasoning which led us to substitute the large tube, the difference was not as great as was anticipated, and amounted to not more than 5% during the early stages of the cloud. Since the large tube obviously gives more accurate results its use has been adopted as a permanent part of the apparatus.

TRAVEL OF GAS CLOUD

In connection with the study of the relative concentration of clouds, with variations in height, a number of white phorus shoots have been completed in which samples were taken near the ground and at an elevation of 50 to 60 feet. Results indicated that at points two or three hundred yards from the firing point, clouds vary considerably in concentration with variation in height, but at a distance of 500 to 600 yards from the firing line, the density is generally uniform from the ground up to a height of 60 feet, the highest point measured.

White phosphorus shoots have been held in which height, width and obscurence measurements were made, in an effort to determine relationship between the rate of rise of the cloud and the difference between air and surface temperature.

In connection with the study of wind eddies and turbulence a number of white phosphorus shoots were completed. In studying the data collected graphs have been prepared with the object of determining the relationship of the effect of terrain and changes in wind velocity and direction on cloud travel.

A recording hot wire anemometer is being developed for obtaining a picture of the finer structure of the air currents for use in calculating the travel of smoke clouds.

Effort is being made to find a method of determining the viscosity of smoke by work in the laboratory and new method of determining viscosity of air by use of a delicate manometer, utilizing interference fringes formed when monochromatic light falls on very thin glass diaphragm on the surface of which rests a thin glass plate. Advantage - very rapid readings may be taken on a very small passage of smoke through the capillary tube thus decreasing the clogging effect of smoke.

DISPERSION OF SMOKE FROM SHIPS

On January 5th a thorough inspection of the boiler set-up on the destroyer Bruce was made at the Philadelphia Navy

Yard so as to be able to plan methods of introducing material into the stack.

A dispersion plant has been set up at Edgewood Arsenal for use in connection with the study of dispersion of smoke. from ships.

SHIP PROTECTION

Calculations have been made on different types of filters for the removal of gases and smokes from the air. These calculations indicate that a multitubular filter having tubes 1" to 1-1/8" inside diameter and a 3/4" layer of charcoal is smaller for a given flow of air than the other types studied. It was found that filters gave excess resistance, probably due to a gelatinous substance found between the fibers after formation of the filter. A different grade of material was secured and filters made from it show no indication of the gelatinous film observed on other grades.

NEUTRALIZATION OF GASES

Bleaching powder and liquid mustard were placed in a medium sized desiccator, the bleaching powder resting on the bottom of the desiccator, and the mustard, which was placed in a petri dish, resting on the perforated porcelain plate. Weighed test pieces of the metals of equal area were suspended from glass hooks, the metals hanging several inches above the petri dish. The top of the desiccator was replaced and the metals were allowed to be exposed for forty-eight hours, after which they were removed and washed. They were then dried and reweighed. From the area and loss in weight, the inches penetration of metal per month was calculated. In practice the quantity of bleaching powder used will be in excess of the quantity of mustard which is to be destroyed, hence, the corrosive action will not be exactly comparable to the above.

GAS DETECTORS

Detection of H.S.

A quantitative method for the detection of H.S. has been developed and is satisfactory for the determination of H.S. in the laboratory or in the field when butyl mercaptan and diethyl selenide are not present. One-thousandth mg/l. of mustard gas can be detected, which is below the point where it can be detected by odor (.0023 mg/l.) The test depends on the fact that chlorine in dilute water solution reacts with mustard and will also decolorize certain dyes. Consequently if mustard is present it reacts with the chlorine and the dye is not decolorized.

The test is very delicate for mustard, which gives a brown color, diethyl selenide (brown) and M-1 (white or pale yellow). The following substances do not interfere with the test: butyl mercaptan, hydrogen sulphide, phosgene, chlorpicrin.

PROTECTIVE CLOTHING

It is found that light increases the decomposition of Impregnito "B". High relative humidity increases the rate of decomposition. High temperature alone does not materially increase the rate but when the material is exposed to light, high humidity and high temperature the rate of decomposition is quite high.

Development of Navy Protective Suit

Several model suits have been made. Changes in design are necessary.

Protective Clothing (Ventilated Type)

Preliminary work on materials for such a suit has been started.

ANTI-FOULING PAINT FOR SHIP BOTTOMS

Experimental anti-fouling paints have been made up for test. A different anti-corrosive paint must be used to offset the corrosive properties of each anti-fouling paint. These have also been prepared.

Experimental work on the Edgewood (plastic) type of paint is practically completed, as far as new formulas are concerned. Several samples have been made and sent to Beaufort for exposure test. A number of these paints are being tested at Edgewood by suspending painted plates in sea-water.

MARINE PILING INVESTIGATION

The results from the test of the toxicity of chlorine generated near piling by electrolysis of sea-water have shown that chlorine so generated had only slight toxic properties.

A number of pieces under test so far show no attack by teredo.

Complete report of work to date has been prepared and is to be included in the report of the Committee on Marine Piling Investigations, National Research Council.

SPECIFICATIONS

Specifications for all Chemical Warfare Service material are being prepared, 155 remaining to be written out of a total of 535.

PREVENTION OF ACCIDENTS BY ILLUMINATING GAS

On November 22, 1923, a conference was held at Edgewood Arsenal between the Chemical Warfare Officers, Public Health Officials of Baltimore and Philadelphia, and representatives of a number of gas companies, for the purpose of discussing the possibility of finding a method for preventing accidents and suicides with illuminating gas, and finding leaks in gas mains. It was decided that the most difficult part of the problem was to obtain a method for maintaining the chemical agents in suspension in the gas, and that capsaisin was the most promising material for the purpose. The result of the conference was that the Chemical Warfare Service is to be informed when a suitable place for experiments is found and notified of the amount of material necessary to conduct experiments when action will be taken to determine in what manner the material will be obtained, and in what way the Chemical Warfare Service can assist in making the experiments.

MEDICAL RESEARCH

An investigation of the action of mustard within the body is being made at Edgewood Arsenal. Difference was found between mustard and HCl in animals but no difference on plants. This is another item of proof that the toxicity of mustard is due to the action of the entire molecule.

Chlorine apparatus for treatment of colds has been developed and tested with good results. Report E.A.M.R.D. No. 21 shows very large percentage of cures.

BOOKS AND PUBLICATIONS

The following are among the books and pamphlets in the Technical Reference Library, Office of the Chief of Chemical Warfare Service. These publications are available for use of all officers and employees of the Chemical Warfare Service , and may be loaned to any Chemical Warfare officer outside of Washington upon written request from him. The conditions under which these loans are made outside of the Chemical Warfare Service/Office are as follows:

Written request should be made by the officer desiring the use of any publication, giving the class number, title and name of author. Upon receipt of this information, the publication will be loaned for a period of two weeks. A card is sent with the publication,which must be signed and returned to the library immediately upon receipt. When the publication is returned to the library the receipt will be returned to the borrower. No publications can be withheld from the library for a period greater than two weeks without special permission.

Class No.	Name of Publication
355 St	American Campaigns, Vols. I and II, by Steele
355 F 249	American Guns in the War with Germany, by Farros
355 F-915	Chemical Warfaro, by Fries and West
662.6 B 639	Coal and its Scientific Uses, by Bone
540 S 155	Creative Chemistry, by Slosson
355 B 189	Development of Tactics, World War, by Balck
662.2 D 222	Dictionnaire des Matieres Explosives, by Daniel
667.2 Sh 84	Dyes Classified by Intermediates, by Shreve

Class No.	Name of Publication
682.2 M 355	Explosives, Vols. I and II, by Marshall
543.7 D 423	Gas Analysis, by Dennis
543.5 B 458	Gases used in Warfare, by Berolziemer
355 L 965	General Staff and its Problems, Vols. I and II, by Ludendorf
355 F 249	Gas Warfare, by Farrow
355 F187	(The) German General Staff, by von Falkenhayn
355 F 936	Guide to Military History of the World War by Frothingham
620.2 L 619	Handbook of Chemical Engineering, by Luddell
355 C 886	How America Went to War, Vols. I, II and III, by Crowell and Wilson
[illegible].7 M 363	Industrial Chemistry Organic, by Martin
542.72 G 857	Industrial Gases, by Greenwood
543.5 Un 2	Lethal War Gases, by Underhill
355 L 965	Ludendorf's Own Story, Vols. I and II, by Ludendorf
660 R 631	Manual of Industrial Chemistry, by Rogers
355 D 273	Medical Department, U.S. Army, in World War, by Davenport and Love, Part 1, Vol. XX
662.2 E 87	Modern High Explosive, by Eissler

Class No.	Name of Publication
321.4 B 843	Modern Democracies, by Bryce
353 Og 3	National Governments and the World War, by Ogg and Beard
299 St 6	(The) New World of Islam, by Stoddard
355. Ir 9	(The) Next War, by Irwin
355 C 573	On War, by von Clausewitz
660 T 398	Outlines of Industrial Chemistry, by Thorp
543.5 W 735	Pathology of War Gas Poisoning
543.5 H 119	Poisonous Gas in Warfare, Part II, by Haferkorn
541.9 K 182	Physical and Chemical Constants, by Kaye and Laby
355 N 235	Principles of Strategy, by Naylor
355 F 681	Principles of War, by Foch
355 L 52	(The) Riddle of the Rhine, by Lefebure
621.3842 Si 26	Radio, by the Signal Corps
355 F 958	Reformation of War, by Fuller
355 B 999	Sea Power in the Pacific, by Bywater
355 N 289	Solution of Tactical Problems, by Needham

Class No.	Name of Publication
623.71 Sh 28	Studies in Map Reading and Field Sketching, by Shaw
543 G 875	Technical Methods of Analysis, by Griffin
355 Sc 95	(Die) Technit im Weltkriege, by Schwarte
355 Si 58	(The) Victory at Sea, by Sims
355 B 457	War of the Future, by von Bernhardi
355 Z 4	What about Chemical Warfare, by Zuick
355 L 262	With "E" of the First Gas by Langer and McMullin

MOTION PICTURE FILMS AND LANTERN SLIDES

The following motion picture films are in the Training Division, Office of the Chief of Chemical Warfare Service. These are available for loan when there will be no interference with plans for their use by the Office of the Chief of Chemical Warfare Service.

Activities of the Chemical Warfare Service

The Chemical Warfare Service in the World War.

Lantern slides are in the Technical Division, Office of the Chief of Chemical Warfare Service, and are available for loan on request. Among these are the following:

Title	Number
Alabama, Battleship: before bombing, October, 1921	3193
Alabama, Bombing; Effect of H.E. bomb containing 135 lbs. of T.N.T. dropped from 3000 ft. altitude.	3189
Alabama, Bombing: - H.E. bomb bursting on bow	3195
Alabama, Bombing - 100-lb.W.P.. bomb bursting on bow. Dropped from about 3000 ft.	3196
Alabama, Bombing - Smoke cloud from 100-lb. W.P. bomb in 3196	3197
Alabama, Bombing - Smoke cloud from W.P. bomb. See 3196 and 3197	3199

Title	Number
Alabama, Bombing: Showing wreckage on deck.	3221
Alabama, Bombing: Bombing planes on their way to carry out tests against the Alabama.	3223
Alabama, Bombing: A good hit amidship with a 25-lb. W.P. bomb.	3229
Alabama, Bombing: Showing hole under bridge.	3235
Alabama, Bombing: 100-lb. W.P. bomb equipped with water impact fuze bursting about 25 ft. astern	3246
Alabama, Bombing: Airplane above battleship dropping four 100-lb. W.P. bombs, one of which struck in the fighting top.	3252
Alabama, Bombing: View taken $1\frac{1}{2}$ min. after 3252	3208
Alabama, Bombing: View taken 3 to 5 min. after 3252.	3254
Alabama, Bombing: Result of H.E. bomb.	3238
Alabama, Bombing: Showing deck and guns after bombardment with W.P. and H.E.	3225
Alabama, Bombing: Showing marks on deck, turret, and equipment from burning phosphorus.	3253
Alabama, Bombing: Officers on board wearing gas masks after bombing with C.N.	3248
Alabama, Bombing: Navy type smoke bomb, floating.	3249
Alabama, Bombing: Smoke screen developed around ship by Navy type smoke bomb.	3250
Alabama, Bombing: Smoke screen from Navy type smoke bombs.	3251
Ammunition Chart. - Ammunition required to cause wearing of respirator.	020
Ammunition Chart - Ammunition required to cause fatal effects.	021
Airplane Glider - special German glider from photogravure.	0100.
Airplane Glider - special German glider from another view of 0100.	0101
Bombs and Darts	1940
Candle, D.M., Test - Smoke cloud from rear. Cloud not at maximum.	2004
Candle, D.M., Test. - Berlin, Md. Smoke cloud, close view, from rear.	2005
Chart, Chemical Warfare Service Organization. Plate 1.	013

Title	Number
Chart, Chemical Warfare Service, Field Service. Plate 2.	014
Candle, smoke, B.M.	2229
Candles, D.M. - Development of a cloud from eight D.M. candles. Pictures made at intervals of one second.	2943
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The above list will be continued in future issues of this digest.

The following lectures are on file in the Technical Reference Library and are available for issue for a period of two weeks to Chemical Warfare Service officers, for use in instruction of Reserve Officers, R.O.T.C. Units and C.M.T.C. Camps:

"The Value of a Chemical Warfare Service", article by Brigadier General Amos A. Fries, Chief of Chemical Warfare Service, March 21, 1922.

"The Peacetime Value of Chemical Warfare", speech by Brigadier General Amos A. Fries, Chief of Chemical Warfare Service, for broadcasting, January 8, 1923.

"Chemical Agents in Battle", address delivered by Major E.J.Atkisson, C.W.S., at the U.S. Naval Academy, March 11, 1922.

"Future Armed Conflicts", lecture rewritten from "What the next war will be like", delivered by Brigadier General Amos A. Fries, Chief of Chemical Warfare Service, before the Philadelphia Forum.