DEPARTMENT OF THE ARMY TECHNICAL MANUAL **TM 3-215**

DEPARTMENT OF THE AIR FORCE MANUAL **AFM 355-7**

MILITARY CHEMISTRY AND CHEMICAL AGENTS

DEPARTMENTS OF THE ARMY AND THE AIR FORCE

DECEMBER 1963

CHANGE
No. 1

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D.C., *16 March 1965*

MILITARY CHEMISTRY AND CHEMICAL AGENTS

TM 3-215/AFM 355-7, 6 December 1963, is changed as follows:

Make the following changes in pen and ink:

Page 4, paragraph 2*v*, line 5. Change "tactically" to, according to use.

Page 6, paragraph 6*a*(3), line 2. Change "all markings in black" to, all lettering in black or white.

Page 8, paragraph 17, line 1. Change "latest" to latent.

Page 9, paragraph 17, line 10. Change "packing" to pancaking.

Page 10, paragraph 24, line 6. Delete the dash after the word "exposure" and the comma after the word "is."

Paragraph 24, line 12. Change "3,200-mk-min/m^3" to 3,200 mg-min/m^3.

Page 14, paragraph 30*b*(20), line 2. Change "40 mg-min/m^3" to 400 mg-min/m^3.

Page 20, paragraph 31*d*(2), line 1. Change "AsH^3" to AsH_3.

Page 24, paragraph 32*f*(24), line 7. Change "milk" to mild.

Page 29, paragraph 32*l*(15), line 2. Change "phenlyarsenious" to phenylarsenious.

Page 30, paragraph 32*m*(19)(*a*), line 1. Change "3,00 to 5,00" to 3,000 to 5,000.

Page 35, paragraph 34*c*(22), line 1. Change "Instaneous" to Instantaneous.

Page 37, paragraph 34*g*(22), line 2. Change "effective" to effects.

Line 3. Change "Hs" to The.

Page 40, paragraph 35*c*(5), line 13. After "detergent-wetting" add agent.

Page 44, paragraph 40*a*(4), line 3. Change "breatehd" to breathed.

Paragraph 40*b*, line 1. Change "Tantanium" to Titanium.

Paragraph 40*b*(19), line 1. Change "Alakli" to Alkali.

Page 47, paragraph 40*d*(2), line 11. Change "ehxachloroethane" to hexachloroethane.

Page 62, paragraph 60*a*, line 16. Change the comma after "teams" to a period; and in lines 16–17 delete "and is assigned chiefly to task forces."

Page 68, paragraph 69*a*, line 7. Change "Piperdine" to Piperidine.

Page 73, paragraph 79*c*(1), line 11. Change "Toulene" to Toluene.

Page 74, paragraph 79*c*(5), line 5. Change "mark" to mask.

Page 83, paragraph 95*e*(1)(*c*), line 1. Change "gren" to green.

Page 86, paragraph 98*g*(3)(*b*), line 12. Change "AS_2O_3" to As_2O_3.

Page 89, appendix I. Change title of FM 21–48 to Chemical, Biological, and Radiological (CBR), and Nuclear Defense Training Exercises.

2. Definitions

The following terms are defined as they apply to military chemistry and chemical agents:

* * * * *

d. Chemical Agent—a solid, liquid * * * or signaling smoke.

Note. (Added) Incendiaries and incapacitants are considered chemical agents.

* * * * *

m.1 (Added) *Defoliants.* — Chemical compounds which cause trees, shrubs, and other plants to shed their leaves prematurely. Representative examples of potential defoliants are ammonium thiocyanate and zinc chloride. In the process of defoliation, exposed leaves go through a stage of discoloration; ammonium thiocyanate turns leaves a bright maple-red, and zinc chloride turns them yellowish brown. The discoloration effect may be used to mark areas of a forest for reconnaissance or as guidance for aircraft. Defoliation may be of value to prevent ambush or friendly forces along routes of movement in jungles and forests and to deny concealment to the enemy. The use of defoliants on a small scale is practical; however, the amounts required for large areas might be considered too great from a logistical standpoint.

* * * * *

o.1 (Added) *Herbicides.* — any chemical preparations used to kill or inhibit growth of plants. Some herbicides kill or inhibit growth (damage plant tissue) primarily by contact with plant tissue whereas others kill or inhibit growth as a result of translocation. The former are also referred to as contact herbicides and the latter as plant growth regulators. Contact herbicides are mostly inorganic chemicals such as sodium chlorate, sodium arsenite, calcium cyanimide, and ammonium sulfamate. A more limited number of contact herbicides are organic compounds such as trichloroacetic acid and pentachlorophenol. Contact herbicides are generally being replaced by the much more potent plant growth regulators. These are also herbicidals (therefore also known as herbicides, although commonly called plant growth regulators) in suitable concentrations against certain plants.

* * * * *

r.1 (Added) *Plant Growth Regulators.*—chemical antiplant agents which regulate or inhibit plant growth. Plant growth regulators are also referred to as "plant hormones" or phytohormones, herbicides, and weed killers. They are relatively nonspecific and initiate a number of superficially unconnected changes in plants when applied in low concentrations; in high concentrations, they may inhibit growth or even produce death. The injury produced is systematic rather than the localized tissue damage produced by inorganic herbicides.

* * * * *

v.1 (Added) *Toxins.*—poisonous products of animal or vegetable cells which, on injection into animals or man, cause the formation of antibodies called antitoxins. The most important toxins are those produced by bacteria. Phytotoxins, produced by plants, include ricin from the castor bean and abrin from the seed of the indian licorice *Alrux Praecatoxius;* the zootoxins, produced by animals, include snake venoms and spider poisons.

* * * * *

4. Classification of Chemical Agents

* * * * *

c. Use. Chemical agents may be grouped according to use as follows:

* * * * *

(7) (Added) *Antiplant agents.* Agents that cause damage to plants.

(8) (Added) *Antimateriel agents.* Agents that cause deterioration of or damage to materiel.

(Some chemical agents * * * FM 21–48 and TM 3–300.

d. Physiological Action. Of the chemical agents, only the toxic chemical, riot control, and antiplant agents are classified according to their physiological action; however, white phosphorous (WP) and incendiary agents may produce casualties. These agents and their physiological actions are given in (1) through (*8*) below.

* * * * *

(7) (Added) *Plant growth regulators.* Chemical antiplant agents that regulate or inhibit plant growth.

(8) (Added) *Defoliants.* Chemical compounds that prematurely remove the leaves from plants.

For classification of the incapacitating agents, see paragraph 35*c*.

35. Miscellaneous

* * * * *

c. Incapacitating Chemical Agents.

* * * * *

(5) *Decontamination.* Decontamination of personnel * * * with clear water.

Note. (Added) The material in *d* and *e* below to some extent temporarily duplicates information contained in paragraphs 81, 82, 106, 107, and 108 of TM 3–216. Because the material deals with chemical rather than biological agents, this portion of TM 3–216 will be deleted from that manual when it is revised.

d. (Added) *Chemical Antiplant Agents.* Chemical agents effective against plants are the following chemical compounds which possess high offensive potential for destroying or seriously limiting the production of food and defoliating vegetation. These compounds are plant growth regulators that modify the normal pattern of plant growth, defoliants that damage or defoliate plants, or desiccants that dry up plant foliage. A comparison of chemical and biological antiplant agents is given below.

Chemical antiplant agents	Biological antiplant agents
Nonliving	Living
Do not require an incubation period	Require an incubation period
Effective against many plants	Effective against one plant
Little dependence on meteorological conditions	Great dependence on meteorological conditions.
Not affected by prolonged storage	Decrease in viability during prolonged storage
Will not cause epiphytotic spread	Will cause spread
Amount required to produce effects desired:	Amount required to produce infection:
About 0.5 to 3 pounds per acre.	About 0.5 gram per acre.

(1) *Plant growth regulators.* Chemical plant growth regulators, also known as herbicides, include compounds such as 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); and isopropyl N-phenyl carbamate (ICP). These compounds are effective in killing plants when used in concentrations as low as 0.5 pound per acre. This concentration is generally nontoxic to man and animals. There are no proven defensive measures against these compounds. By the time symptoms appear, nothing can be done to prevent damage. These compounds are detoxified in the soil after a period of several weeks to several months. Growth regulators of the 2,4-D type were first studied in 1942, and by 1960 the annual production in the United States was over 40 million pounds. They are employed extensively in agriculture for selectively controlling weeds in economic crops; in eradicating vegetation along roads, railroads, and power transmission lines; and in killing brush and weeds on range land. Growth regulators must be applied with care, since serious injury to economic crops can occur. In some instances, 2,4-D, applied as a dust, has drifted 10 miles or more, causing serious injury to sensitive crops such as cotton and grapes. The extent of plant injury from the use of growth regulators appears to depend ultimately upon alterations in either the rate or direction of cell division. In addition, various biochemical processes involved in the metabolism of carbohydrates and nitrogenous substances may be influenced, either with or without detectable changes in the morphology of the plant.

(*a*) *2,4-Dichlorophenoxyacetic acid (2,4-D).*

This is a white, crystalline powder with a melting point of 284° F. and a water solubility of 650 parts per million. It is commonly employed as a salt or ester. The salts are soluble in water. The esters most commonly used are the butyl and isopropyl esters, which are liquids soluble in oil and insoluble in water. For agricultural use, the esters are generally applied as oil-in-water emulsions. The esters are more effective than the salts or the acid in penetrating the leaf cuticle and killing resistant species. The esters may be applied as highly concentrated sprays. Rain immediately after application will not reduce the effectiveness of the spray. The effectiveness of the salts in aqueous solution sprays is reduced slightly by rain that falls immediately after application but is not reduced by rain that falls 6 or more hours after spraying. 2,4-D produces injury to all broadleaf plant species such as cotton, sweet potatoes, beans, sugar beets, Irish potatoes, flax, nut and fruit trees, and soybeans. Plant injury may occur within an hour after spraying and usually will be evident within 24 hours. The first noticeable injury occurs in the stems and leaves, which twist and bend. The stems sometimes form loops and coils. In some plants, the stems and leaves dry until the plants are completely dead; in other plants, the stems remain green for several weeks but may swell, develop cracks, and form callous tissue. Sometimes thick pads of tissue develop along the stems and at the joints. Numerous watery, translucent buds often appear at the crown but do not grow into new shoots. Several weeks after treatment, seriously affected plants may develop spongy enlarged roots. The outer portion of the root may slough off and leave wet, stringy cores that will later dry up or rot.

(*b*) *2,4,5-Trichlorophenoxyacetic acid (2,4,5-T).*

This is a white, crystalline substance with a melting point of 313° F. and a water solubility of 190 parts per million. It may be employed as either a salt or an ester. The general chemical and physical properties, as well as the effects on plants, are similar to those of 2,4-D. 2,4-D and 2,4,5-T differ in their ability to affect certain plant species. For example, 2,4-D is more effective on sugar beets; 2,4,5-T is more effective on Irish potatoes and certain woody plants.

(*c*) *Isopropyl N-phenyl carbamate (IPC).*

This is a white, crystalline substance with a melting point of 185° F. and a water solubility of 250 parts per million. This compound affects small grains such as wheat, rye, oats, barley, grasses, and a few broadleaf species. When IPC is applied to small grains as a soil contaminant in concentrations of 1 to 2 pounds per acre, substantial yield reductions may result. Generally, the compound is not absorbed by the plant tops. Within 1 to 2 weeks after treatment, the leaves of cereals become a darker green and cease to elongate. Following this, the leaf tips die and the leaves dry out progressively until the plants die. Death usually occurs within 3 weeks after the first noticeable plant injury. The 3-chloro substitution product of IPC, known as isopropyl N-(3-chlorophenyl) carbamate, has a melting point of 104° F. and an extremely low water solubility. The technical material may be liquid at 77° F., since small quantities of impurities lower the melting point. This compound is generally slightly more effective than IPC.

(2) *Defoliants and desiccants.*

(*a*) *General.* Chemical antiplant agents may be employed to defoliate or to desiccate. These chemicals may require a few weeks to defoliate or desiccate, depending on the particular plant species, its age, environment, vigor of growth, and the concentration or dosage sprayed on the plants. In some cases, the herbicides for defoliation will ultimately cause the vegetation to die. Some chemicals are indiscriminate in killing plants while others kill selectively. By manipulating the dosage of certain chemicals, either effect can be achieved.

(*b*) *Defoliants.* Defoliants are chemical antiplant agents used to prematurely remove the leaves from plants. The normal separation of leaves from vegetation is dependent on growth processes which take place in a few particular layers of cells at the point of attachment of the leaves to the plant. These are the abscission layers of cells. Natural leaf fall normally occurs over an extended period of 1 to 3 weeks or more. However, in some species, as in certain oaks, the leaves may die and shrivel but remain attached throughout the winter until separation may be forced by the expanding buds the following spring. Certain chemicals can induce and hasten unseasonal abscission (leaf drop) by certain species. These chemical compounds, however, require 2 to 4 weeks or more for some species to defoliate. The ideal defoliant is a chemical that acts in a day or, at least, in a few days. Field tests, using a mixture of 50 percent 2,4-dichlorophenoxyacetate,, 30 percent normal butyl, 2,4,5-trichlorophenoxyacetate, and 20 percent isobutyl 2,4,5-tricholorophenoxyacetate as a herbicide for defoliation, determined the dosage to be 1½ gallons per acre for mangrove targets. This mixture is also known as "Purple." Mangrove trees are very sensitive, and almost complete defoliation occurs in about 1 week. Some chemicals which have been used commercially for defoliation are ammonium thiocyanate; tributyl phosphate; pentachlorophenol; 3,6-endoxohexahydrophthalic acid; and a 50–50 mixture of butyl esters of 2,4-dichlorophenoxyacetate and 2,4,5-trichlorophenoxyacetate. Defoliation is useful in decreasing enemy concealment, denying areas for concealment to the enemy, clearing areas for fields of fire, and exposing enemy fortifications camouflaged with vegetation.

(*c*) *Desiccants.* Desiccants are chemical antiplant agents used to dry up plant foliage. With these types of agents a range of susceptibility is also shown by various species of plants. Chemical desiccation (drying) of foliage does not invariably lead to leaf drop. On the contrary, leaf drop may be somewhat delayed.

The use of desiccants would not necessarily be very effective in killing vegetation unless extended, repeated applications were employed. However, such chemical treatment may possibly be followed with fire. Some chemicals which have been used commercially for dessication purposes are butyl dibutyl phosphinate (BDP), dibutyl butyl phosphinate (DBP), and ammonium sulfamate. Most chemical desiccants cause a change in the color of foliage within an hour to a few hours, depending on the plant species and the agent. This color change is readily apparent from the air. Desiccation is useful in marking targets, release points, drop zones, and bomb release lines.

e. (Added) *Toxins* (*Chemical Agents*). Toxins are relatively unstable, poisonous substances chemically allied to proteins and may be of microorganism, plant, or animal origin. They are usually antigenic and induce the production of specific antitoxins (antibodies developed against toxins) in suitable animals. Toxins do not develop their poisonous effects immediately; they have a delayed action which varies with the particular toxin.

(1) *Botulinum toxin.*

(*a*) *Description.* This is a proteinlike exotoxin formed by the botulinum bacillus. Through repeated purification procedures, it has been obtained in a crystalline form and is one of the most powerful toxins known. There are at least six distinct types: A, B, C, D, E, and F. Types A, B, E, and F are known to be toxic for man; types C and D are toxic for animals but very rarely for man.

(*b*) *Effects produced.* The toxin produces an acute food poisoning known as botulism which has a high incidence of fatality. Botulism is characterized by vomiting, constipation, thirst, general weakness, headache, fever, dizziness, double vision, and dilation of the pupils; paralysis is the usual cause of death.

(*c*) *Sources of the toxin.* Sources of the toxin are the bacteria *Clostridium botulinum* and *Cl. parabotulinum,* which are rod-shaped, slightly motile, sporulating, grampositive, anaerobic bacilli. The principal reservoir of these bacteria is soil. The bacteria grow and form their toxin under anaerobic conditions, usually in improperly preserved canned foods such as meats, sea foods, corn, string beans, spinach, and olives.

(*d*) *Modes of transmission.* Transmission is through eating uncooked or improperly cooked food contaminated with botulinum toxin. Fresh well-cooked foods are not involved, as heat destroys the toxin. The bacteria do not grow or reproduce in the human body; poisoning is due entirely to the toxin already formed in the ingested material. The toxin could possibly be introduced through breaks in the skin or by inhalation, as in the case of laboratory accidents.

(*e*) *Latent period.* Symptoms of poisoning usually do not appear until 12 to 72 hours after food containing the preformed toxin has been consumed; the length of time depends upon the amount of toxin contained in the food consumed.

(*f*) *Susceptibility and resistance.* All persons are susceptible to the poisoning. The few who recover have an active immunity of uncertain duration and degree.

(*g*) *Prevalence.* The poisoning has worldwide distribution; it may occur wherever improperly canned food products are consumed.

(*h*) *Mortality.* The mortality rate is approximately 65 percent in the United States where poisoning usually is a result of eating contaminated canned foods. In Europe, poisoning is usually a result of eating contaminated smoked, salted, or spiced meats; and the mortality rate is about 25 percent.

(*i*) *Immunization.* The poisoning is not common enough to justify widespread immunization. However, active immunization with botulinum toxoid is of proved protective value for high-risk groups such as laboratory technicians.

(*j*) *Treatment.* Treatment is mainly supportive. Antitoxin therapy is of doubtful value, particularly where large doses of the toxin have been consumed.

(*k*) *Epidemicity.* Food poisoning is not contagious; epidemics occur only where widespread distribution and consumption of a contaminated food product occur.

(*l*) *Stability.* The toxin is stable for a week in nonmoving water. It persists for a long time in food when not exposed to air. The toxin is destroyed by boiling for 15 minutes or, when in food, by cooking for 30 minutes at 176° F. Botulinum spores resist boiling for 6 hours; however, pressure cooking will destroy the spores. Botulinum toxin differs from other bacterial toxins in that it is not destroyed by gastrointestinal secretions.

(2) *Staphlococcus toxin (staphlococcus food poisoning).*

(*a*) *Description.* Toxin is produced in food by certain strains of staphlococci. Since this toxin has a specific action on the cells of the intestinal mucosa, it is an enterotoxin. Unlike most bacterial exotoxins, it is stable at boiling temperature and is quite incapable of eliciting the formation of immune bodies.

(*b*) *Effects produced.* Staphlococcus food poisoning is produced following the ingestion of food in which various strains of staphlococci are growing. It is usually characterized by sudden, sometimes violent, onset with severe nausea; vomiting; stomach cramps; severe diarrhea; and prostration. Patients usually feel normal 24 hours after the attack begins.

(*c*) *Sources of poisoning.* Foods implicated as sources of the food poisoning are chiefly creamy pastries, raw milk, milk products, and meat. The source of the food contamination is not known in most cases but is probably of human origin. Food handlers who are nasal or skin carriers of pathogenic staphlococci or who have an open staphlococcal lesion on hands, arms, or face have been traced as sources of poisoning. The implicated foods usually have been allowed to remain at a warm temperature before consumption, thus providing ample time for formation of the toxin.

(*d*) *Modes of transmission.* Modes of transmission include consumption of contaminated custard-filled pastries, processed meats (particularly ham), and contaminated pasteurized or unpasteurized milk from cows with infected udders. Improper food handling is responsible for many outbreaks.

(*e*) *Latent period.* One-half to 4 hours, usually 2 to 4 hours, elapse between consumption of contaminated food and appearance of symptoms.

(*f*) *Susceptibility and resistance.* Most persons are susceptible, but individual reactions are variable.

(*g*) *Prevalence.* The toxin is distributed worldwide and is probably the principal cause of acute food poisoning.

(*h*) *Mortality.* Fatalities are extremely rare.

(*i*) *Immunization.* No immunization is available.

(*j*) *Treatment.* Treatment is supportive.

(*k*) *Epidemicity.* Food poisoning is noncontagious. Most outbreaks are small and confined to persons who have eaten from the same contaminated food supply.

(*l*) *Stability.* The toxin is resistant to freezing, boiling for 30 minutes, and to potable quantities of chlorine. The organisms which develop the toxin remain viable after 67 days of refrigeration.

37. Oil Incendiaries

* * * * *

e. Peptizers. A peptizer is * * * heater is available. Water (at high temperatures), octoic acid, 2-ethylhexoic acid, and cresylic acid (mixtures of xylenols and cresols) are the most common peptizers; cresylic acid is preferred for use with M1 and M2 thickeners, and 2-ethylhexoic acid is preferred for use with M4 thickener. For detailed information on the recommended proportions of peptizer, thickener, and gasoline to be used in the preparation of thickened fuels for portable and mechanized flamethrowers, land mines, and flame field expedients, see TM 3–366. However, there are * * * tested before use.

* * * * *

48. Chemical Methods

Most of the * * * through *c* below.

* * * * *

c. Liquid Contact Detectors.

(1) (Superseded) *General.* Liquid contact detectors are applied directly to liquid chemical agents or to materials contaminated with them. The principles of liquid contact detectors have been used in developing ABC–M8 paper which will detect V, G, and H and M6A1 paper and M7A1 (M7), crayon which will detect liquid blister agents only.

* * * * *

51. Chemical Agent Detector Kit, M18 (Standard B)

* * * * *

b. Contents. This kit consists of:

* * * * *

(6) (Superseded) *ABC–M8 Chemical Agent Detector Paper.* This book contains 25 sheets and has directions for use printed on the back of the cover. This replaces the M6A1 liquid vesicant detector paper which is now standard B and the M6 paper which is obsolete.

* * * * *

52. Chemical Agent Detector Kit, M18A1 (Standard A)

* * * * *

b. Contents.

* * * * *

(12) (Superseded) Book of ABC–M8 chemical agent detector paper. This replaces M6A1 liquid vesicant detector paper which is now standard B.

* * * * *

53. Chemical Agent Detector Kit, M15A1A

* * * * *

c. Contents. The kit contains:

* * * * *

(8) (Added) One book of ABC–M8 chemical agent detector paper.

* * * * *

55. Chemical Agent Sampling Kit, M12

* * * * *

b. Description. This kit contains one book of ABC–M8 chemical agent detector paper, sampling bottles, an extraction apparatus, cleaning solvent, repair and replacement items, and a component carrier-type kit about 12 by 4 by 4 inches. The component carrier-type * * * for further information.

By Order of the Secretaries of the Army and Air Force:

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Chief of Staff.

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Corps (3)
Div (2)
Div Arty (1)
Bde (1)
Gp (1)
Bn (1)
Co/Btry (1)
USA Cml Bio Lab (10)
USA Cold Rgn Rsch
  Engr Dev Lab (10)
Units org under fol TOE:
  3–500 (AA–AC) (5)
  17–22 (1)

NG: State AG (3); units—same as active Army except allowance is one (1) copy to each unit.
USAR: Same as active Army except one (1) copy to each unit.
For explanation of abbreviations used, see AR 320–50.
Air Force:
F

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CHANGE
No. 2

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D.C., *15 June 1967*

MILITARY CHEMISTRY AND CHEMICAL AGENTS

TM 3-215/AFM 355-7, 6 December 1963, is changed as follows.

Page 2. Paragraph 2*g* is superseded as follows:

g. Chemical Operations—employment of chemical agents (excluding riot control agents) (1) to kill, or incapacitate for a significant period of time, man or animals; or (2) to hinder the use of space, facilities, or material.

In subparagraphs *j*, line 1, and *k*, line 1, the word "toxic" is deleted.

Page 3. Paragraph 2*q*.1 is added after paragraph 2*q*.

q.1. *Oxime*—2-PAM Chloride (Protopam Chloride or Pralidoxime Chloride) used in nerve agent poisoning. Reacts directly with the nerve agent, converting it to a harmless compound; reacts directly with cholinesterase, thus protecting it from inhibition; and reactivates the inhibited cholinsterase, both in blood and tissue. Relieves muscle paralysis.

Paragraph 2*r*.1 is added after paragraph 2*r*, and paragraph 2*r*.1 (added) in Change 1 (16 Mar 65), is changed to read "2*r*.2."

r.1. *Physostigmine*—an alkaloid from *physostigma venenosum*. Used to relieve symptoms of BZ casualties.

Page 5. In paragraph 4*c*, *Note.*, line 4, "and FM 21-40" is deleted.

Page 6. In paragraph 6*a*(1)(*b*), the title is changed to read "*Riot control and incapacitating agents.*"

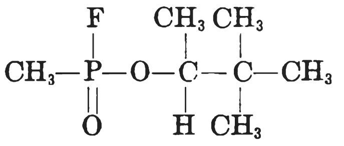
Page 10. In paragraph 21, line 5, "(BBC)" is changed to read "(CA)."

Page 11. In paragraph 28, line 4, the word "toxic" is deleted.

Pages 15, 16, 18, 22, 24, 26, 27, 28, 29, 30, and 31. The following sentence is added at the end of paragraphs 30*b*(26), 30*c*(26), 30*d*(25), 32*c*(27), 32*f*(26), 32*g*(26), 32*j*(25), 32*k*(26), 32*l*(27), 32*m*(26), 32*n*(26): Liquid agent on the skin may be decontaminated by use of the skin decontamination pad in the M13 individual decontaminating and reimpregnating kit.

Page 17. Paragraph 30*d*(3)(*a*) is superseded as follows:

(*a*) *Structural.*



$$\begin{array}{ccccccccccc} & & \text{F} & & & & \text{CH}_3 & & \text{CH}_3 & & \\ & & | & & & & | & & | & & \\ \text{CH}_3 & — & \text{P} & — & \text{O} & — & \text{C} & — & \text{C} & — & \text{CH}_3 \\ & & \| & & & & | & & | & & \\ & & \text{O} & & & & \text{H} & & \text{CH}_3 & & \end{array}$$

Page 18. In paragraph 30*e*(4), line 6, "(household bleach(" is changed to read "(household bleach)."

Page 26. In paragraph 32*i*(1), line 11, the words "M18" are deleted; line 12, "M15A1" is changed to read "M15A2A," and "M18A1" is changed to read "M18A2." In paragraph 32*i*(1), the last sentence is rescinded.

Page 31. In paragraph 33*a*, line 3, the word "toxic" is deleted.

Pages 36, 37. In paragraph 34*f*, the title, and paragraph 34*f*(24), lines 1 and 5, "BBC" is changed to read "CA."

Page 37. In paragraph 34*f*(19), lines 1 and 2, "Approximately 4,000 mg-min/m^3" is changed to read "Estimated 8,000 to 11,000 mg-min/m^3."

In paragraph 34*f*(19), the following line is added at the end of the paragraph:

Lethal dosage can be obtained in inclosed areas.

Page 38. In paragraph 34*g*(24), lines 1-3, the first sentence is rescinded.

In paragraph 34*g*(26), the word "Short." is superseded by "Varies, depending upon amount of contamination."

Page 39. In paragraph 35*b*(2)(*a*), in line 5, "soluable" is changed to read "soluble."

Par
(

fc

FM 21–41	Soldier's Handbook for Defense Against Chemical and Biological Operations and Nuclear Warfare
FM 21–48	Chemical, Biological, and Radiological (CBR) and Nuclear Defense Training Exercises
TM 3–220	Chemical, Biological and Radiological (CBR) Decontamination
TM 3–240/AFM 105–7	Field Behavior of Chemical, Biological, and Radiological Agents
TM 3–250	Storage, Shipment, and Handling of Chemical Agents and Hazardous Chemicals
TM 3–281/TO 39C–10CCB–6	Impregnating Plant, Clothing, M2
TM 3–300	Ground Chemical Munitions
TM 3–303/TO 11D2–3–3–1	Impregnating Set, Clothing, Field, M3; Impregnating Outfit, Clothing, Field, M1 Kit, Testing, Impregnite-in-Clothing, M1
TM 3–310–15	Breathing Apparatus, Compressed Air, M15; Adapter, Compressed Air Breathing Apparatus, M4; and Detector Kit, Carbon Monoxide, Calorimetric, M23
TM 3–400/11C2–1–1	Chemical Bombs and Clusters
TM 3–409	Impregnating Plant, Clothing, M2A1
TM 3–522–15	Mask, Protective, Field, M9 and Mask, Protective, Field, M9A1
TM 3–1040–202–12	Operator and Organizational Maintenance Manual, Generator, Smoke, Mechanical, Pulse Jet, M3A3
TM 3–4240–202–15/ TO 14P4–9–1	Organizational, DS, GS, and Depot Maintenance Manual: Mask, Protective, Field, ABC–M17
TM 3–4240–207–12	Operator and Organizational Maintenance Manual: Filter Unit, Gas-Particulate, 300 cfm, ged, ABC–M6, and Filter Unit, Gas-Particulate, 300 cfm, emd, ABC–M6
TM 3–4240–207–35	Field and Depot Maintenance Manual: Filter Unit, Gas-Particulate, ged, 300 cfm, ABC–M6, and Filter Unit, Gas-Particulate, emd, 300 cfm, ABC–M6
TM 3–4240–212–15/ TO 14S5–4–1	Operator, Organizational, Field and Depot Maintenance Manual: Breathing Apparatus, Oxygen Generating, M20
TM 3–4240–218–15	Operator, Organizational, Field and Depot Maintenance Manual: Mask, Gas, Rocket Propellant, M21
TM 3–4240–221–15	Operator, Organizational, Field and Depot Maintenance Manual: Mask, Protective, Tank, ABC–M14A1 and Mask, Protective, Tank, M14
TM 3–4240–224–12	Organizational Maintenance Manual: Breathing Apparatus, Compressed Air, M15 (end item Code 310)
TM 3–4240–230–12	Operator and Organizational Maintenance Manual: Mask, Gas, Acid and Organic Vapors, M10
TM 3–4240–231–12	Operator and Organizational Maintenance Manual (Including Repair Parts and Special Tool Lists): Mask, Gas, All-Purpose, M11A1
TM 3–4240–232–12	Operator and Organizational Maintenance Manual (Including Repair Parts and Special Tool Lists): Mask, Gas, Ammonia, M12
TM 3–6665–211–12	Operator and Organizational Maintenance Manual: Detector Kit, Chemical Agents, VGH, AN–M15A1 and AN–M15A1A
TM 3–6665–212–12	Organizational Maintenance Manual: Detector Kit, Chemical Agent, ABC–M18A1
TM 8–285/NAVMED P–5041/AFM 160–12	Treatment of Chemical Agent Casualties
TM 9–1300–203	Artillery Ammunition
TM 9–1901–1/TO 11A–1–39	Ammunition for Aircraft Guns

TM 10–1680A	Laundry unit, trailer mounted, w/extractor and washer, Prosperity model PLMW–51A, Army model SPV 22 (FSN 3510–351–9922); Prosperity model PLMW–51A, Army model SPV 22A (FSN 3510–174–3185); Prosperity model TUA–1, Army model SPV 29 (FSN 3510–214–1028); Troy Laundry Machinery model TLMW–51, Army model SPV 17 (FSN 3510–351–9923); Troy Laundry Machinery model TLMW–55, Army model SPV 32 (FSN 3510–287–3715); Laundry unit, trailer mounted, w/generator and tumbler drying; Prosperity model PLMT–51A, Army model SPV 22 (FSN 3510–351–9924); Prosperity model PLMT–51A, Army model SPV 22A (FSN 3510–174–3186); Prosperity model TUA–2, Army model SPV 29 (FSN 3510–214–1029); Troy Laundry units, Extractor & washer: Prosperity—PLMW–51A; TUA–1; Troy Laundry Machinery—TLMW–51; –55; Laundry units, Generator & tumbler drying: Prosperity—PLMT–51A, TUA–2; Troy Laundry Machinery—TLMT–51; –55
TM 10–8415–204–13	Organizational and DS Maintenance Manual: Rocket Fuel Handlers' Clothing, Toxological Agents Protective Clothing, Vesicant Gas Protective Clothing, Explosive Handlers' Clothing
TOE 3–97G	General Chemical Laboratory
TOE 3–500G	Chemical Service Organization
TB CML 44	Kit, Agent Sampling, M12
TB CML 68	Testing Kit, Impregnite-in-Clothing, M2

Note. Army publications referred to in this manual are applicable to the Air Force only in those instances where the Air Force publication number is also indicated. Army publications not applicable will not be requisitioned bv Air Force Activities.

Page 94. In appendix V, lines 4 and 5, ‘‘$\frac{C=F-32}{1.8}$,’’ are changed to read ‘‘$C=\frac{F-32}{1.8}$.’’

In column three, lines one and two,

‘‘°C.	°F.
155	311
155	302’’

are changed to read

‘‘°C.	°F.
150	302
155	311’’

Table 1, following page 101. In column 2, Tear Agents, item 5, ‘‘BBC’’ is changed to read ‘‘CA.’’ In column 24, ‘‘M9A2, M10A2, and M18’’ are deleted; ‘‘M15A2A and M18A2’’ are added.

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No. 3–215
AIR FORCE MANUAL
No. 355–7

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
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MILITARY CHEMISTRY AND CHEMICAL AGENTS

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*This manual supersedes TM 3–215/AFM 355–7, 3 August 1956, including C 1, 20 April 1959, and C 2, 25 September 1961.

CHAPTER I

INTRODUCTION

1. Purpose and Scope

a. This manual provides an adequate source of practical information on chemical agents—their classifications, physical and chemical properties and physiological effects, use in the field, detection and identification, and decontamination. Individual and collective protective items are also discussed. (For detailed information on munitions employed; techniques of employment; and effects of weather, terrain, and other factors on operations, see FM 3–10.)

b. The material presented in this manual is applicable to nuclear and nonnuclear warfare.

2. Definitions

The following terms are defined as they apply to military chemistry and chemical agents:

a. Aerosol—a liquid or solid, comprised of finely divided particles, suspended in a gaseous medium. Examples of common aerosols are mist, fog, and smoke. Aerosols usually are not visible.

b. Atropine—an alkaloid obtained from atropa belladonna. It inhibits the action of the craniosacral division of the autonomic nervous system. Used to relieve the symptoms of nerve agents.

c. Casualty Agent—an agent capable of producing serious injury or death when used in field concentrations.

d. Chemical Agent—a solid, liquid, or gas, which, through its chemical properties, produces lethal or damaging effects on man, animals, plants, or material, or produces a screening or signaling smoke.

e. Chemical Agent Casualty—a person who has been sufficiently affected by a chemical agent to die or require evacuation or one who suffers a marked loss of effectiveness in performing his military duties for a significant period of time.

f. Chemical Agent Symbol—the U.S. Army code designation of any chemical agent. This is a combination of one to three letters or letter-number combinations; it must not be confused with the chemical formula.

g. Chemical Operations — employment of chemical agents by weapon systems to produce casualties or damage.

h. Chemical Weapons System—an integrated relationship of chemical agents, munitions or spraying devices, and carrier vehicles alined to conduct chemical operations.

i. Concentration—the amount of a chemical agent present in a unit volume of air. Usually expressed in milligrams per cubic meter (mg/m^3).

j. Contaminate—the act of applying a toxic chemical agent on a person, object, or area.

k. Contamination—the presence of a toxic chemical agent on a person, object, or area. Contamination density is usually expressed in mg/m^2, or pounds per hectare.

l. Decontaminating Material—any substance used to chemically destroy, physically remove, seal in, or otherwise make harmless a chemical agent.

m. Decontamination—the process of making any contaminated object, person, or area safe for unprotected personnel by chemically destroying, physically removing, sealing in, or otherwise making harmless the chemical agent on or around it. (In general, only areas or materiel contaminated by agents which have a long duration of effectiveness need be decontaminated, since agents with a short duration of effectiveness are quickly evaporated.)

n. Dosage.

(1) *Ct product.* The Ct product expresses in a single figure the interrelationship of concentration and the duration of exposure of personnel to toxic chemical agents which exert their effects in vapor or aerosol form. These two

factors—concentration and time—determine the effectiveness of an agent. Since Ct is a combination of two factors, for most toxic chemical agents the same effect can be attained by exposure to a high concentration for a short time or to a lower concentration for a longer time. For example, exposure to a phosgene (CG) concentration of 320 mg/m^3 for 10 minutes would produce the same effect as 160 mg/m^3 for 20 minutes or 3,200 mg/m^3 for 1 minute. (Factors causing variation are noted in (4) below.)

(2) *Dosage (Ct).* Dosage (Ct) is the concentration of chemical agent in the atmosphere multiplied by the time the concentration remains, expressed as mg-min/m^3. The dosage received by a person depends upon how long he is exposed to the concentration. That is, *the respiratory dosage* in mg-min/m^3 is equal to the time in minutes an individual is unmasked in an agent cloud multiplied by the concentration of the cloud. The *skin dosage* is equal to the time of exposure in minutes of an individual's unprotected skin multiplied by the concentration of the agent cloud. (This is generally understood as being the effect upon the whole body.) The physiological effectiveness of skin and respiratory aerosol dosages are influenced by particle size as well as time and concentration, since retention by the lungs and impingement upon the skin are functions of particle size. They are usually expressed in mg-min/m^3 for a particular size. Dosage is usually expressed as median lethal dosage (LCt_{50}). (See par. 24 for further information.)

(3) *Liquid contamination.* The weight of liquid agent received by a person on his skin is usually expressed as median lethal dose (LD_{50}) in milligrams of contaminant per kilogram of body weight (mg/kg).

(4) *Restrictions.* Actually an individual may receive an amount of chemical agent that is less or more than expected for a given dosage (Ct), depending upon some of the following variables:

(*a*) How long the breath was held during short exposures.

(*b*) Speed with which mask was donned.

(*c*) Ability to fit mask and other mask leakage factors.

(*d*) Whether the chemical agent was also absorbed through the skin.

(*e*) Whether the chemical agent stimulated rate of breathing.

(*f*) Rate and depth of breathing of individual at time of exposure.

(*g*) Amount of physical exertion of the individual at time of exposure.

(*h*) Rate of detoxification, especially if exposure was long. For tabulation purposes such variables are ignored; and the Ct values are assumed to measure the amount of chemical agent received by an individual breathing at a normal rate in a temperate climate with average humidity. These values provide a basis of comparison for the chemical agents.

o. Harassing Concentration—a concentration of a toxic chemical agent which requires masking or other protective measures. Such concentrations may be insufficient to kill, but sufficient to interfere with normal operations.

p. Incapacitating Agent—an agent that produces temporary physiological or mental effects, or both, which will render individuals incapable of concerted effort in the performance of their assigned duties.

q. Incendiary—a chemical agent used primarily for igniting combustible substances with which it is in contact by generating sufficient heat to cause ignition.

r. Persistency—an expression of the duration of effectiveness of a chemical agent. This is dependent on physical and chemical properties of the agent, weather, methods of dissemination, and conditions of terrain. "Persistent" and "nonpersistent" should not be used to denote classes of chemical agents.

s. Riot Control Agent—an agent that produces only a temporary irritating or incapacitating effect when used in field concentrations.

t. Screening Smoke—a chemical agent which, when burned, hydrolyzed, or atomized, produces an obscuring smoke; used to limit observation and reduce effectiveness of aimed fire. Screening smoke is not normally used for toxic effect against personnel.

u. Signaling Smoke—any type of smoke, usually colored, emitted from a hand or rifle grenade or from a pyrotechnic signal, used to convey a prearranged signal.

v. Toxic Chemical Agent—a toxic chemical, irrespective of physical state, that may be used effectively in field concentrations to produce injury or death. Toxic chemical agents are classified tactically as casualty agents.

w. Toxicity—the property possessed by a material which enables it to injure the physiological mechanism of an organism by chemical means, with the maximum effect being death.

x. Training Agent—an agent authorized for training purposes.

3. Requisites and Desirable Features of Chemical Agents

a. Requisites of a Chemical Agent.

(1) It must be very toxic, produce effective smoke, have powerful incendiary properties, or have a desired effect on man, plants, or materials. It must also be capable of being utilized so that the desired mission can be performed.

(2) It must be stable or capable of being stabilized during the period of time between its production and use.

(3) It must be procurable from available raw materials in the quantity required for effective military use.

(4) It must be capable of being disseminated from a device practicable for field use in sufficient concentration to produce the desired effect on the target.

(5) It must be capable of being handled and transported, provided proper precautions are observed.

b. Desirable Additional Features.

(1) It should be capable of being produced quickly in existing commercial plants without extensive alterations in equipment.

(2) It should have little or no corrosive action on the munition or container during storage. (Corrosive action of the disseminated agent, however, is sometimes an added advantage.)

(3) It should possess such inherent properties that complete protection from it is difficult for the enemy. If possible, the agent should be capable of minimizing the effectiveness of the protective equipment of potential enemies.

(4) It should be difficult to detect by ordinary methods available to field armies prior to the time of onset of physiological and/or psychological effects. (Colorless, odorless, and nonirritating chemical agents are desirable.)

(5) The mechanism of action, protective measures, and method of treatment for the agent should be known.

4. Classification of Chemical Agents

a. General. Chemical agents are classified in three ways: by physical state (including degree of volatility), use, and physiological action. Persistent and nonpersistent should not be used as terms to classify chemical agents.

b. Physical State. Chemical agents may exist as solids, liquids, or gases. To a certain extent the state in which an agent normally exists determines its use, duration of effectiveness, physiological action, and the type of munition used for its dissemination.

c. Use. Chemical agents may be grouped according to use as follows:

(1) *Toxic chemical agents (casualty agents).* Agents capable of producing serious injury or death when used in field concentrations.

(2) *Incapacitating agents.* Agents that produce temporary physiological or mental effects, or both, which will render individuals incapable of concerted effort in the performance of their assigned duties.

(3) *Riot control agents.* Agents that produce only a temporary irritating or incapacitating effect when used in field concentrations.

(4) *Training agents.* Agents authorized for training purposes.

(5) *Screening and signaling smokes.* Screening smokes are agents that produce an obscuring smoke when burned, hydrolyzed, or atomized; they are used to deny observation and reduce effectiveness of aimed fire. Signaling smokes are similar to screening smokes except that they are generally colored and are used for visual communication instead of to obscure.

(6) *Incendiaries.* Munitions used primarily for setting fire. They may cause casualties from burns.

(Some chemical agents have more than one use. In such cases, the most important use determines the primary classification.)

Note. This manual seeks only to show the general relationship between chemical agent properties and uses. Use concepts are covered specifically in FM 3-10, FM 3-50, and FM 21-40. Additional information useful in training and tactical employment of chemical agents is contained in FM 21-48 and TM 3-300.

d. Physiological Action. Of the chemical agents, only the toxic chemical and riot control agents are classified according to their physiological action; however, white phosphorus (WP) and incendiary agents may produce casualties. These agents and their physiological actions are given in (1) through (6) below.

(1) *Choking agents.* Agents causing irritation and inflamation of bronchial tubes and lungs. Their primary physiological action is limited to the respiratory tract, with injury extending to the deepest part of the lungs.

(2) *Nerve agents.* Agents which, when absorbed into the body by inhalation, by ingestion, or through the skin, affect bodily functions by reacting in an irreversible reaction involving tissue fluids, permitting accumulation of acetylcholine and continual stimulation of the parasympathetic nervous system, as well as affecting other parts of the autonomic nervous system. The passage of nerve impulses is interfered with, thus disturbing essential bodily functions such as breathing, vision, and muscular control.

(3) *Blood agents.* Agents which, when absorbed into the body—primarily by breathing — affect bodily functions through action on the oxygen-carrying properties of the blood and interfere with normal transfer of oxygen from lungs via the blood to body tissues.

(4) *Blister agents.* Agents readily absorbed by both exterior and interior parts of the body, causing inflammation, blisters, and general destruction of tissues. The vapors, besides affecting the skin, attack the respiratory tract; the effects are usually more severe in the upper tract. Eyes are very susceptible to blister agents.

(5) *Vomiting agents.* Chemical agents that cause vomiting, and may also cause coughing, sneezing, pain in the nose and throat, nasal discharge, or tears. Headache often follows.

(6) *Tear agents.* Agents causing a copious flow of tears and intense (although temporary) eye pain. In high concentrations, they are irritating to the skin and cause a temporary burning and itching sensation. High concentrations can also cause burns.

For classification of the incapacitating agents, see paragraph 35*c*.

5. Duration of Effectiveness of Chemical Agents (Persistent Effect)

Factors that determine the duration of time a chemical agent exists at the point of dissemination are as follows:

a. Physical Properties of the Agent. Volatility is one physical property that is specially important in determining the duration of effectiveness of an agent.

b. Weather Conditions at Time and Point of Dispersion. Temperature, temperature gradient, and wind speed are the most important weather factors in determining duration of effectiveness.

c. Method of Dissemination. The state of physical division (dissemination) greatly affects the effectiveness of normally liquid or solid agents. In explosive munitions the degree of dispersion is dependent upon the amount and type of burster charge and upon the fuzing of the munition (air or ground burst). Nonexploding types of munitions such as aerosol generators and spray tanks are devices for varying the degree of dissemination and thus determining the duration of effectiveness of chemical agents.

d. Conditions of Terrain or Target. Vegetation, soil, large bodies of water, contour, and buildings play an important part in the duration of effectiveness of a chemical agent at the point of dissemination.

6. Identification of Chemical Munitions

a. Standard Color Coding System. All chemical munitions presently being manufactured are marked according to the standard color coding system (Mil Std 709).

(1) *Chemical agents.* Chemical agents, including casualty (toxic chemical) agents and irritant (riot control) agents, are indicated by a gray background with appropriately colored bands and markings to indicate the duration of effectiveness, use, filling and nature of the agent on release. The presence of a high or low explosive bursting element is indicated by a yellow or brown band, respectively. However, the yellow or brown color coding shall be used only if the quantities of contained explosives are sufficient to cause the item to function as a high or low explosive and/or are hazardous to the user.

(*a*) *Casualty (toxic chemical) agents.* Gray background with green markings; one green band for nonpersistent effect agents, two green bands for persistent effect agents, and three green bands for all nerve agents.

(*b*) *Irritant (riot control) agents.* Gray background with red markings; one red band for nonpersistent effect agents; two red bands for persistent effect agents.

(2) *Incendiaries.* Light red background with all markings in black.

(3) *Smoke.* Light green background with all markings in black except white phosphorus (WP) and plasticized white phosphorus (PWP) which shall be lettered in light red to indicate their incendiary nature for safety, storage, and handling purposes.

(4) *Practice.* Blue background with all markings in black.

b. Five-Element Marking System. All chemical munitions manufactured before June 1960 follow the five-element marking system. According to this system, all chemical munitions except firestarters and M25 series baseball grenades have a gray background. The number of bands indicates the duration of effectiveness. (One band around the munition indicates a nonpersistent effect agent and two bands indicate a persistent effect agent.) The color of the markings indicates the use of the munition. Green markings on the gray background signify casualty agents; red markings—irritant agents; purple—incendiaries; and yellow—smokes. A descriptive word such as gas, riot, smoke, or incendiary indicates the general nature of the agent on release. A Chemical Corps Symbol (GB, VX, HD) indicates the exact filling. In addition to the previous markings all chemical munitions, marked under either system, will have the lot number and the date of manufacture (in the appropriate color) marked on them. (For additional information on chemical munitions, see FM 3–8 and TM 3–250, TM 3–300, TM 3–400, TM 9–1300–203, and TM 9–1901–1/TO 11A–1–39.)

CHAPTER 2

CHEMICAL AGENT PROPERTIES OF MILITARY VALUE

Note. Only the properties of military significance are discussed in this chapter. For a comparative listing of properties of chemical agents, see tables I and II.

Section I. PHYSICAL PROPERTIES

7. Vapor Density

Vapor density is the ratio of the density of any gas or vapor to the density of air, under the same conditions of temperature and pressure. Vapor density is of some value in providing information as to the probable duration of effectiveness of a chemical agent in valleys and depressions. Diffusion is usually a minor factor in the dissemination of chemical agents, especially after the chemical agent has been diluted by air. Air currents and other influences tend to offset any effects of diffusion or vapor density.

8. Molecular Weight

Molecular weight is the value represented by the sum of the atomic weights of all the atoms in the molecule.

Table I. Properties of Chemical Agents.
(Located in back of manual)

Table II. Properties of Screening Smokes.
(Located in back of manual)

Example: The molecular weight of ethyldichlorarsine (ED) ($C_2H_5AsCl_2$) is:

$$\begin{array}{lrr} \text{C (At. wt.} = 12) & \times 2 = & 24 \\ \text{H (At. wt.} = 1) & \times 5 = & 5 \\ \text{As (At. wt.} = 74.9) & \times 1 = & 74.9 \\ \text{Cl (At. wt.} = 35.5) & \times 2 = & 71 \\ \hline \text{Molecular weight} & = & 174.9 \end{array}$$

The molecular weights of any two vapors are in the same proportion to each other as their vapor densities. For example, CG–or–$COCl_2$, with a molecuar weight of 98.92 has a vapor density of 3.4 times that of air, which has an average molecular weight of 29.

$$\text{Vapor densities} \quad \frac{3.4}{1} = 3.4$$

$$\text{Molecular wts.} \quad \frac{98.92}{29} = 3.4$$

9. Liquid and Solid Densities

The density of a liquid chemical agent is the weight in grams of 1 milliliter of the liquid at a specified temperature. The density of a solid chemical agent is the weight of 1 cubic centimeter of the solid at a specified temperature. Liquid or solid density is of interest in computing the chemical efficiency of a munition since toxicities are always expressed in units of weight. For example, a munition filled with CG which has a liquid density of about 1.4 will contain twice as much chemical agent by weight, and will have a much higher chemical efficiency than a munition of the same volume filled with hydrogen cyanide (AC) which has a liquid density of about 0.7. The chemical efficiency of a munition is found by dividing the weight of the filling by the total weight of the filled munition.

10. Melting Point

Melting point is the temperature at which a solid changes to the liquid state. The design, functioning, and ballistics of a chemical munition are determined largely by the melting point of its chemical filling. Because of the low melting point of WP, a WP-filled shell must be stood on end when stored in temperatures above its melting point so that, on melting, the center of gravity will remain unchanged and thus prevent instability of the shell in flight.

11. Freezing Point

Freezing point is the temperature at which a liquid changes to a solid. It is important to know the freezing point of a chemical agent because dissemination characteristics vary markedly with physical state. For example, HD can freeze in a spray tank at low temperatures and cannot be ejected.

12. Boiling Point

Boiling point is the temperature at which the vapor pressure of a liquid equals the atmospheric pressure. An estimation of the duration of effectiveness (under a given set of conditions) of a chemical agent may be made when its boiling point is known. The vapor pressure and evaporating tendency of chemical agents vary inversely with their boiling points. For example, HD boils at 228° C. and evaporates relatively slowly at ordinary temperatures. CG boils at 7.5° C., and evaporates rapidly at moderate temperatures.

13. Vapor Pressure

Vapor pressure is the pressure exerted by a vapor when a state of equilibrium has been reached between it and its liquid or solid state; vapor pressure is usually expressed in millimeters of mercury. It is the pressure which exists in a closed space above the surface of a substance when no other gas, such as air, is present. Vapor pressure varies with temperature; therefore, the temperature must be specified in order to determine the vapor pressure. At any temperature, any substance—liquid or solid—will have some vapor pressure, however small; it is only when this is appreciable that an ensuing vapor can have value as a chemical agent. Vapor pressure is one of the most important properties in considering the tactical usefulness and duration of effectiveness of a chemical agent. However, solid or liquid agents of low vapor pressure may be disseminated effectively as microscopic airborne (aerosol) particles by mechanical or thermal means.

14. Volatility

Volatility is the weight of vapor present in a unit volume of air, under equilibrium conditions, at a specified temperature. The volatility depends on vapor pressure and varies inversely with temperatures. Volatility is expressed as milligrams of vapor per cubic meter (mg/m^3). Vapor pressure and volatility are related, and vapor pressure is most understandable and useful when it is translated into volatility. Using "T" to express the absolute temperature of the atmosphere, the volatility of a chemical agent may be calculated numerically in milligrams per cubic meter by the following equation derived from the perfect gas law:

$$\text{V (volatility)} = \frac{\textit{Gram-molecular weight} \times \textit{vapor pressure in mm at } T\ (^\circ K) \times 16{,}000}{\text{T } (^\circ\text{K})}$$

$$^\circ\text{K} = {}^\circ\text{C} + 273$$

Knowledge of either vapor pressure or volatility is not sufficient to judge the effectiveness of a chemical agent unless the degree of toxicity and physiological action of the chemical agent are also considered. A highly toxic chemical agent of relatively low volatility, such as Sarin (GB), may be far more lethal than a less toxic chemical agent of much higher volatility, such as CG.

15. Flash Point

Flash point is the temperature at which sufficient vapors of a chemical agent are given off to be combustible when a flame is applied under controlled conditions. The flash point is of interest only in the case of a few chemical agents, particularly hydrogen cyanide (AC) and occasionally in special uses of HD. The usefulness of AC is greatly lessened because its low flash point frequently causes it to burn when a munition containing it bursts.

16. Decomposition Temperature

Decomposition temperature is the temperature at which a substance breaks down into other substances. This temperature can be used to evaluate candidate chemical agents since a low decomposition temperature (one which is markedly lower than the boiling point) will usually mean that the chemical agent cannot be disseminated by customary means without excessive decomposition.

17. Latent Heat of Vaporization

The latest heat of vaporization is the heat required to change 1 gram of liquid into vapor without change in temperature; that is, it is the total heat in calories that disappears at any given temperature when 1 gram of liquid evaporates under an external pressure of 1 atmosphere. This property is important because it is the chief factor in determining the behavior of high-volatility chemical agents at the moment of release from shells or bombs.

Most chemical agents are in liquid form within the munition. In some, the liquid is under considerable pressure. When pressurized munitions burst, the liquid may be rapidly transformed into vapor, requiring for the process a quantity of heat equivalent to the latent heat of vaporization. This results in cooling of the chemical agent and its surroundings, causing the vapor to settle. This settling action produces the effect known as "packing," that is, a spreading downward and outward of the newly released agent. Some chemical agents show the desirable pancaking effect to a greater degree than others because of high latent heats of vaporization. CG and cyanogen chloride (CK) are examples of agents exhibiting good pancaking effect. Chemical agents which are liquid at ordinary temperatures and pressures do not exhibit this effect since they require the application of energy to volatilize them.

18. Theoretical Minimum Void

a. Definition. The theoretical minimum void is the minimum amount of space which must be left in a container during filling to allow for the expansion of the filling with increase in temperature.

b. Safety Factor. The safety factor (K_c) is the amount of void that should be left in a container in addition to the theoretical minimum void. The safety factor (expressed in percent of container volume) is determined for the specific operation, and is based on the size and dependability of the container. (Allowance is made for decreased quality of container metals under wartime procurement.) The safety factor is determined for each specific case. The actual void may be calculated directly for any temperature—

Actual void = theoretical minimum void + safety factor (K_c)

c. Specific Volume. The specific volume is the reciprocal of the density.

$$SV = \frac{1}{\text{density}}$$

d. Formulas. Either of the following formulas may be used to calculate the theoretical minimum void (SV_f = final specific volume of filling; SV_i = initial specific volume of filling).

(1) Theoretical minimum void (%)

$$= \frac{SV_f - SV_i}{SV_i} \times 100$$

This formula is used to calculate the percent of increase in volume of the filling based on the volume at filling temperature.

(2) Theoretical minimum void (%)

$$= \frac{SV_f - SV_i}{SV_f} \times 100$$

This formula is used to calculate the percent of increase in the volume of the filling based on the volume at the highest temperature to which the filling will be subjected. Calculations may be made with this formula to determine the minimum void for any given filling independent of container size or type. This is the preferred formula to use.

e. Sample Calculation. Using a filling temperature of 60° F. and an estimated maximum storage temperature of 140° F., calculate the theoretical minimum void for a container of mustard.

SV_i of HD at 60° F. = 0.7553 cc/gm

SV_f of HD at 140° F. = 0.8130 cc/gm

Using formula in *d*(2) above:

Theoretical minimum void

$$= \frac{(0.8130 - 0.7553) \times 100}{0.8130} = 7.10\%$$

Section II. CHEMICAL PROPERTIES

19. Hydrolysis

a. General. Hydrolysis is the reaction of any chemical substance with water whereby decomposition of the substance occurs and one or more new substances are produced. Hydrolysis is of great importance in chemical operations.

b. Rate of Hydrolysis. The rate of hydrolysis is the rate at which the various chemical agents are decomposed by water. For the production of screening smokes titanium tetrachloride (FM) and sulfur trioxide-chlorosulfonic solution (FS), a rapid rate of hydrolysis is desired in order to utilize the smoke screen more effectively before it is dissipated by wind and air currents. Rapid hydrolysis is also an important factor in lowering the duration of effectiveness of toxic chemical agents. For example, lewisite (L) is rapidly hydrolyzed and therefore has a shorter duration of effectiveness than HD which hydrolyzes very slowly at ordinary temperatures.

c. Hydrolysis Products. Hydrolysis products are those new substances formed when a chemical agent reacts with or is decomposed by water. In certain cases, hydrolysis does not completely destroy the toxicity of a chemical agent because the hydrolysis product is also toxic, as in the case of L and most other chemical agents containing arsenic. With the exception of toxic products, hydrolysis products are of little importance in the study of chemical agents.

20. Hydration

Hydration is the combining of a substance with water. It is of interest primarily in connection with the formation of smoke particles, as when HCl and SO_3 (from FS), and P_2O_5 (from WP) serve as nuclei for the collection of water to form smoke particles.

21. Stability in Storage

Stability in storage determines the practical usefulness of a chemical agent since, if it is decomposed in storage, it will have little value regardless of any other properties which may recommend it. (Bromobenzylcyanide (BBC) is a chemical agent whose instability in storage outweighs its advantages as an otherwise excellent tear agent)

22. Action of Metals, Plastics, or Fabrics

The action of a chemical agent on certain materials acts as a limitation to the use of the agent. If a chemical agents acts corrosively on commonly used container metals, it will be difficult and probably prohibitively expensive to maintain in storage. Use of acidic chemical agents is limited by the fact that, upon release, they may cause damage to certain materials. FS, for example, causes nylon to deteriorate upon contact.

Section III. PHYSIOLOGICAL EFFECTS

23. General

Chemical agents have various physiological effects upon the human body. They are used for their toxic effects—that is, to produce a harmful physiological and/or psychological reaction when applied to the body externally, when breathed, or when taken internally. Most chemical agents cause a disorganization of bodily functions.

24. Median Lethal Dosage (LCt_{50})

The median lethal dosage of an agent employed for inhalation as a vapor or aerosol is generally expressed as the LCt_{50}. The LCt_{50} of a chemical agent is the dosage-vapor concentration of the agent multiplied by the time of exposure—that is, lethal to 50 percent of exposed personnel. It varies with the degree of protection furnished by masks and clothing worn by personnel. The unit used to express LCt_{50} is milligram minutes per cubic meter. Thus, toxicity tables give for CG an LCt_{50} value of 3,200 mk-min/m^3.

Note. Lethal dosage may also be expressed in other than median, for example: LCt_{25} (amount required to kill 25 percent of an exposed group of personnel), and LCt_{90} (amount required to kill 90 percent of an exposed group of personnel).

25. Median Incapacitating Dosage (ICt_{50})

The incapacitating dosage of an agent is generally expressed as the median incapacitating dosage—the amount of inhaled vapor or liquid agent on the skin which is sufficient to disable 50 percent of exposed personnel. For inhalation effect, the median incapacitating dosage is expressed as the ICt_{50}, and for liquid effect as the ID_{50}. They vary in accordance with the protection furnished by masks and clothing worn by personnel.

Note. For men as active as those marching with full field packs at a moderately rapid pace, the lethal and in capacitating dosages through the respiratory route are 25 percent of the values indicated for specific agents.

26. Rate of Detoxification

The rate of detoxification is the rate at which the body is able to counteract the effects of a poisonous substance. It is an important factor in determining the hazards of repeated exposure to low concentrations of toxic chemical agents. Some chemical agents are not detoxified at appreciable rates by the human body. GB is cumulative to a large degree. If 50 percent of a lethal dosage is received, minor symptoms will appear. If another 50 percent of the lethal dosage is received within the next few hours, death will result. Within the next few weeks after the initial 50 percent is received, a second dosage somewhat less than the full lethal dosage will kill. Other chemical agents are also cumulative in their effects. For example, an exposure of 1 hour to HD or CG followed within a few hours by another exposure of 1 hour has approximately the same effect as a single exposure of 2 hours' duration. The disabling or lethal dosage in the case of such cumulative agents is proportional to the time factor within reasonable limits. GB, while having a cumulative toxic effect, also has a detoxification effect which is important. For example, the median lethal dosage of GB is approximately 70 mg-min/m^3 over periods of 30 seconds to several minutes. However, if the concentration breathed is so high that 15 to 25 milligrams are rceeived in one breath, this amount can be lethal since there is no time for any appreciable amount of detoxification to occur. AC is destroyed by the body at the rate of about 0.017 milligram per kilogram (2.2 pounds) of body weight per minute. For example, 1.2 milligrams of AC per minute could be breathed by or injected into a 154-pound man indefinitely without injuring him; yet if he were to breathe or be injected with approximately 62 milligrams over a period of 10 minutes he would be killed. This ability of the body to detoxify AC and its inability to detoxify CG means that, for short exposures, the LCt_{50} (amount in Cts required to kill half of the individuals exposed) for AC is lower than for CG; whereas, for long exposures the LCt_{50} for CG is lower than for AC. Continued exposure of personnel to low concentrations of HD may result in sensitivity to very low concentrations of HD. The fact that such chemical agents as AC and CK are detoxified at a fairly rapid rate by the body means that high concentrations of such chemical agents are needed for maximum casualty effects.

27. Skin and Eye Toxicity

Some agents are highly toxic if absorbed through the skin or eyes, while others are nontoxic. The tear agents normally have little effect on the body except through the eyes. However, CS will affect the upper respiratory tract for a short period of time. The blister agents affect all the internal and external body surfaces indiscriminately and are able to exert their full casualty effect through these surfaces. The nerve agents exert their full toxic effect through the skin and the eyes as well as through the lungs. Liquid AC can be toxic by absorption through the skin and eyes. Agents other than nerve agents and AC are relatively nontoxic through the skin especially if this highly volatile material is hindered from evaporating from the skin. The vomiting agents and choking agents exert their effect only if inhaled.

28. Rate of Action

The rate of action of a chemical agent is the rate at which the body reacts to or is affected by that agent. There is a wide variation in the rate of reaction to the toxic chemical agents, even to those of similar tactical or physiological classifications. For example, HD causes no immediate sensation on the skin and causes no effect for several hours except in a few cases where effects have been delayed for 10 to 12 days. L on the contrary, produces an immediate burning sensation on the skin upon contact, and blistering in about half an hour. None of the other blister agents are as delayed as HD in their effects. Decontamination of the blister agents must be accomplished within 1 to 2 minutes after the receipt of the contamination if serious effects are to be prevented. The nerve agents and the blood agents, with the single exception of arsine (SA), are characterized by the great rapidity with which they act. First aid measures such as administering antidote, generally must be carried out within 2 minutes after lethal dosages of these agents have been absorbed if death is to be averted. The vomiting agents also exert their effects within a short time after being inhaled.

CHAPTER 3

SPECIFIC CHEMICAL AGENTS AND THEIR PROPERTIES

Note. This chapter contains the physical, chemical, and physiological properties of specific chemical agents which might be used or encountered in the field. Brief information is also given on their use, detection, identification, decontamination, and protective measures to be taken against them. A comparison of the properties of the chemical agents is given in table I.

Section I. TOXIC CHEMICAL AGENTS

29. Choking Agents

a. General. Choking agents injure unprotected man chiefly in the respiratory tract—that is, in the nose, throat, and particularly the lungs. In extreme cases, membranes swell, lungs become filled with liquid, and death results from lack of oxygen; thus these agents "choke" an unprotected man. Fatalities of this type are referred to as "dry-land drownings."

b. Phosgene (CG).

(1) *General.* CG, normally a chemical agent with a short duration of effectiveness, was used extensively in World War I. In fact, more than 80 percent of World War I chemical agent fatalities were caused by CG. Because of its long history, CG has been more fully evaluated perhaps than any other chemical agent.

(2) *Chemical name.* Carbonyl chloride.

(3) *Formula.* $COCl_2$.

(4) *Molecular weight.* 98.92.

(5) *Vapor density (compared to air).* 3.4.

(6) *Liquid density.* 1.38 at 20° C.

(7) *Freezing point.* —128° C. (Also given as —118° and —104° C.)

(8) *Boiling point.* 7° C.

(9) *Vapor pressure.* 1,173 mm Hg at 20° C.; 555 mm Hg at 0° C.; 365 mm Hg at —10° C.

(10) *Volatility.* 422,000 mg/m³ at —40° C.; 2,200,000 mg/m³ at —10° C.; 6,370,000 mg/m³ at 20° C.

(11) *Flash point.* None.

(12) *Decomposition temperature.* 800° C.

(13) *Latent heat of vaporization.* 60 calories per gram.

(14) *Rate of hydrolysis.* Not readily hydrolyzed under usual field conditions; however, rain destroys its effectiveness, and heavy vegetation, jungle, and forests cause considerable loss of CG by hydrolysis on leaf surfaces.

(15) *Hydrolysis products.* Hydrogen chloride and carbon dioxide.

(16) *Stability in storage.* Stable in steel containers if CG is dry.

(17) *Action on metals or other materials.* None when CG is dry; acidic and corrosive when it is moist.

(18) *Odor.* New-mown hay or grass; green corn.

(19) *Median lethal dosage.* The LCt_{50} is 3,200 mg-min/m³. Since the effects of CG are cumulative, this Ct is not significantly changed with variations in time of exposure (within reasonable limits, par. 25).

(20) *Median incapacitating dosage.* 1,600 mg-min/m³.

(21) *Rate of detoxification.* Not detoxified; cumulative.

(22) *Skin and eye toxicity.* None.

(23) *Rate of action.* Delayed. Although immediate symptoms may follow exposure to a high concentration of CG, a delay of 3 hours or more may elapse before exposure to a low concentration causes any ill effects.

(24) *Physiological action.* CG exerts its effect solely on the lungs, and results

in damage to the capillaries. It causes seepage of watery fluid into the air sacs. When a lethal amount of CG is received, the air sacs become so flooded that air is excluded and the victim dies of anoxia (oxygen deficiency). If the amount of CG is less than lethal, and proper care is provided, the watery fluid is reabsorbed, the air cell walls heal, and the patient recovers. The severity of poisoning cannot be estimated from the immediate symptoms, since the full effect is not usually apparent until 3 or 4 hours after exposure. Most deaths occur within 24 hours.

(25) *Protection required.* Protective mask.

(26) *Decontaminants.* For confined areas, aeration. (Decontamination is not required in the field.)

(27) *Munitions suitable for use.* Mortar shell, bombs, rockets, and cylinders.

(28) *Duration of effectiveness.* Short. However, vapor may persist for some time in low places under calm or light winds and stable atmospheric conditions (inversion).

(29) *Use.* Delayed-action casualty agent.

c. *Diphosgene (DP).*

(1) *General.* As a shell filling, DP has the advantage of a high boiling point which permits filling in the field, whereas CG, with a low boiling point, must be kept refrigerated during filling operations under summer conditions. However, DP does have certain disadvantages. Since it is slightly lacrimatory, troops are not as easily surprised as with CG. Furthermore, its lower volatility adds to the difficulty of setting up an effective surprise concentration. (DP is converted to CG in the body and exerts its effect after this conversion.)

(2) *Chemical name.* Trichloromethyl chloroformate.

(3) *Formula.* $ClCOOCCl_3$.

(4) *Molecular weight.* 197.85.

(5) *Vapor density (compared to air).* 6.9.

(6) *Liquid density.* 1.66 at 20° C.

(7) *Freezing point.* —57° C.

(8) *Boiling point.* 127° to 128° C.

(9) *Vapor pressure.* 10.3 mm Hg at 20° C.; 2.4 mm Hg at 0° C.

(10) *Volatility.* 19,300 mg/m^3 at 0° C.; 54,300 mg/m^3 at 20° C; 72,500 mg/m^3 at 25° C. The volatility of DP is much lower than that of CG; this lower volatility gives DP a duration of effectiveness of about three times that of CG under similar conditions.

(11) *Flash point.* None.

(12) Decomposition temperature. 301° to 351° C. (Yields two molecules of CG.)

(13) *Latent heat of vaporization.* Data not available, but this property is unimportant in a chemical agent such as DP which is liquid even at high summer temperatures and which evaporates at a moderate rate.

(14) *Rate of hydrolysis.* Slow at ordinary temperatures.

(15) *Hydrolysis products.* Hydrogen Chloride and carbon dioxide.

(16) *Stability in storage.* Unstable because of conversion to CG.

(17) *Action on metals or other materials.* Metals act as catalyzers in conversion to CG.

(18) *Odor.* New-mown hay or grass; green corn.

(19) *Median lethal dosage.* 3,200 mg-min/m^3. Since the effects of DP are cumulative, the Ct is not significantly changed with variations in time of exposure (within reasonable limits, par. 25).

(20) *Median incapacitating dosage.* 1,600 mg-min/m^3.

(21) *Rate of detoxification.* Not detoxified; cumulative.

(22) *Skin and eye toxicity.* No effect on skin; slight lacrimatory effect.

(23) *Rate of action.* Delayed. Although immediate symptoms may follow exposure to a high concentration of DP, a delay of 3 hours or more may elapse before exposure to a low concentration causes any ill effects.

(24) *Physiological action.* Since DP is converted to CG in the body, the physiological action is the same for both agents. The casualty effect is exerted solely on the lungs and results in damage to capillaries.

(25) *Protection required.* Protective mask.

(26) *Decontaminants.* For confined area, live steam, ammonia, and aeration. (Decontamination is not required in the field.)

(27) *Munitions suitable for use.* Mortar shell, large-caliber artillery shell, bombs, and rockets.

(28) *Use.* Delayed or immediate-action casualty agent, depending upon dosage rate.

30. Nerve Agents

a. General. While the nerve agents differ in molecular structure, they have the same physiological action on man in that they upset the balance between the sympathetic (adrenergic) and parasympathetic (cholinergic) nervous systems which together are the autonomic nervous system. Normally in the body there is controlled discharge within the nervous system due to destruction by cholinesterase of acetylcholine, a product of nerve cell metabolism. The nerve agents were found by German scientists to react with the cholinesterase in an irreversible reaction in tissue fluid permitting accumulation of acetylcholine and continual stimulation of the nervous system. Rapid use of so-called autonomic blocking agents which act directly on the effector nerve cell will nullify the effect of acetylcholine. No apparent chemical reaction seems to occur between these autonomic blocking agents and acetylcholine. Atropine salts are the most commonly used autonomic blocking agents. Because the major action of these chemical agents is on the parasympathetic nerve system, they are often popularly called nerve agents. Analysis of these agents disclosed the physical and chemical properties discussed below.

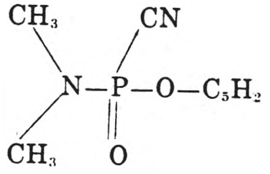
b. Tabun (GA).

(1) *General.* A colorless to brownish liquid giving a colorless vapor.

(2) *Chemical name.* Dimethylaminoethoxy-cyanophosphine oxide.

(3) *Formula.*

(*a*) *Structural.*



(*b*) *Molecular.* $(CH_3)_2N(C_2H_5O)CNPO$.

(4) *Molecular weight.* 162.3.

(5) *Vapor density (compared with air).* 5.63.

(6) *Liquid density.* 1.073 at 25° C.

(7) *Freezing point.* —49° to —50° C.

(8) *Boiling point.* 246° C.

(9) *Vapor pressure.* 0.070 mm Hg at 25° C.

(10) *Volatility.* 90 mg/m^3 at 0° C.; 610 mg/M^3 at 25° C.; 858 mg/m^3 at 30° C.

(11) *Flash point.* 78° C.

(12) *Decomposition temperature.* 130° C.

(13) *Latent heat of vaporization.* 79.56 calories per gram (average value between 25° and 50° C.).

(14) *Rate of hydrolysis.* Reacts slowly with water but fairly rapidly with strong acids or alkalies; self buffering at pH 4 to 5. Autocatalytic below pH 4, due to presence of HCN. Half life 7 hours at pH 4 to 5. Hydrolysis catalyzed by phosphate.

(15) *Hydrolysis products.* HCN and other products.

(16) *Stability in storage.* Stable in steel containers at ordinary temperature.

(17) *Action on metals or other materials.* None.

(18) *Odor.* Faintly fruity; none when pure.

(19) *Median concentration detectable (by eye effects).* 3.2 mg/m^3.

(20) *Median lethal dosage (respiratory).* Approximately 40 $mg\text{-}min/m^3$ for resting men. Median incapacitating dosage (respiratory) approximately 300 $mg\text{-}min/m^3$ for resting men.

(21) *Rate of detoxification.* Slight but definite.

(22) *Skin and eye toxicity.*

(*a*) *Eye effect.* Very high toxicity; much greater through eye than through skin. Vapor causes pupil of eye to contract, resulting in difficulty in seeing in dim light.

(*b*) *Skin effect.* LD_{50} (liquid) 1–1.5 gm/man. Liquid decontamination of smallest drop is essential. Vapor penetrates skin readily. Skin LCt_{50} of vapor is not known exactly—probably between 20,000 and 40,000 $mg\text{-}min/m^3$.

(23) *Rate of action.* Very rapid.

(24) *Physiological symptoms.* Individuals poisoned by GA display approximately the same sequence of symptoms regardless of the route by which the poison enters the body (whether by inhalation, absorption, or ingestion). These symptoms, in normal order of appearance, are: running nose; tightness of chest; dimness of vision and pinpointing of the eye pupils; difficulty in breathing; drooling and excessive sweating; nausea; vomiting, cramps, and involuntary defecation and urination; twitching, jerking, and staggering; and headache, confusion, drowsiness, coma, and convulsion. These symptoms are followed by cessation of breathing and death. Symptoms appear much more slowly from skin dosage than from respiratory dosage. Although skin absorption great enough to cause death may occur in 1 to 2 minutes, death may be delayed for 1 to 2 hours. Respiratory lethal dosages kill in 1 to 10 minutes, and liquid in the eye kills nearly as rapidly. The number and severity of symptoms which appear are dependent on the quantity and rate of entry of the nerve agent which is introduced into the body. (Very small skin dosages sometimes cause local sweating and tremors with little other effect.)

(25) *Protection required.* Protective mask and protective clothing. Ordinary clothing gives off GA for about 30 minutes after contact with vapor. This should be considered before unmasking. Immediately remove all liquid from clothing.

(26) *Decontaminants.* Bleach slurry, dilute alkali solutions, or DS2. In confined area, steam and ammonia. Hot soapy water.

(27) *Munitions suitable for use.* Mortar shell, artillery shell, bombs, spray, and rockets.

(28) *Duration of effectiveness.* Depends upon munitions used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions.

(29) *Use.* Quick-acting casualty agent.

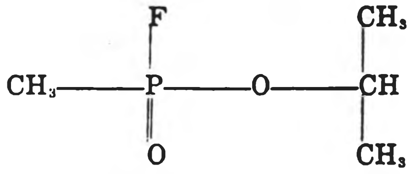
c. Sarin (GB).

(1) *General.* A colorless liquid; its vapor is also colorless.

(2) *Chemical name.* Methylisopropoxyfluoro-phosphine oxide.

(3) *Formula.*

(*a*) *Structural.*



$$\mathrm{CH_3{-}\overset{F}{\underset{\overset{\|}{O}}{P}}{-}O{-}\overset{CH_3}{\underset{CH_3}{CH}}}$$

(*b*) *Molecular.* $CH_3(C_3H_7O)FPO$.

(4) *Molecular weight.* 140.10.

(5) *Vapor density* (compared with air). 4.86.

(6) *Liquid density.* 1.0887 at 25° C.

(7) *Freezing point.* —56° C.

(8) *Boiling point.* 147° C.

(9) *Vapor pressure.* 2.2 mm Hg at 25° C.

(10) *Volatility.* 2,850 mg/m^3 at 0° C.; 16,800 mg/m^3 at 25° C.; 23,000 mg/m^3 at 30° C.

(11) *Flash point.* Nonflammable.

(12) *Decomposition temperature.* Not available.

(13) *Latent heat of vaporization.* 84.93 calories per gram (average value between 25° and 50° C.).

(14) *Rate of hydrolysis.* Variable with pH. Half life 7.5 hours at pH 1.8; 30 hours

in unbuffered solution. Very rapidly hydrolyzed in alkaline solutions.

(15) *Hydrolysis products*. HF under acid conditions; isopropyl alcohol and polymers under alkaline conditions.

(16) *Stability in storage*. Fairly stable in steel at 65° C. Stability improves with increasing purity.

(17) *Action on metals or other materials*. Slightly corrosive to steel.

(18) *Odor*. Almost none in pure state.

(19) *Median lethal dosage (respiratory)*. 100 mg-min/m^3 for resting man; 70 mg-min/m^3 for men engaged in mild activity.

(20) *Median incapacitating dosage (respiratory)*. 75 mg-min/m^3 for resting man; 35 mg-min/m^3 for man engaged in mild activity.

(21) *Rate of detoxification*. Low detoxification rate; essentially cumulative.

(22) *Skin and eye toxicity*.

(*a*) *Eye effect*. Very high toxicity; much greater through eye than through skin. Vapor causes pupil of eye to contract; vision difficult in dim light.

(*b*) *Skin effect*. LD_{50} 1.7 gm/man. Liquid does not injure skin but penetrates it rapidly. Immediate decontamination of the smallest drop is essential. Vapor penetrates skin also. Skin LCt_{50} of vapor is approximately 12,000 mg-min/m^3 for naked man, and 15,000 mg-min/m^3 for man in ordinary combat clothing. Median incapacitating dosage from vapor on skin is approximately 8,000 mg-min/m^3 with ordinary clothing.

(23) *Rate of action*. Very rapid—death usually within 15 minutes after fatal dosage absorbed.

(24) *Physiological symptoms*. Individuals poisoned by GB display approximately the same sequence of symptoms regardless of the route by which the poison enters the body (whether by inhalation, absorption, or ingestion). These symptoms, in normal order of appearance, are: running nose; tightness of chest; dimness of vision and pinpointing of the eye pupils; difficulty in breathing; drooling and excessive sweating; nausea, vomiting, cramps, and involuntary defecation and urination; twitching, jerking, and staggering; and headache, confusion, drowsiness, coma, and convulsion. These symptoms are followed by cessation of breathing and death. Symptoms appear much more slowly from skin dosage than from respiratory dosages. Although skin absorption great enough to cause death may occur in 1 to 2 minutes, death may be delayed for 1 to 2 hours. Respiratory lethal dosages kill in 1 to 10 minutes, and liquid in the eye kills nearly as rapidly. The number and severity of symptoms which appear are dependent on the quantity and rate of entry of the nerve agent which is introduced into the body. (Very small skin dosages sometimes cause local sweating and tremors with little other effect.)

(25) *Protection required*. Protective mask and protective clothing. Ordinary clothing gives off GB for about 30 minutes after contact with vapor. This should be considered before unmasking. Immediately remove all liquid contamination on clothing.

(26) *Decontaminants*. Bleach slurry, dilute alkali solution, or DS2. In confined area, steam and ammonia. Hot soapy water.

(27) *Munitions suitable for use*. Mortar shell, artillery shell, bombs, spray, and rockets.

(28) *Duration of effectiveness*. Evaporates at approximately the same rate as water. Depends upon munitions used and the weather.

(29) *Use*. Quick-acting casualty agent.

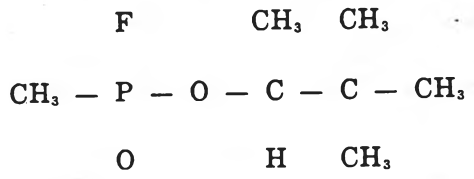
d. Soman (GD).

(1) *General*. GD is a colorless liquid which gives off a colorless vapor.

(2) *Chemical name*. Methylpinacolyloxyfluorophosphine oxide.

(3) *Formula.*

(*a*) *Structural.*



$$\mathrm{CH_3}-\underset{\mathrm{O}}{\overset{\mathrm{F}}{\mathrm{P}}}-\mathrm{O}-\underset{\mathrm{H}}{\overset{\mathrm{CH_3}}{\mathrm{C}}}-\underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{C}}}-\mathrm{CH_3}$$

(*b*) *Molecular.* $CH_3(C_6H_{13}O)FPO$.

(4) *Molecular weight.* 182.178.

(5) *Vapor density (compared with air).* 6.33.

(6) *Liquid density.* 1.0222 at 25° C.

(7) *Freezing point.* Not exact (solidifies to noncrystalline glasslike material).

(8) *Boiling point.* 167° C.

(9) *Vapor pressure.* 0.31 mm Hg at 25° C.

(10) *Volatility.* 4,480 mg/m^3 at 30° C.; 3,060 mg/m^3 at 25° C.; 370 mg/m^3 at 0° C.

(11) *Flash point.* High enough not to interfere with military use.

(12) *Decomposition temperature.* Not available.

(13) *Latent heat of vaporization.* 78.49 calories per gram (average value between 25° and 50° C.).

(14) *Rate of hydrolysis.* Varies with pH; complete in 5 minutes in 5 percent NaOH solutions.

(15) *Hydrolysis products.* Essentially HF.

(16) *Stability in storage.* Less stable than GA and GB.

(17) *Action on metals or other materials.* Slightly corrosive to metals.

(18) *Odor.* Fruity; with impurities, odor of camphor.

(19) *Median incapacitating dosage.* GB, GA range.

(20) *Rate of detoxification.* Low detoxification rate; essentially cumulative.

(21) *Skin and eye toxicity.*

(*a*) *Eye effect.* Very high toxicity; vapor causes pupil of eye to contract, resulting in difficulty in seeing in dim light. Toxicity much greater through eye than through skin.

(*b*) *Skin effect.* Extremely toxic by skin absorption. Liquid does not injure skin, but penetrates it rapidly. Immediate decontamination of smallest drop is essential. Skin LCt_{50} of vapor is not known.

(22) *Rate of action.* Very rapid. Death usually occurs within 15 minutes after fatal dosage is absorbed.

(23) *Physiological symptoms.* Individuals poisoned by GD display approximately the same sequence of symptoms regardless of the route by which the poison enters the body (whether by inhalation, absorption, or ingestion). These symptoms, in normal order of appearance, are: running nose; tightness of chest; dimness of vision and pinpointing of the eye pupils; difficulty in breathing; drooling and excessive sweating; nausea, vomiting, cramps, and involuntary defecation and urination; twitching, jerking, and staggering; and headache, confusion, drowsiness, coma, and convulsion. These symptoms are followed by cessation of breathing and death. Symptoms appear much more slowly from skin dosage than from respiratory dosages. Although skin absorption great enough to cause death may occur in 1 to 2 minutes, death may be delayed for 1 to 2 hours. Respiratory lethal dosages kill in 1 to 10 minutes, and liquid in the eye kills nearly as rapidly. The number and severity of symptoms which appear are dependent on the quantity and rate of entry of the nerve agent which is introduced into the body. (Very small skin dosages somes cause local sweating and tremors with little other effect.)

(24) *Protection required.* Protective mask and protective clothing. Ordinary clothing gives off GD for about 30 minutes after contact with vapor. This should be considered before unmasking. Immediately remove all liquid contamination on clothing.

(25) *Decontaminants.* Bleach slurry and dilute alkali solutions. In confined area, steam and ammonia. Hot soapy water.

(26) *Munitions suitable for use.* Mortar shell, artillery shell, bombs, and spray.

(27) *Duration of effectiveness.* Depends upon munitions used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions.

(28) *Use.* Quick-acting casualty agent.

e. V-agents. The standard V-agent is VX.

(1) *General characteristics.* Included in the category of nerve agents are the V-agents. V-agents are generally colorless and odorless liquids which do not evaporate rapidly or freeze at normal temperatures. Because of their low volatility, their vapor effect is limited and the duration of their effectiveness is increased. V-agents are absorbed by vegetation.

(2) *Effects.* In liquid or aerosol form, V-agents affect the body in a manner similar to that of the G-agents. V-agents are usually disseminated as liquid droplets which produce casualties when absorbed through the skin. Since liquid G-agents evaporate quickly from the skin, the dosage required to produce casualties by that route is high and the time to appearance of casualties is correspondingly short as compared with the much less volatile V-agents. If evaporation is excluded, the time to appearance of casualties would be roughly similar at the same dose level with both V-agents and G-agents. Aerosolized V-agents produce casualties by inhalation and by absorption of agent droplets through the skin.

(3) *Protection required.* Field protective mask and permeable (impregnated) protective clothing protect against vapor; impermeable clothing provides protection against liquid droplets.

(4) *Decontamination.* For personnel decontamination, V-agents may be effectively removed from the skin by use of protective ointment or a 5 percent solution of sodium hypochlorite (household bleach(in water. Prompt decontamination of skin is imperative; decontamination undertaken within 1 minute after contamination is twice as effective as it would be if delayed 5 minutes. For decontamination by means of showering, the body should be first flushed with copious quantities of cold water, then washed with plenty of soapy warm water. Surfaces and material can be effectively decontaminated with supertropical bleach, slurry, DANC solution, or DS2 solution. See TM 3–220.

(5) *Use.* Quick-acting casualty agent with a normally long duration of effectiveness.

(6) *Munitions suitable for use.* Large-caliber artillery shell, spray, rockets, and mines.

31. Blood Agents

a. General. Blood agents are absorbed into the body primarily by breathing. They affect bodily functions through action on the enzyme cytochrome-oxidase, thus preventing the normal transfer of oxygen from the blood to body tissue.

b. Hydrogen Cyanide (AC).

(1) *Chemical name.* Hydrogen cyanide or hydrocyanic acid.

(2) *Formula.* HCN.

(3) *Molecular weight.* 27.02.

(4) *Vapor density (compared to air).* 0.93.

(5) *Liquid density.* 0.697 at 10° C.

(6) *Freezing point.* –14° C.

(7) *Boiling point.* 26° C.

(8) *Vapor pressure.* 757 mm Hg at 26° C.

(9) *Volatility.* 37,000 mg/m^3 at –40° C.; 1,075,000 mg/m^3 at 25° C.

(10) *Flash point.* Low. Agent is ignited 50 percent of the time when disseminated from artillery shell.

(11) *Decomposition temperature.* Above 65.5° C.

(12) *Latent heat of vaporization.* 210 calories per gram.

(13) *Rate of hydrolysis.* Low under field conditions.

(14) *Hydrolysis products.* NH_3, HCOOH, and amorphous brown solids.

(15) *Stability in storage.* Unstable except when very pure. Forms explosive polymer on long standing. Can be stabilized by addition of small amounts of phosphoric acid or sulphur dioxide.

(16) *Action on metals or other materials.* Little or none.

(17) *Odor.* Similar to peach kernels.

(18) *Median lethal dosage.* Median lethal dosage varies widely with concentration because of the rather high rate at which AC is detoxified by the body. For example, at 200 mg/m^3 concentration, the lethal dosage is approximately 2,000 $mg\text{-}min/m^3$, whereas at 150 mg/m^3 the lethal dosage is approximately 4,500 $mg\text{-}min/m^3$.

(19) *Median incapacitating dosage.* Varies with the concentration.

(20) *Rate of detoxification.* Rapid—0.017 mg/kg/min.

(21) *Skin and eye toxicity.* Moderate.

(22) *Rate of action.* Very rapid. Death occurs within 15 minutes after a lethal dosage has been received.

(23) *Physiological action.* AC interferes with utilization of oxygen by the body tissues by inhibition of the enzyme cytochrome-oxidase. AC causes a marked stimulation of the breathing rate.

(24) *Protection required.* Protective mask. Personnel handling the liquid agent should also wear protective clothing.

(25) *Decontaminants.* None required under field conditions.

(26) *Munitions suitable for use.* Mortar shell, bombs, and rockets.

(27) *Duration of effectiveness.* Short; the agent is highly volatile, and in the gaseous state it is lighter than air.

(28) *Use.* Quick-acting casualty agent.

c. Cyanogen Chloride (CK).

(1) *Chemical name.* Cyanogen chloride.

(2) *Formula.* CNCl.

(3) *Molecular weight.* 61.48.

(4) *Vapor density (compared to air).* 2.1.

(5) *Liquid density.* 1.18 at 20° C.

(6) *Freezing point.* —7° to —5° C.

(7) *Boiling point.* 13° C.

(8) *Vapor pressure.* 1,010 mm Hg at 20° C.

(9) *Volatility.* 6,132,000 mg/m^3 at 25° C.

(10) *Flash point.* None.

(11) *Decomposition temperature.* Above 100° C.

(12) *Latent heat of vaporization.* 103 calories per gram. This is sufficiently high to provide a satisfactory pancaking effect.

(13) *Rate of hydrolysis.* Very low.

(14) *Hydrolysis products.* HCl and (HOCN).

(15) *Stability in storage.* Stable at 65° C. for 30 days. Tends to undergo condensation or polymerization in storage to form the solid compound, cyanuric chloride $C_3N_3Cl_3$ (cyclic). Impurities promote polymerization which may occur with explosive violence.

(16) *Action on metals or other materials.* None if CK is dry.

(17) *Odor.* Its irritating and lacrimatory properties are so great that the odor can go unnoticed.

(18) *Median concentration detectable (by lacrimatory effect).* 12 mg/m^3.

(19) *Median lethal dosage.* 11,000 $mg\text{-}min/m^3$.

(20) *Median incapacitating dosage.* 7,000 $mg\text{-}min/m^3$.

(21) *Rate of detoxification.* 0.02 to 0.1 mg/kg/min.

(22) *Skin and eye toxicity.* Too low to be of military importance; highly irritating to eyes and mucous membranes.

(23) *Rate of action.* Not available. It is assumed that the effect of CK arises from its conversion to AC in the body. In general, CK may be considered a rapid-acting chemical agent.

(24) *Physiological action.* The general action of CK is similar to that of AC—it

interferes with utilization of oxygen by the body tissues. However, it differs from AC in that it has a choking effect, has a strong irritating effect, and causes a slow breathing rate.

(25) *Protection required.* Protective mask. CK will break or penetrate a protective mask canister or filter element more readily than most other agents; however, a very high concentration is required.

(26) *Decontaminants.* None required under field conditions.

(27) *Munitions suitable for use.* Mortar shell, bombs, rockets, and grenades.

(28) *Duration of effectiveness.* Short. Vapor may persist in jungle and forest for some time under suitable weather conditions.

(29) *Use.* Quick-acting casualty agent. Used for filter element penetration.

d. Arsine (SA).

(1) *Chemical name.* Arsenic trihydride, arsine.

(2) *Formula.* AsH^3.

(3) *Molecular weight.* 77.93.

(4) *Vapor density (compared to air).* 2.69.

(5) *Liquid density.* 1.34 at 20° C.

(6) *Freezing point.* —114° C.

(7) *Boiling point.* —63° C.

(8) *Vapor pressure.* 11,360 mm Hg at 20° C. This high vapor pressure means that SA is difficult to liquefy and to store.

(9) *Volatility.* 30,900,000 mg/m^3 at 0° C. This is by far the highest volatility found among the compounds considered for tactical use as chemical agents. This fact, coupled with a relatively low latent heat of vaporization, qualifies SA as the most rapidly dispersing chemical agent.

(10) *Flash point.* SA ignites so easily that it cannot be used in shells. It may also explode in air.

(11) *Decomposition temperature.* 280° C.

(12) *Latent heat of vaporization.* 53 calories per gram.

(13) *Rate of hydrolysis.* Rapid, but an equilibrium condition is reached quickly. (Under certain conditions, SA forms a solid product with water which decomposes at 30° C.)

(14) *Hydrolysis products.* Arsenic acids and a hydride containing fewer hydrogen atoms than SA itself.

(15) *Stability in storage.* Not stable in uncoated metal containers. Metals catalyze decomposition of SA.

(16) *Action on metals and other materials.* Reacts slowly with copper, brass, and nickel. May also be decomposed by contact with other metals.

(17) *Odor.* Mild garliclike odor.

(18) *Median lethal dosage.* 5,000 $mg\text{-}min/m^3$. It is estimated that 2 milligrams of SA per kilogram of body weight would be lethal to man.

(19) *Median incapacitating dosage.* 2,500 $mg\text{-}min/m^3$.

(20) *Rate of detoxification.* Not rapid enough to be of importance.

(21) *Skin and eye toxicity.* None.

(22) *Rate of action.* Effects are delayed from 2 hours to as much as 11 days.

(23) *Physiological action.* SA interferes with functioning of the blood, and damages the liver and kidneys. Slight exposure causes headache and uneasiness. Increased exposure causes chills, nausea, and vomiting. Severe exposure damages blood, causing anemia.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* None required.

(26) *Munitions suitable for use.* No munition is yet available for dissemination of SA because of its high vapor pressure and low stability.

(27) *Duration of effectiveness.* Short.

(28) *Use.* Delayed-action casualty agent.

32. Blister Agents

The blister agents are used for casualty effect; the use of ground may be restricted, movements slowed, and use of materiel or installation hampered. These agents affect the eyes and lungs and blister the skin. During

World War I mustard was the only blister agent in major use. It was recognized by a distinctive odor and had a fairly high duration of effectiveness under normal conditions. Since then, blister agents have been developed which are odorless and vary in duration of effectiveness. Most blister agents are insidious in action; there is little or no pain at the time of exposure except to L and phosgene oxime (CX) which causes immediate pain on contact. The development of casualties is somewhat delayed. CX produces a wheal (similar to a bee sting) rather than a water blister which the other blister agents produce. Protection from blister agents is extremely difficult since they attack any part of the body which comes in contact with the liquid or vapor.

a. Arsenicals. The arsenicals are a group of related compounds in which arsenic is the central atom. In these agents the hydrogen atoms of AsH_3 are replaced by various organic radicals and chloride or cyanide. The arsenical chemical agents discussed under blister agents (*j* through *n* below) include L, mustard-lewisite mixture (HL), phenyldichloroarsine (PD), ethyldichloroarsine (ED), and methyldichloroarsine (MD). Disadvantages of these agents are that they hydrolyze rapidly and are not as toxic as other blister agents.

b. Levinstein Mustard (H). This is mustard made by the Levinstein process. It contains about 30 percent sulfur impurities, which give it a pronounced odor. The properties of H are essentially the same as those listed for HD in *c* below.

c. Distilled Mustard (HD).

(1) *General.* HD is H which has been purified by washing and vacuum distillation. HD, however, has less odor and a slightly greater blistering power (negligble in the field) than H, and is more stable in storage.

(2) *Chemical name.* 2,2'-dichloro-diethyl sulfide.

(3) *Formula.* $(ClCH_2CH_2)_2S$.

(4) *Molecular weight.* 159.08.

(5) *Vapor density (compared to air).* 5.4

(6) *Liquid density.* 1.27 at 20° C.

(7) *Solid density.* 1.37 at 0° C.

(8) *Freezing point.* 14° C.

(9) *Boiling point.* 227.8° C.

(10) *Vapor pressure.* 0.072 mm Hg at 20° C.

(11) *Volatility.* 22 mg/m^3 at −18° C. (solid); 75 mg/m^3 at 0° C. (solid); 610 mg/m^3 at 20° C. (liquid); 2,857 mg/m^3 at 40° C. (liquid).

(12) *Flash point.* 105° C. Low enough to cause occasional ignition if explosive charges in the shell are too great.

(13) *Decomposition temperature.* 149° to 177° C.

(14) *Latent heat of vaporization.* 94 calories per gram. (This property is not of great importance in a chemical agent of low volatility as the sustained vapor concentration is essentially a function of the temperature of the surroundings.)

(15) *Rate of hydrolysis.* Very slow at ordinary temperature.

(16) *Hydrolysis products.* Hydrogen chloride and thiodiglycol.

(17) *Stability in storage.* Stable in steel or aluminum containers.

(18) *Action on metals or other materials.* Very little when pure.

(19) *Odor.* Garliclike.

(20) *Median lethal dosage.*

 (*a*) *Inhalation.* 1,500 mg-min/m^3.

 (*b*) *Skin absorption (masked personnel).* 10,000 mg-min/m^3.

(21) *Median incapacitating dosage.*

 (*a*) *Eye injury.* 200 mg-min/m^3.

 (*b*) *Skin absorption (masked personnel).* 2,000 mg-min/m^3. Wet skin absorbs more mustard than dry skin. For this reason, HD exerts a casualty effect at lower concentrations in hot humid weather, since the body is then moist with perspiration. The dosage given above for skin absorption applies to temperatures of approximately 21° to 27° C., as the body would not normally be perspiring at these temperatures. Above 27° C., perspiration causes increased skin absorption. The incapacitating dosage drops rapidly as perspiration increases; at 32° C., 1,000 mg-min/m^3 could be incapacitating.

(22) *Rate of detoxification.* Very low. Even very small repeated exposures are cumulative in their effects or more than cumulative due to sensitization. This has been shown in the postwar case histories of workers in mustard-filling plants. Exposure to vapors from spilled HD causes minor symptoms, such as "red eye." Repeated exposure to such vapors produces 100 percent disability by irritating the lungs and causing a chronic cough and pain in the chest.

(23) *Skin and eye toxicity.* Eyes are very susceptible to low concentrations; higher concentrations are required to produce incapacitating effects by skin absorption than by eye injury.

(24) *Rate of action.* Delayed—usually 4 to 6 hours until first symptoms appear. Latent periods have been observed, however, up to 24 hours and, in rare cases, up to 12 days.)

(25) *Physiological action.* Mustard acts first as a cell irritant and finally as a cell poison on all tissue surfaces contacted. The first symptoms of HD poisoning usually appear in from 4 to 6 hours; the higher the concentration, the shorter the interval of time between the exposure to the agent and the first symptoms. The physiological action of HD may be classified as local and general. The local action results in conjunctivitis or inflammation of the eyes; erythema (redness of the skin) which may be followed by blistering or ulceration; and inflammation of the nose, throat, trachea, bronchi, and lung tissue. Susceptibility also varies with individuals. Injuries produced by HD heal much more slowly and are more liable to infection than burns of similar intensity produced by physical means or by other chemicals. This is due to the action of HD in making the blood vessels incapable of carrying out their functions of repair, and by the fact that necrotic (dead or dying) tissue acts as a good medium for bacterial growth.

(26) *Protection required.* Protective mask and permeable protective clothing for vapor; impermeable clothing for protection against liquid.

(27) *Decontaminants.* Bleach, DANC solution, M5 ointment, fire, or DS2.

(28) *Munitions suitable for use.* Land mines, spray tanks, bombs, artillery shell, mortar shell, and rockets.

(29) *Duration of effectiveness.* Depends upon munition used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.

(30) *Use.* Delayed-action casualty agent.

d. Nitrogen Mustards. The nitrogen mustards are a group of related compounds which may be considered as derivatives of ammonia (NH_3) because the hydrogen atoms are replaced by various organic radicals. In each of these chemical agents, nitrogen is the central atom. These compounds have recently been discussed in open scientific literature because of the discovery that they possess medicinal value. Three members of the group are described individually in *e* through *g* below.

e. Nitrogen Mustard (HN–1).

(1) *Chemical name.* 2,2′dichloro-triethylamine.

(2) *Formula.* $(ClCH_2CH_2)_2NC_2H_5$.

(3) *Molecular weight.* 170.08.

(4) *Vapor density (compared to air).* 5.9.

(5) *Liquid density.* 1.09 at 25° C.

(6) *Freezing point.* —34° C.

(7) *Boiling point.* 85° C. at 10 mm Hg. At atmospheric pressure, HN–1 decomposes below boiling point.

(8) *Vapor pressure.* 0.25 mm Hg at 25° C.

(9) *Volatility.* 140 mg/m^3 at —10° C.; 329 mg/m^3 at 0° C.; 1,590 mg/m^3 at 20° C.; 3,240 mg/m^3 at 30° C. HN–1 closely parallels HD in the variation of volatility with temperature and is

of little value as a vapor hazard when weather is cold.

(10) *Flash point.* High enough not to interfere with military use of the agent.

(11) *Decomposition temperature.* Decomposes before boiling point is reached.

(12) *Latent heat of vaporization.* 77 calories per gram.

(13) *Rate of hydrolysis.* Quite slow.

(14) *Hydrolysis products.* Hydroxyl derivatives and condensation products. (Intermediate products, all of which are toxic, are produced during hydrolysis.)

(15) *Stability in storage.* Adequate for use in munition.

(16) *Action on metals and other materials.* None.

(17) *Odor.* Faint fishy or musty.

(18) *Median lethal dosage.*
   (*a*) *Inhalation.* 1,500 mg-min/m^3.
   (*b*) *Skin absorption (masked personnel).* 20,000 mg-min/m^3.

(19) *Median incapacitating dosage.*
   (*a*) *Eye injury.* 200 mg-min/m^3.
   (*b*) *Skin absorption (masked personnel).* 9,000 mg-min/m^3.

(20) *Rate of detoxification.* Not detoxified; cumulative.

(21) *Skin and eye toxicity.* Eyes are very susceptible to low concentration; higher concentrations are required to produce incapacitating effects by skin absorption than by eye injury.

(22) *Rate of action.* Delayed—12 hours or longer.

(23) *Physiological action.* Irritates the eyes in dosages which do not significantly damage the skin or respiratory tract, insofar as single exposures are concerned. This irritation appears in a shorter time than that from HD. After mild vapor exposure, there may be no skin lesions. After severe vapor exposures, or after exposure to liquid HN–1, erythema may appear earlier than in HD contamination. There may be irritation and itching as with HD. Later, blisters may appear in the erythematous areas. The skin lesions are similar to those caused by HD. Effects on the respiratory tract include irritation of the nose and throat, hoarseness progressing to loss of voice, and a persistent cough. Fever, labored respiration, and moist rales may develop. Bronchopneumonia may appear after the first 24 hours. Following ingestion or systemic absorption, the HN–1's cause inhibition of cell mitosis resulting in depression of the blood-forming mechanism and injury to other tissues. Severe diarrhea, which may be hemorrhagic, occurs. Lesions are most marked in the small intestine and consist of degenerative changes and necrosis in the mucous membranes. Ingestion of 2 to 6 milligrams causes nausea and vomiting.

(24) *Protection required.* Protective mask and permeable protective clothing for vapor; impermeable clothing for protection against liquid.

(25) *Munitions suitable for use.* Land mines, artillery shell, mortar shell, bombs, rockets, and spray tanks.

(26) *Duration of effectiveness.* Depends on munitions used and the weather. Somewhat shorter than HD whose heavily splashed liquid persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.

(27) *Use.* Delayed-action casualty agent.

f. Nitrogen Mustard (HN–2).

(1) *General.* HN–2 is highly unstable and is no longer seriously considered as a chemical agent. It is rated as somewhat more toxic than HN–1.

(2) *Chemical name.* 2,2′dichloro-diethyl methylamine.

(3) *Formula.* $(ClCH_2CH_2)_2NCH_3$.

(4) *Molecular weight.* 156.07.

(5) *Vapor density (compared to air).* 5.4.

(6) *Liquid density.* 1.15 at 20° C.

(7) *Freezing point.* —65° to —60° C.

(8) *Boiling point.* 75° C. at 15 mm Hg. At atmospheric pressure, HN–2 decomposes below boiling point.

(9) *Vapor pressure.* 0.29 mm Hg at 20° C.; 1.16 mm Hg at 40° C.; 5,106 mg/m^3 at 30° C.; 9,300 mg/m^3 at 40° C.

(10) *Volatility.* 2,580 mg/m^3 at 25° C.

(11) *Flash point.* High enough not to interfere with military use of the agent.

(12) *Decomposition temperature.* Decomposes before boiling point is reached. Instability of HN–2 is associated with its tendency to polymerize or condense; the reactions involved could generate heat to cause an explosion.

(13) *Latent heat of vaporization.* 78.8 calories per gram.

(14) *Rate of hydrolysis.* In winter, hydrolysis is fairly rapid until 50 percent complete. Alkalies induce hydrolysis.

(15) *Hydrolysis products.* Complex condensates or polymers.

(16) *Stability in storage.* Not stable.

(17) *Action on metals or other materials.* None.

(18) *Odor.*

(*a*) *In dilute form.* Like soft soap.

(*b*) *In high concentrations.* Fruity.

(19) *Median lethal dosage (by inhalation).* 3,000 mg-min/m^3.

(20) *Median incapacitating dosage.*

(*a*) *Eye injury.* 100 mg-min/m^3.

(*b*) *Skin absorption (masked personnel).* Somewhere between the values given for HN–1 and HN–3.

(21) *Rate of detoxification.* Not detoxified.

(22) *Skin and eye toxicity.* HN–2 has the greatest blistering power of the nitrogen mustards in vapor form but is intermediate as a liquid blistering agent. Toxic eye effects are produced more rapidly than by HD.

(23) *Rate of action.* Skin effects delayed 12 hours or longer.

(24) *Physiological action.* Irritates the eyes in dosages which do not significantly damage the skin or respiratory tract, insofar as single exposures are concerned. This irritation appears in a shorter time than that from HD. After a milk vapor exposure, there may be no skin lesions. After a mild vapor exposure, or after exposure to liquid HN–2, erythema may appear earlier than in HD contamination. There may be irritation and itching as with HD. Later, blisters may appear in the erythematous areas. The skin lesions are similar to those caused by HD. Effects on the respiratory tract include irritation of the nose and throat, hoarseness progressing to loss of voice, and a persistent cough. Fever, labored respiration, and moist rales may develop. Bronchopneumonia may appear after the first 24 hours. Following ingestion or systemic absorption, the HN–2's cause inhibition of cell mitosis resulting in depression of the blood-forming mechanism and injury to other tissues. Severe diarrhea, which may be hemorrhagic, occurs. Lesions are most marked in the small intestine and consist of degenerative changes and necrosis in the mucous membranes. Ingestion of 2 to 6 milligrams causes nausea and vomiting.

(25) *Protection required.* Protective mask and permeable protective clothing for vapor; impermeable clothing for protection against liquid.

(26) *Decontaminants.* Bleach, DANC solution, M5 ointment, fire, or DS2.

(27) *Munitions suitable for use.* Land mines, artillery shell, mortar shell, bombs, rockets, and spray tanks.

(28) *Duration of effectiveness.* Depends upon munitions used and the weather. Somewhat shorter than HD whose heavily splashed liquid persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.

(29) *Use.* Delayed-action casualty agent.

g. Nitrogen mustard (HN–3).

(1) *General.* HN–3 is the most stable in storage of the three nitrogen mustards and would seem to be admirably suited for use in artillery shells.

(2) *Chemical name.* 2,2′, 2″-trichlorotriethylamine.

(3) *Formula.* $N(CH_2CH_2Cl)_3$.

(4) *Molecular weight.* 204.54.

(5) *Vapor density (compared to air).* 6.9.

(6) *Liquid density.* 1.24 at 25° C.

(7) *Freezing point.* —4° C.

(8) *Boiling point.* 137° to 138° C. at 15 mm Hg. At atmospheric pressure, HN–3 decomposes below boiling point.

(9) *Vapor pressure.* 0.0109 mm Hg at 25° C.

(10) *Volatility.* 24 mg/m^3 at 0° C.; 120 mg/m^3 at 25° C.; 257 mg/m^3 at 30° C.; 400 mg/m^3 at 40° C. These values indicate that HN–3 would not be a satisfactory substitute for HD. With no greater vapor toxicity than HD, the volatility of HN–3 is too low to yield an effective vapor concentration even under tropical conditions.

(11) *Flash point.* High enough not to interfere with military use of the agent.

(12) *Decomposition temperatures.* Decomposes before boiling point is reached; relatively high.

(13) *Latent heat of vaporization.* 72 calories per gram.

(14) *Rate of hydrolysis.* Very slow.

(15) *Hydrolysis products.* Not identified; probably some hydrogen chloride.

(16) *Stability in storage.* Stable enough for use as a bomb filling even under tropical conditions. However, the agent darkens and deposits a crystalline solid in storage.

(17) *Action on metals or other materials.* None if HN–3 is dry.

(18) *Odor.* None when pure.

(19) *Median lethal dosage.*

- (*a*) *Inhalation.* 1,500 $mg\text{-}min/m^3$.
- (*b*) *Skin absorption (masked personnel).* 10,000 $mg\text{-}min/m^3$.

(20) *Median incapacitating dosage.*

- (*a*) *Eye injury.* 200 $mg\text{-}min/m^3$.
- (*b*) *Skin absorption (masked personnel).* 2,500 $mg\text{-}min/m^3$. This information is based on estimates and indicates that HN–3 closely approaches HD in toxicity and that it is the most toxic of the nitrogen mustards.

(21) *Rate of detoxification.* Not detoxified; cumulative.

(22) *Skin and eye toxicity.* Eyes are very susceptible to low concentrations; higher concentrations are required to produce incapacitating effects by skin absorption.

(23) *Rate of action.* Most symptoms delayed 4 to 6 hours as after exposure to HD but in some cases lacrimation, eye irritation, and photophobia develop immediately.

(24) *Physiological action.* Irritates the eyes in dosages which do not significantly damage the skin or respiratory tract, insofar as single exposures are concerned. This irritation appears in a shorter time than that from mustard. After mild vapor exposure, there may be no skin lesions. After severe vapor exposure, or after exposure to liquid HN–3, erythema may appear earlier than in HD contamination. There may be irritation and itching as with HD. Later, blisters may appear in the erythematous areas. The skin lesions are similar to those caused by HD. Effects on the respiratory tract include irritation of the nose and throat, hoarseness progressing to loss of voice, and a persistent cough. Fever, labored respiration, and moist rales may develop. Bronchopneumonia may appear after the first 24 hours. Following ingestion or systemic absorption, the HN–3's cause inhibition of cell mitosis resulting in depression of the blood-forming mechanism and injury to other tissues. Severe diarrhea, which may be hemorrhagic, occurs. Lesions are most marked in the small intestine and consist of degenerative changes and necrosis in the mucous membranes. Ingestion of 2 to 6 milligrams causes nausea and vomiting.

(25) *Protection required.* Protective mask and permeable protective clothing for vapor; impermeable clothing for protection against liquid.

(26) *Decontaminants.* Bleach, DANC solution, M5 ointment, fire, or DS2.

(27) *Munitions suitable for use.* Land mines, artillery shell, mortar shell, bombs, rockets, and spray tanks.

(28) *Duration of effectiveness.* Considerably longer than HD (see HD).

(29) *Use.* Delayed-action casualty agent.

h. Mustard-T Mixture (HT).

(1) *General.* HT is a mixture of 60 percent HD and 40 percent T. T, a sulfur and chlorine compound similar in structure to HD, is a clear yellowish liquid with an odor similar to HD. HT has a strong blistering effect, has a longer duration of effectiveness, is more stable, and has a lower freezing point than HD. Its low volatility makes effective vapor concentrations in the field difficult to obtain. Properties are essentially the same as those of HD.

(2) *Physiological action.* Causes blisters, irritates the eyes, and is toxic when inhaled.

(3) *Protection required.* Protective mask and permeable protective clothing for vapor; impermeable clothing for protection against liquid.

(4) *Decontaminants.* Bleach, DANC solution, fire, DS2, or M5 ointment.

(5) *Duration of effectiveness.* Depends on munitions used and the weather. Somewhat longer than HD whose heavily splashed liquid persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.

(6) *Use.* Delayed-action casualty agent.

i. Phosgene Oxime (CX). Dichloroformoxime—Cl_2CNOH.

(1) *General characteristics.* CX may appear as a colorless, low-melting point (crystalline) solid or as a liquid. It has a high vapor pressure, slowly decomposes at normal temperatures (depending on temperature and humidity), boils at 53 to 54° C. (28 mm), melts at 39 to 40° C., and is readily soluble in water. It has a disagreeable penetrating odor. CX can be detected in the field by use of the M18, M15A1, and M18A1 chemical agent detector kits. CX is also detected by the M9A2 kit by the blue dot tube, and in the M10A1 kit.

(2) *Effects.* CX is a powerful irritant which produces *immediate* pain varying from a mild prickling sensation to a feeling resembling a severe bee sting. It causes violent irritation to the mucous membrane of the eyes and nose. When it comes in contact with the skin, the area becomes blanched in 30 seconds and is surrounded by a red ring. A wheal forms in about 30 minutes and the blanched area turns brown in about 24 hours, with a scab forming in about a week. The scab generally falls off in about 3 weeks. Itching may be present throughout healing, which in some cases may be delayed beyond 2 months.

(3) *Protection.* A properly fitting protective mask protects the respiratory system; the remainder of the body can be protected by a complete set of protective clothing.

(4) *Decontamination.* Because of its rapid reaction with the skin, decontamination will not be entirely effective after pain occurs. Nevertheless decontamination should be accomplished as rapidly as possible by flushing the area with copious amounts of water to remove any agent which has not reacted with the skin.

j. Lewisite (L).

(1). *Chemical name.* Dichloro (2-chlorovinyl) arsine.

(2) *Formula.* $ClCH{:}CHAsCl_2$.

(3) *Molecular weight.* 207.35.

(4) *Vapor density (compared to air).* 7.2.

(5) *Liquid density.* 1.89 at 20° C.

(6) *Freezing point.* —18° C. ± 0.1° C. (depending on purity and isomers present).

(7) *Boiling point.* 190° C.

(8) *Vapor pressure.* 0.087 mm Hg at 0° C.; 0.394 mm Hg at 20° C.; 32.50 mm Hg at 100° C.

(9) *Volatility.* 967 mg/m^3 at 0° C.; 2,300 mg/m^3 at 20° C.; 8,890 mg/m^3 at 30° C.

(10) *Flash point.* None.

(11) *Decomposition temperature.* Above 100° C.

(12) *Latent heat of vaporization.* 58 calories per gram from 0° to 190° C.

(13) *Rate of hydrolysis.* Rapidly hydrolyzed in liquid or vapor state.

(14) *Hydrolysis products.* Hydrogen chloride and chlorovinyl-arsenious oxide. The latter is a nonvolatile blister-forming solid not readily washed away by rains. Alkaline hydrolysis destroys these blister-forming properties.

(15) *Stability in storage.* Stable in steel or glass container.

(16) *Action on metals or other materials.* None if L is dry.

(17) *Odor.* Usually geraniumlike; very little odor when pure.

(18) *Median lethal dosage.*

  (*a*) *Inhalation.* 1,200 to 1,500 mg-min/m^3.

  (*b*) *Skin absorption (masked personnel).* 100,000 mg-min/m^3. When the humidity is high, L hydrolyzes so rapidly that it is difficult to maintain a concentration sufficient for blistering of bare skin. This difficulty is still further increased by the high vapor pressure and short duration of effectiveness of L.

(19) *Median incapacitating dosage.*

  (*a*) *Eye injury (from vapor).* Below 300 mg-min/m^3.

  (*b*) *Skin absorption (masked personnel).* Over 1,500 mg-min/m^3. L irritates the eyes and skin and gives warning of its presence.

(20) *Rate of detoxification.* The body does not detoxify L.

(21) *Skin and eye toxicity.* An exposure of 1,500 mg-min/m^3 produces severe and probably permanent corneal damage to the eyes. L has approximately the same blistering action to the skin as HD, even though the lethal dosage for L is much higher.

(22) *Rate of action.* Rapid.

(23) *Physiological action.* L produces effects similar to HD but, in addition, acts as a systemic poison, causing pulmonary edema, diarrhea, restlessness, weakness, subnormal temperature, and low blood pressure. In order of severity and appearance of symptoms it is: a blister agent; a toxic lung irritant; and, when absorbed in the tissues, a systemic poison. Liquid L causes an immediate searing sensation in the eye and permanent loss of sight if not decontaminated within 1 minute. L produces an immediate and strong stinging sensation to the skin; reddening of the skin starts within 30 minutes. Blistering does not appear until after about 13 hours. Like HD, it is cell poison. Skin burns are much deeper than with HD. When inhaled in high concentrations it may be fatal in as short a time as 10 minutes.

(24) *Protection required.* Protective mask and protective clothing.

(25) *Decontaminants.* Bleach, DANC solution, fire, DS2, or caustic soda.

(26) *Munitions suitable for use.* Land mines, spray tanks, bombs, artillery shell, mortar shell, and rockets.

(27) *Duration of effectiveness.* Somewhat shorter than HD. Very short duration under humid conditions.

(28) *Use.* Moderately delayed-action casualty agent.

k. Mustard-Lewisite Mixture (HL).

(1) *General.* Mustard-lewisite mixture is a variable mixture of HD and L which provides a low-freezing mixture for use in cold weather operations or as high-altitude spray. Properties are listed for the eutectic mixture (the mixture having the lowest possible freezing point) which is 63 percent L and 37 percent HD by weight. Other mixtures, such as 50–50, may be prepared to meet predetermined weather conditions and have advantages over the eutectic mixture because of the increased HD content. Mixtures of H

and L are not satisfactory because of poor storage characteristics.

(2) *Chemical name.* None; see components.

(3) *Formula.* None; see components.

(4) *Molecular weight.* 178.5 (on basis of eutectic mixture).

(5) *Vapor density (compared to air).* 6.0.

(6) *Liquid density.* Between the densities of the components; approximately 1.66 at 20° C.

(7) *Freezing point.* —14° C.

(8) *Boiling point.* Indefinite, but below 190° C.

(9) *Vapor pressure.* 0.02 mm Hg at —11° C.; 0.248 mm Hg at 20° C.; 1.03 mm Hg at 40° C.

(10) *Volatility.* 240 mg/m^3 at —11° C.; 2,730 mg/m^3 at 20° C.; 10,270 mg/m^3 at 40° C.

(11) *Flash point.* High enough not to interfere with the military use of the agent.

(12) *Decomposition temperature.* Above 100° C.

(13) *Latent heat of vaporization.* Intermediate between the heats of vaporization of the components.

(14) *Rate of hydrolysis.* L is rapidly hydrolyzed in the liquid or vapor state; HD hydrolyzes slowly at ordinary temperatures.

(15) *Hydrolysis products.* Hydrogen chloride, thiodiglycol, and chlorovinylarsenious oxide. Alkaline hydrolysis destroys the blistering properties.

(16) *Stability in storage.* Satisfactory in lacquered steel containers.

(17) *Action on metals and other materials.* Little or none if dry.

(18) *Odor.* Garliclike.

(19) *Median lethal dosage.*

(*a*) *Inhalation.* About 1,500 mg-min/m^3.

(*b*) *Skin absorption.* Above 10,000 mg-min/m^3.

(20) *Median incapacitating dosage.*

(*a*) *Eye injury.* About 200 mg-min/m^3.

(*b*) *Skin absorption.* 1,500 to 2,000 mg-min/m^3.

(21) *Rate of detoxification.* Not detoxified.

(22) *Skin and eye toxicity.* Very high.

(23) *Rate of action.* Produces immediate stinging of skin and redness within 30 minutes; blistering delayed about 13 hours.

(24) *Physiological action.* Liquid causes severe damage to eyes. Contamination of the skin is followed after a short time by reddening, then by blistering which tends to cover the entire area of the reddened skin. The respiratory lesions are similar to those produced by mustard, except that in the most severe cases pulmonary edema may be accompanied by pleural effusion. Liquid on the skin, as well as inhaled vapor, is absorbed and may cause systemic poisoning. This change is manifested in capillary permeability which permits loss of sufficient fluid from the blood stream to cause blood thickening, shock, and death.

(25) *Protection required.* Protective mask and protective clothing.

(26) *Decontaminants.* Bleach, DANC solution, fire, DS2, caustic soda, or M5 protective ointment.

(27) *Munitions suitable for use.* Land mines, artillery shell, mortar shell, bombs, rockets, and spray tanks.

(28) *Duration of effectiveness.* Depends on munitions used and the weather. Somewhat shorter than HD whose heavily splashed liquid persists 1 to 2 days under average weather conditions and a week or more under very cold conditions.

(29) *Use.* Delayed-action casualty agent.

l. Phenyldichloroarsine (PD).

(1) *General.* Although phenyldichloroarsine is classed here as a blister agent, it also acts as a vomiting agent.

(2) *Chemical name.* Phenyldichloroarsine.

(3) *Formula.* $C_6H_5AsCl_2$.

(4) *Molecular weight.* 222.91.

(5) *Vapor density (compared to air).* 7.7.

(6) *Liquid density.* 1.65 at 20° C.

(7) *Freezing point.* —16° C.

(8) *Boiling point.* 252° C.

(9) *Vapor pressure.* 0.021 mm Hg at 20° C.; 0.113 mm Hg at 40° C.

(10) *Volatility.* 404 mg/m^3 at 20° C. The vaporizing tendency of PD is too low to give it any value as a blister agent in the field. If dispersed as an aerosol, it would be effective against unprotected troops, although only as an agent with a short duration of effectiveness.

(11) *Flash point.* High enough not to interfere with the military use of the agent.

(12) *Decomposition temperature.* Stable to boiling point.

(13) *Latent heat of vaporization.* 67 calories per gram.

(14) *Rate of hydrolysis.* Rapid.

(15) *Hydrolysis products.* Hydrogen chloride and phenlyarsenious oxide.

(16) *Stability in storage.* Very stable.

(17) *Action on metals or other materials.* None.

(18) *Odor.* None.

(19) *Median concentration detectable (by nasal and throat irritation).* 0.9 mg/m^3.

(20) *Median lethal dosage (by inhalation).* 2,600 mg-min/m^3.

(21) *Median incapacitating dosage.* 16 mg-min/m^3 as a vomiting agent; 1,800 mg-min/m^3 as a blistering agent.

(22) *Rate of detoxification.* No specific information, but, as with related arsenicals, PD is probably rapidly detoxified in sublethal dosages.

(23) *Skin and eye toxicity.* About 30 percent as toxic as HD to the eyes; that is, 633 mg-min/m^3 would produce casualties by eye injury. On bare skin PD is about 90 percent as blistering as HD, but it is decomposed immediately by wet clothing.

(24) *Rate of action.* Immediate effect on eyes; effects on skin delayed ½ hour to 1 hour.

(25) *Physiological action.* Similar to the vomiting agents but with added blistering action. Its limited use during World War I did not indicate any marked superiority of PD over the other vomiting agents used.

(26) *Protection required.* Protective mask and protective clothing.

(27) *Decontaminants.* Bleach, caustic soda DS2, or DANC.

(28) *Munitions suitable for use.* Artillery shell, mortar shell, land mines, spray tanks, and rockets.

(29) *Duration of effectiveness.* Depends on munitions used and the weather. Somewhat shorter than HD under dry conditions; short duration when wet. (Heavily splashed liquid HD persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.)

(30) *Use.* Delayed-action casualty agent.

m. Ethyldichloroarsine (ED).

(1) *General.* Ethyldichloroarsine was introduced by the Germans in March 1918 in an effort to produce a volatile agent with a short duration of effectiveness that would be quicker acting than DP or HD and would be more lasting in its effects than PD.

(2) *Chemical name.* Ethyldichloroarsine.

(3) *Formula.* $C_2H_5AsCl_2$.

(4) *Molecular weight.* 174.88.

(5) *Vapor density (compared to air).* 6.0.

(6) *Liquid density.* 1.69 at 20° C.

(7) *Freezing point.* —64° C.

(8) *Boiling point.* 156° C.

(9) *Vapor pressure.* 2.09 mm Hg at 20° C.; 15.1 mm Hg at 50° C.

(10) *Volatility.* 6,500 mg/m^3 at 0° C.; 20,000 mg/m^3 at 20° C.; 27,200 mg/m^3 at 25° C.

(11) *Flash point.* High enough not to interfere with the military use of the agent.

(12) *Decomposition temperature.* Stable to boiling point.

(13) *Latent heat of vaporization.* 52.5 calories per gram.

(14) *Rate of hydrolysis.* Rapid.

(15) *Hydrolysis products.* Hydrogen chloride and ethylarsenious oxide.

(16) *Stability in storage.* Stable in steel.

(17) *Action on metals or other materials:* None on steel; attacks brass at 50° C; destructive to rubber and plastics.

(18) *Odor.* Fruity, but biting and irritating.

(19) *Median lethal dosage.*

  (*a*) *Inhalation.* 3,00 to 5,00 mg-min/m^3, depending upon the period of exposure. Since ED is detoxified by the body at an appreciable rate, the product of concentration and time is not a constant. As t increases C does not decrease proportionately. For example, exposure to 40 mg/m^3 for 75 minutes might have an effect similar to exposure to 30 mg/m^3 for 166 minutes.

  (*b*) *Skin absorption.* 100,000 mg-min/m^3.

(20) *Median temporarily incapacitating dosage (by inhalation).* 5 to 10 mg-min/m^3.

(21) *Rate of detoxification.* Sublethal amounts are detoxified rapidly as with other arsenicals.

(22) *Skin and eye toxicity.* Vapor is irritating but not harmful to eyes and skin except on prolonged exposure. Liquid ED has approximately one-twentieth the blistering action of liquid L.

(23) *Rate of action.* Irritating effect on nose and throat is intolerable after 1 minute at moderate concentrations; blistering effect is less delayed than with HD whose skin effects may be delayed 12 hours or longer.

(24) *Physiological action.* As with other chemical agents containing arsenic, ED is irritating to the respiratory tract and will produce lung injury upon sufficient exposure. The vapor is irritating to the eyes and the liquid may produce severe eye injury. The absorption of either vapor or liquid through the skin in sufficient amounts may lead to systemic poisoning or death. Blistering of the skin is produced by prolonged contact with either liquid or vapor.

(25) *Protection required.* Protective mask and protective clothing.

(26) *Decontaminants.* Decontamination is not usually necessary in the field. If required for closed spaces, DANC, bleach, caustic soda, or DS2 may be used.

(27) *Munitions suitable for use.* Land mines, artillery shell, mortar shell, spray tanks, and rockets.

(28) *Duration of effectiveness.* Evaporates approximately as rapidly as water. Short duration under wet conditions.

(29) *Use.* Delayed-action casualty agent.

n. Methyldichloroarsine (MD).

(1) *General.* Methyldichloroarsine is similar to ethyldichloroarsine.

(2) *Chemical name.* Methyldichloroarsine.

(3) *Formula.* CH_3AsCl_2.

(4) *Molecular weight.* 160.86.

(5) *Vapor density (compared to air).* 5.5.

(6) *Liquid density.* 1.830 at 20° C.

(7) *Freezing point.* —55° C.

(8) *Boiling point.* 133° C.

(9) *Vapor pressure.* 2.17 mm Hg at 0° C.; 7.6 mm Hg at 20° C.

(10) *Volatility.* 74.900 mg/m^3 at 20° C.

(11) *Flash point.* High enough not to interfere with the military use of the agent.

(12) *Decomposition temperature.* Stable to boiling point.

(13) *Latent heat of vaporization.* 49 calories per gram.

(14) *Rate of hydrolysis.* Very rapid.

(15) *Hydrolysis products.* Hydrogen chloride and methylarsenious oxide.

(16) *Stability in storage.* Stable in steel containers.

(17) *Action on metals or other materials.* None on steel.

(18) *Odor.* None.

(19) *Median lethal dosage.* No accurate data; probably similar to ED, 3,000 to 5,000 mg-min/m^3, depending upon time.

(20) *Median incapacitating dosage (by inhalation).* 25 mg-min/m^3.

(21) *Rate of detoxification.* Detoxified at an appreciable rate.

(22) *Skin and eye toxicity.* Blistering action slightly less than that of HD. Has effect on eyes similar to that of L (produces corneal damage) but less severe. Concentration required for blistering effect is too high to attain in the field.

(23) *Rate of action.* Immediate irritation of eyes and nose. Blistering effect is delayed several hours.

(24) *Physiological action.* As with L and the other similar arsenicals, MD is irritating to the respiratory tract and produces lung injury upon sufficient exposure. The vapor is irritating to the eyes and the liquid may produce severe eye injury. The absorption of either vapor or liquid through the skin in sufficient amounts may lead to systemic poisoning or death. Blistering of the skin is produced by prolonged contact with either liquid or vapor.

(25) *Protection required.* Protective mask and protective clothing.

(26) *Decontaminants.* Bleach, DANC solution, caustic soda, or DS2.

(27) *Munitions suitable for use.* Artillery shell, mortar shell, land mines, and rockets.

(28) *Duration of effectiveness.* Relatively short. Evaporates much faster than water.

(29) *Use.* Delayed-action casualty agent.

Section II. RIOT CONTROL AND MISCELLANEOUS AGENTS

33. Vomiting Agents

a. General. The three vomiting agents listed below are normally solids which, when heated, vaporize and then condense to form toxic aerosols. Under field conditions, vomiting agents cause great discomfort to their victims; when released indoors, they may cause serious illness or death. The vomiting agents are used for mob and riot control. The three principal vomiting agents are discussed in *b* through *d* below.

b. Diphenylchloroarsine (DA).

(1) *Chemical name.* Diphenylchloroarsine.

(2) *Formula.* $(C_6H_5)_2AsCl$.

(3) *Molecular weight.* 264.5.

(4) *Vapor density (compared to air).* Forms no appreciable vapor.

(5) *Liquid density.* 1.387 at 50° C.

(6) *Freezing point.* 44° C.

(7) *Boiling point.* 307° C.

(8) *Vapor pressure.* 0.0016 mm Hg at 20° C.

(9) *Volatility.* 7.2 mg/m^3 at 20° C.

(10) *Flash point.* 350° C.

(11) *Decomposition temperature.* 300° C.

(12) *Latent heat of vaporization.* 56.6 calories per gram. Latent heat of vaporization is of little importance in a chemical agent which is dispersed by an external heat source.

(13) *Rate of hydrolysis.* Slow in mass but rapid when finely divided.

(14) *Hydrolysis products.* Diphenylarsenious oxide and hydrogen chloride. The oxide is very poisonous if taken internally.

(15) *Stability in storage.* Stable when pure.

(16) *Action on metals or other materials.* None when dry.

(17) *Odor.* No pronounced odor.

(18) *Median lethal dosage.* 15,000 mg-min/m^3 (estimated).

(19) *Median incapacitating dosage.* 12 mg-min/m^3 if received over 10-minute periods; probably higher for shorter time.

(20) *Rate of detoxification.* Any merely incapacitating amount is detoxified completely within 1 to 2 hours.

(21) *Skin and eye toxicity.* Irritating; not toxic.

(22) *Rate of action.* Very rapid; within 2 or 3 minutes after 1 minute of exposure.

(23) *Physiological action.* In progressive order: irritation of the eyes and mu-

cous membranes, viscous discharge from the nose similar to that caused by a cold, sneezing and coughing, severe headache, acute pain and tightness in the chest, and nausea and vomiting. For moderate concentrations the effects last about 30 minutes after an individual leaves the contaminated atmosphere. At higher concentrations, the effects may last up to several hours.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* None required in the field. Caustic soda or chlorine used for gross contamination in inclosed spaces.

(26) *Munitions suitable for use.* Grenades and candles.

(27) *Duration of effectiveness.* Short because agent is disseminated as an aerosol.

(28) *Use.* Training and riot control.

c. Adamsite (DM).

(1) *Chemical name.* Diphenylaminochloroarsine (also phenarsazine chloride).

(2) *Formula.* $NH(C_6H_4)_2AsCl$.

(3) *Molecular weight.* 277.57.

(4) *Vapor density (compared to air).* DM does not vaporize at ordinary temperatures and must be dispersed as an aerosol through application of heat.

(5) *Solid density.* 1.65 at 20° C.

(6) *Freezing point.* 195° C.

(7) *Boiling point.* 410° C.

(8) *Vapor pressure.* Negligible.

(9) *Volatility.* Negligible.

(10) *Flash point.* None under usual conditions.

(11) *Decomposition temperature.* Above boiling point.

(12) *Latent heat of vaporization.* 54.8 calories per gram. This property is of little importance when a chemical agent is dispersed as an aerosol by means of heat from an outside source.

(13) *Rate of hydrolysis.* Quite rapid when in aerosol form.

(14) *Hydrolysis products.* Diphenylarsenious oxide and hydrogen chloride. The oxide is very poisonous if taken internally.

(15) *Stability in storage.* Stable when pure.

(16) *Action on metals or other materials.* None when dry.

(17) *Odor.* No pronounced odor.

(18) *Median lethal dosage.* 15,000 mg-min/m^3.

(19) *Median incapacitating dosage.* 22 mg-min/m^3 for 1-minute exposure; 8 mg-min/m^3 for 60-minute exposure.

(20) *Rate of detoxification.* Quite rapid in small amounts. Incapacitating amounts lose their effect after about 30 minutes.

(21) *Skin and eye toxicity.* Irritating; relatively nontoxic.

(22) *Rate of action.* Very high. Only about 1 minute is required for temporary incapacitation at a concentration of 22 mg/m^3.

(23) *Physiological action.* In progressive order: irritation of the eyes and mucous membranes, viscous discharge from the nose similar to that caused by a cold, sneezing and coughing, severe headache, acute pain and tightness in the chest, and nausea and vomiting. The effects develop more slowly than with DA and, for moderate concentrations, last about 30 minutes after an individual leaves the contaminated atmosphere. At higher concentrations, the effects may last up to 3 hours.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* None needed in field; bleaching powder or DS2 used for gross contamination in inclosed places.

(26) *Munitions suitable for use.* Candles and grenades.

(27) *Duration of effectiveness.* Short, because agent is disseminated as an aerosol.

(28) *Use.* Training and riot control.

d. Diphenylcyanoarsine (DC).

(1) *Chemical name.* Diphenylcyanoarsine.

(2) *Formula.* $(C_6H_5)_2AsCN$.

(3) *Molecular weight.* 255.0.

(4) *Vapor density (compared to air).* Does not form appreciable vapor.

(5) *Liquid density.* 1.32 at 50° C.

(6) *Freezing point.* 30.0° C.

(7) *Boiling point.* 290° C.

(8) *Vapor pressure.* 4.7×10^{-5} mm Hg at 20° C.

(9) *Volatility.* 2.79 mg/m^3 at 20° C.

(10) *Flash point.* Low.

(11) *Decomposition temperature.* About 25 percent decomposed at 300° C. Largely decomposed as a result of dispersing blast.

(12) *Latent heat of vaporization.* 79.3 calories per gram. Because of its high heat of vaporization, a source of heat must be applied to DC to obtain a vapor concentration which is militarily significant.

(13) *Rate of hydrolysis.* Very slow.

(14) *Hydrolysis products.* Hydrogen cyanide and diphenylarsenious oxide.

(15) *Stability in storage.* Stable at all ordinary temperatures.

(16) *Action on metals or other materials.* None.

(17) *Odor.* Similar to a mixture of garlic and bitter almonds.

(18) *Median lethal dosage.* 10,000 mg-min/m^3. It would be nearly impossible to build up a concentration of DC which would be lethal within a practicable time.

(19) *Median incapacitating dosage.* 30 mg-min/m^3 for 30-second exposure; 20 mg-min/m^3 for 5-minute exposure.

(20) *Rate of detoxification.* Rapid. Incapacitating amounts lose their effect after about 1 hour.

(21) *Skin and eye toxicity.* Irritating; not toxic.

(22) *Rate of action.* Very rapid. Higher concentrations are intolerable in about 30 seconds.

(23) *Physiological action.* In progressive order: irritation of the eyes and mucous membranes, viscous discharge from the nose similar to that caused by a cold, sneezing and coughing, severe headache, acute pain and tightness in the chest, and nausea and vomiting. DC is more toxic than DA. For moderate concentrations the effects last about 30 minutes after an individual leaves the contaminated atmosphere. At a higher concentration, the effects may last up to several hours.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* None required in the field. Alkali solution or DS2 may be used for decontamination in inclosed spaces.

(26) *Munitions suitable for use.* Candles and grenades.

(27) *Duration of effectiveness.* Short, because agent is disseminated as an aerosol.

(28) *Use.* Training and riot control.

34. Tear Agents

a. General. The tear agents cause flow of tears and irritation of the skin. Since there is small likelihood of tear agents producing casualties, they are used rarely except for training and riot control. They have little more than nuisance value in war in view of the effectiveness of the modern protective mask. The principal tear agents are discussed in *b* through *g* below.

b. Chloroacetophenone (CN).

(1) *Chemical name.* Chloroacetophenone.

(2) *Formula.* $C_6H_5COCH_2Cl$.

(3) *Molecular weight.* 154.59.

(4) *Vapor density (compared to air).* 5.3.

(5) *Liquid density.* 1.26 at 55° C.

(6) *Solid density.* 1.32 at 15° C.

(7) *Freezing point.* 54° to 55° C.

(8) *Boiling point.* 244° to 245° C.

(9) *Vapor pressure.* 0.0017 mm Hg at 0° C.; 0.0054 mm Hg at 20° C.; 0.158 mm Hg at 55° C.

(10) *Volatility.* 30 mg/m^3 at 0° C.; 105 mg/m^3 at 20°.

(11) *Flash point.* High enough not to interfere with the military use of the agent.

12) *Decomposition temperature.* Stable to boiling point.

(13) *Latent heat of vaporization.* 98 calories per gram. As with vomiting agents, CN must be vaporized or dispersed by some other means than by its own volatility.

(14) *Rate of hydrolysis.* Not readily hydrolyzed.

(15) *Hydrolysis products.* Hydrogen chloride and hydroxymethylphenylketone.

(16) *Stability in storage.* Stable.

(17) *Action on metals or other materials.* Tarnishes steel slightly.

(18) *Odor.* Fragrant; similar to apple blossoms.

(19) *Median lethal dosage.* No exact data, but believed to be about 11,000 mg-min/m^3.

(20) *Median incapacitating dosage.* 80 mg-min/m^3.

(21) *Rate of detoxification.* Rapid; effects disappear in a few hours.

(22) *Skin and eye toxicity.* Irritating; not toxic in concentrations likely to be encountered in the field.

(23) *Rate of action.* Practically instantaneous.

(24) *Physiological action.* In addition to powerful lacrimatory effects, CN is an irritant to the upper respiratory passages. In higher concentrations, it is irritating to the skin and causes a burning and itching sensation, especially on moist parts of the body. High concentrations can cause blisters. The effects are similar to those of sunburn, are entirely harmless, and disappear in a few hours. Certain individuals experience nausea following exposure to CN.

(25) *Protection required.* Protective mask.

(26) *Decontaminants.* Aeration is sufficient in the field. In closed spaces soda ash solution or alcoholic caustic soda will decontaminate CN.

(27) *Munitions suitable for use.* Mortar shell, grenades, and candles.

(28) *Duration of effectiveness.* Short, because the agent is disseminated as an aerosol.

(29) *Use.* Training and riot control.

c. CNC.

(1) *Chemical name.* None; solution of chloroacetophenone in chloroform.

(2) *Formula.*

(*a*) *Chloroform.* $CHCl_3$ (70 parts by weight).

(*b*) *CN.* $C_6H_5COCH_2Cl$ (30 parts by weight).

(3) *Molecular weight.* 129.6 (on basis of components).

(4) *Vapor density (compared to air).* Not fixed; approximately 4.

(5) *Liquid density.* 1.40 at 20° C.

(6) *Freezing point.* 0.23° C. This is the temperature at which CN crystals separate, and is not a true change of state. It is that temperature at which the solution becomes saturated with CN. If the solution is cooled below this point, solid matter appears and gives the appearance of freezing.

(7) *Boiling point.* Variable. Increases as chloroform boils off and approaches the boiling point of pure CN (60° to 247° C.).

(8) *Vapor pressure.* 61 mm Hg at 5° C.; 127 mm Hg at 20° C.

(9) *Volatility.* This is an indeterminate value under field conditions because the vapor pressure of chloroform is high and the vapor pressure of CN is low. Therefore, there is no true volatility as in the case of a compound.

(10) *Flash point.* None.

(11) *Decomposition temperature.* Stable to the boiling point.

(12) *Latent heat of vaporization.* Not applicable.

(13) *Rate of hydrolysis.* None.

(14) *Hydrolysis products.* None.

(15) *Stability in storage.* Adequate.

(16) *Action on metals or other materials.* Slight.

(17) *Odor.* Similar to chloroform.

(18) *Median lethal dosage.* The active ingredient is CN; therefore, with allowance for the diluting action of the chloroform vapor, with median lethal

dosage would be similar to that for CN—about 11,000 mg-min/m^3.

(19) *Median incapacitating dosage.* About 80 mg-min/m^3.

(20) *Rate of detoxification.* Rapid for sublethal exposures.

(21) *Skin and eye toxicity.* Irritating; not toxic.

(22) *Rate of action.* Instaneous.

(23) *Physiological action.* Causes flow of tears, irritates respiratory system, and causes stinging of skin.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* Aeration is sufficient in the field. In inclosed places, strong soda ash solution or alcoholic caustic soda will decontaminate CNC.

(26) *Munitions suitable for use.* Spray tanks, mortar shell, bombs, and grenades.

(27) *Duration of effectiveness.* Short, because the agent is disseminated as an aersol.

(28) *Use.* Training and riot control.

d. CNS.

(1) *Chemical name.* None; mixture of chloroacetophenone, chloropicrin, and chloroform.

(2) *Formula.*

- (*a*) *CN.* $C_6H_5COCH_2Cl$ (23 percent).
- (*b*) *PS.* $C(NO_2)Cl_3$ (38.4 percent).
- (*c*) *Chloroform.* $CHCl_3$ (38.4 percent).

(3) *Molecular weight.* 144.5 (on basis of components).

(4) *Vapor density (compared to air).* About 5.0.

(5) *Liquid density.* 1.47 at 20° C.

(6) *Freezing point.* About 2° C. This is the point at which crystals of CN separate and is not a true freezing point as with a pure compound.

(7) *Boiling point.* No fixed temperature; varies from 60° to 247° C.

(8) *Vapor pressure.* Indefinite.

(9) *Volatility.* 100,000 mg/m^3 at 20° C. (This value includes the volatility of the solvent.)

(10) *Flash point.* None.

(11) *Decomposition temperature.* Stable to boiling point.

(12) *Latent heat of vaporization.* Not applicable.

(13) *Rate of hydroylsis.* Negligible.

(14) *Hydrolysis products.* None.

(15) *Stability in storage.* Stable.

(16) *Action on metals or other materials.* Very little.

(17) *Odor.* Like flypaper.

(18) *Median lethal dosage.* 11,400 mg-min/m^3.

(19) *Median incapacitating dosage.* 60 mg-min/m^3.

(20) *Rate of detoxification.* The effects of chloropicrin are longlasting and cumulative, and may cause the effects of CNS to be prolonged for weeks. Such a prolonged effect may be highly undesirable in training and riot control.

(21) *Skin and eye toxicity.* Irritating; not toxic.

(22) *Rate of action.* Instantaneous.

(23) *Physiological action.* In addition to having effects described under CN, CNS also has the effects of chloropicrin (PS) which acts as a vomiting agent, a choking agent, and a tear agent. CNS may cause lung effects similar to those of CG and also may cause nausea, vomiting, colic, and diarrhea which may persist for weeks. The lacrimatory effects of PS are much less marked than those of CN and are relatively unimportant in CNS, as shown by the fact that these effects are no greater than with CNC which contains no PS.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* Not required in the field. In inclosed spaces, a hot solution of soda and sodium sulfite may be used for gross contamination.

(26) *Munitions suitable for use.* Bombs, spray tanks, mortar shell, and grenades.

(27) *Duration of effectiveness.* Short.

(28) *Use.* Training and riot control.

e. CNB.

(1) *General.* CNB was adopted in 1920 and remained in use until it was replaced by CNS. The advantage claimed for CNB was that its lower chloroacetophenone content made it more satisfactory than CNC for training purposes. Actually, the same result can be obtained with CNC merely by using a lower concentration.

(2) *Chemical name.* None; solution of chloroacetophenone in benzene and carbon tetrachloride.

(3) *Formula.*

(*a*) *CN.* $C_6H_5COCH_2Cl$ (10 parts by weight).

(*b*) *Carbon tetrachloride.* CCl_4 (45 parts by weight).

(*c*) *Benzene.* C_6H_6 (45 parts by weight).

(4) *Molecular weight.* 119.7 (on basis of components).

(5) *Vapor density (compared to air).* Approximately 4.

(6) *Liquid density.* 1.14 at 20° C.

(7) *Freezing point.* —7° to —30° C.

(8) *Boiling point.* Varies from 75° to 247° C. as the two solvents are vaporized.

(9) *Vapor pressure.* Not pertinent since this is almost entirely due to the solvents.

(10) *Volatility.* Indetermediate because of the effects of the solvents.

(11) *Flash point.* Below 4.44° C. (40° F.).

(12) *Decomposition temperature.* Above 247° C.

(13) *Latent heat of vaporization.* Not applicable.

(14) *Rate of hydrolysis.* None.

(15) *Hydrolysis products.* None.

(16) *Stability in storage.* Adequate.

(17) *Action on metals or other materials.* Very slight.

(18) *Odor.* Like benzene.

(19) *Median lethal dosage.* No specific data, but about the same as for CN (11,000 mg-min/m^3).

(20) *Median incapacitating dosage.* 80 mg-min/m^3.

(21) *Rate of detoxification.* Rapid, if poisonous amounts of solvents have not been inhaled.

(22) *Skin and eye toxicity.* Irritating; not toxic.

(23) *Rate of action.* Instantaneous.

(24) *Physiological action.* Powerfully lacrimatory.

(25) *Protection required.* Protective mask.

(26) *Decontaminants.* None needed in the field. CN can be decontaminated in the presence of the solvents used in CNB by means of a solution of 5 percent NaOH, 20 percent H_2O, and 75 percent carbitol by weight.

(27) *Munitions suitable for use.* Mortar shell, spray tanks, bombs, and grenades.

(28) *Duration of effectiveness.* Short.

(29) *Use.* Training and riot control.

f. Bromobenzylcyanide (BBC).

(1) *Chemical name.* Bromobenzylcyanide.

(2) *Formula.* $C_6H_5CHBrCN$.

(3) *Molecular weight.* 196.0.

(4) *Vapor density (compared to air).* 6.7.

(5) *Solid density.* 1.52 at 20° C.

(6) *Liquid density.* 1.47 at 25° C.

(7) *Freezing point.* 25° C.

(8) *Boiling point.* 242° C., but with decomposition.

(9) *Vapor pressure.* 0.011 mm Hg at 20° C.

(10) *Volatility.* 22 mg/m^3 at 0° C.; 130 mg/m^3 at 20° C.; 420 mg/m^3 at 30° C.

(11) *Flash point.* None; decomposes but does not burn.

(12) *Decomposition temperatures.* Decomposes slowly at 60° C.; more rapidly as the temperature increases. Decomposes completely at 242° C. Hydrobromic acid and dicyanostilbene are formed.

(13) *Latent heat of vaporization.* 55.7 calories per gram at the boiling point.

(14) *Rate of hydrolysis.* Very slow.

(15) *Hydrolysis products.* Complex condensation products.

(16) *Stability in storage.* Fairly stable in glass, lead-lined, or enamel-lined containers.

(17) *Action on metals or other materials.* Vigorous corrosive action on all common metals except lead. Reaction with iron may be explosive.

(18) *Odor.* Like soured fruit, but not unpleasant.

(19) *Median lethal dosage.* Approximately 4,000 mg-min/m^3. Volatility is too low to permit attaining a lethal dosage in the field.

(20) *Median incapacitating dosage.* About 30 mg-min/m^3.

(21) *Rate of detoxification.* Rapidly detoxified at the low concentrations ordinarily encountered.

(22) *Skin and eye toxicity.* Irritating; not toxic.

(23) *Rate of action.* Instantaneous.

(24) *Physiological action.* BBC produces a burning sensation of the mucous membranes and severe irritation and lacrimation of the eyes with acute pain in the forehead. BBC is considerably less toxic than CG.

(25) *Protection required.* Protective mask.

(26) *Decontaminants.* Clothing can be decontaminated by steam or by boiling. Twenty percent alcoholic caustic soda is effective on material, but may damage it. Porous surfaces, such as earth, are very difficult to decontaminate.

(27) *Munitions suitable for use.* Grenades and candles. (Excessive decomposition results from almost any means of dissemination.)

(28) *Duration of effectiveness.* Depends upon munitions used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions.

(29) *Use.* Training and riot control.

g. O-chlorobenzalmalononitrile (*CS*).

(1) *General.* CS is a white crystalline powder. It has a minimum purity of 96 percent, is insoluble in water and ethanol, but soluble in methylene chloride.

(2) *Chemical name.* O-chlorobenzalmalononitrile.

(3) *Formula.* $ClC_6H_4CHC(CN)_2$.

(4) *Molecular weight.* 188.5.

(5) *Bulk density.* 10 to 20 lb, 1 cu ft.

(6) *Melting point.* 93° to 95° C.

(7) *Boiling point.* 310° to 315° C.

(8) *Volatility.* Unknown.

(9) *Flash point.* Unknown.

(10) *Decomposition temperature.* Unknown.

(11) *Latent heat of vaporization.* Unknown.

(12) *Rate of hydrolysis.* Unknown.

(13) *Hydrolysis products.* Unknown.

(14) *Stability in storage.* Stable.

(15) *Action on metals.* Very slight action on steel.

(16) *Odor.* Pepperlike.

(17) *Median lethal dosage.* 25,000 mg-min/m^3 for resting men.

(18) *Median incapacitating dosage.* 10 to 20 mg-min/m^3.

(19) *Rate of detoxification.* Quite rapid. Incapacitating dosages lose their effects in 5 to 10 minutes.

(20) *Skin and eye toxicity.* Highly irritating but not toxic.

(21) *Rate of action.* Very rapid.

(22) *Physiological effects.* CS produces immediate effective even in low concentrations. Hs median effective concentration for respiratory effects is 12 to 20 mg/m^3; concentration for eye effects is 1 to 5 mg/m^3. The onset of incapacitation is 20 to 60 seconds and the duration of effects is 5 to 10 minutes after the affected individual is removed to fresh air. During this time affected individuals are incapable of effective concerted action. The physiological effects include extreme burning of the eyes accompanied by copious flow of tears; coughing, difficulty in breathing, and chest tightness; involuntary closing of the eyes; stinging sensation of moist skin; running nose; and dizziness or swimming of the head. Heavy concentrations will cause nau-

sea and vomiting in addition to the above effects.

(23) *Protection required.* Protection is provided by the protective mask and ordinary field clothing secured at the neck, wrist, and ankles. Personnel handling CS should wear rubber gloves for additional protection.

(24) *Decontaminants.* Area decontamination is not required as CS has a short duration of effectiveness. Personnel exposed to CS may shower as necessary; however, when CS dust or particles are on the skin, showering should be delayed for 6 hours to prevent stinging and reddening of the skin. Individuals affected by CS should move to fresh air, face the wind, and remain well spaced; and should not rub their eyes. To remove accidental gross contamination, personnel should remove clothing and immediately flush body with copious amounts of water to remove most of the agent; apply 5 percent sodium bisulfite solution to remove remainder (except in or around eyes); and then rinse body.

(25) *Munitions suitable for use.* The pure crystalline form (identified by symbol CS) is used as filling for burning-type grenades and capsules. A mixture of 95 percent of the crystalline agent and 5 percent of silica gel aerogel (identified by symbol CSl) is used as filling for bursting-type grenades and in all bulk irritant agent dispersers.

(26) *Duration of effectiveness.* Short.

(27) *Use.* Training and riot control.

35. Miscellaneous

a. Chlorine.

(1) *Chemical name.* Chlorine.

(2) *Formula.* Cl_2.

(3) *Molecular weight.* 70.91.

(4) *Vapor density (compared to air).* 2.4.

(5) *Liquid density.* 1.41 at 20° C.

(6) *Freezing point.* —102° C.

(7) *Boiling point.* —35° C.

(8) *Vapor pressure.* 4,992 mm Hg at 20° C.

(9) *Volatility.* 19,369,000 mg/m^3 at 20° C.

(10) *Flash point.* None.

(11) *Decomposition temperature.* Greater than 1,000° C.

(12) *Latent heat of vaporization.* 68.8 calories per gram.

(13) *Rate of hydrolysis.* Slow.

(14) *Hydrolysis products.* HCl and HOCl.

(15) *Stability in storage.* Stable when dry.

(16) *Action on metals or other materials.* None in field concentrations if Cl is dry. Vigorous action with metals when Cl is moist.

(17) *Odor.* Pungent, like bleaching powder.

(18) *Median lethal dosage.* 19,000 mg-min/m^3.

(19) *Median incapacitating dosage.* 1,800 mg-min/m^3.

(20) *Rate of detoxification.* Rapid.

(21) *Skin and eye toxicity.* Irritates eyes.

(22) *Rate of action.* Rapid.

(23) *Physiological action.* Powerful irritant, first on upper and then on lower respiratory tract.

(24) *Protection required.* Protective mask.

(25) *Decontaminants.* None required.

(26) *Munitions suitable for use.* No standard munitions. Released from cylinders in gas chambers for training.

(27) *Duration of effectiveness.* Short.

(28) *Use.* Used in training, Cl is to be released only in a gas chamber for the standard gas chamber exercise under supervision of a qualified officer. See FM 21–48 for additional information.

b. Simulated Mustard (MR).

(1) *General.* After World War I a number of substances having physical properties similar to HD, and generally containing a dye and an odoriferous constituent, were tested in an attempt to find a substitute for mustard in the testing of dispersion apparatus and munitions, and for training purposes. Almost all of the substances had some disadvantageous feature, such as instability, corrosiveness to metals, staining to fabrics, rel-

atively high cost or, in the case of those containing aniline and nitrobenzene, some toxicity. The use of molasses residuum solution (MR) as a simulant for HD was first suggested in March 1937. Since that time MR has been used successfully in tests of airplane smoke tanks, thin-case bombs, and chemical land mines. MR is well adapted to training needs.

(2) *Name and formula.* MR is a mixture consisting of a 25-percent solution by volume of molasses residuum in water. Molasses residuum is obtained in the manufacture of ethyl alcohol from molasses.

(*a*) As obtained from industry, the concentrated molasses residuum is a dark brown viscous liquid with a characteristics molasses odor. It is soluable in water to the extent of 90 percent.

(*b*) The undiluted material is more viscous than HD, but when one volume of molasses residuum is diluted with three volumes of water it forms a dark brown liquid of thin, sirupy consistency which, although it has a lower specific gravity than either pure or crude mustard, has a viscosity and surface tension sufficiently close to those of HD to insure comparable flow characteristics.

(*c*) It has a low freezing point and can be used in moderately cold weather without danger of freezing.

(*d*) The solution has a distinctive molasses odor which, while not similar to that of HD, is readily recognizable. When the solution is sprayed from an airplane, the molasses odor can be detected on the contaminated area for about 45 minutes to 1 hour.

(*e*) The solution has sufficient color to produce easily defined patterns. The patterns obtained by dispersion from airplane smoke tanks, chemical land mines, and thin-case bombs are similar to those produced by HD.

(3) *Chemical properties.*

(*a*) The 25-percent aqueous solution of molasses residuum is somewhat acidic (pH about 4.5) but no rusting or other evidence of corrosion has been observed as the result of using this solution in airplane smoke tanks, chemical land mines, and thin-case bombs.

(*b*) The solution is harmless by contact to man and animals but, because of the cresol used as stabilizing agent, it should *not* be swallowed.

c. Incapacitating Chemical Agents.

(1) *General.* Incapacitating chemical agents are capable of producing physiological or mental effects that prevent exposed personnel from performing their primary military duties for a significant period of time; there is complete recovery from these effects. The incapacitating agents fall into two general groups:

(*a*) Those which produce temporary physical disability such as paralysis, blindness, or deafness.

(*b*) Those which produce temporary mental aberrations. Unlike the the lethal agents, these incapacitants can produce purely temporary effects without permanent damage. In this respect they resemble the riot control agents.

(2) *Use.* The incapacitating agents suggest employment where military necessity requires control of a situation but where there is good reason for not harming the surrounding population or even the troops. They also suggest covert uses either to confuse defense or retaliatory forces, or to affect the rationality of an important leadership group at some particularly crucial point.

(3) *Incapacitating agent BZ.* The Chemical Incapacitating Weapons System includes those agents and related munitions and disseminating devices designed to produce an incapacitating effect upon man to meet military requirements. Agent BZ and two mu-

nitions have been type-classified Standard B to provide a limited capability to meet these requirements.

(4) *Symptoms.* General symptoms from agent BZ are—
  - (*a*) Interference with ordinary activity.
  - (*b*) Dry, flushed skin.
  - (*c*) Tachycardia.
  - (*d*) Urinary retention.
  - (*e*) Constipation.
  - (*f*) Slowing of mental and physical activity.
  - (*g*) Headache.
  - (*h*) Giddiness.
  - (*i*) Disorientation.
  - (*j*) Hallucinations.
  - (*k*) Drowsiness.
  - (*l*) Sometimes maniacal behavior.
  - (*m*) Increase in body temperature.

(5) *Decontamination.* Decontamination of personnel can be accomplished by washing contaminated parts with soap and water. Flush eyes with clear water only. Clothing and individual equipment should be shaken or brushed and, when conditions permit, thoroughly washed. Hypochlorite or alcohol caustic solutions are suitable decontaminants for BZ on materiel. BZ can be removed by scrubbing, pressure hosing, or drenching the surface with a detergent-wetting solution followed by hosing with clear water.

Section III. INCENDIARIES

36. General

Incendiaries can be used under field conditions to set fire to buildings, industrial installations, ammunition, fuel dumps, and so forth. The mechanics of fire starting involve three essentials—a source of heat acting as a "match" to initiate the fire, a combustible material which serves as kindling, and the fuel. The incendiary supplies the match and the kindling, and the target supplies the fuel. Modern military incendiaries may be divided into three categories—oil, metal, and a combination of oil and metal. Incendiaries may also be classified as those which owe their incendiary effect to a self-supporting exothermic reaction and those which depend upon the presence of oxygen in the surrounding atmosphere for their combustion.

37. Oil Incendiaries

a. General. Oil incendiaries are based upon gasoline and may be either straight gasoline or blends of gasoline with fuel oil of any type issued by the Army, such as No. 1 fuel oil, No. 2 fuel oil, diesel oil, lubricating oil (including sediment-free crankcase drainings), and kerosene. The gasoline or blended gasoline may be used in certain cases in its normal liquid form, but is almost always used in thickened form. Almost any grade of gasoline can be used for incendiary purposes regardless of the octane rating. Aviation gasoline of 100-octane rating should be used only in emergencies, because of its scarcity and cost.

b. Unthickened Fuel. Because oil burns much more slowly than gasoline, oil-gasoline mixtures are used in flame throwers where thickened fuel is not available or in jungle operations where maximum range is not required. Increase in proportion of oil increases range and cuts down on the amount of fuel burned in flight to the target. (In hot climates, less gasoline is required for proper ignition than in cold climates.)

(1) *Mixtures.* If fuel oils are blended with gasoline, equal parts by weight or volume of gasoline and fuel oil may be used. If lubricating oils are blended with gasoline, one part of oil may be used for each four parts of gasoline. Mixtures are purely a matter of choice, and ingredient proportions need not be exact.

(2) *Use.* Unthickened fuel is used only in portable flamethrowers and may be used when thickened fuel is not availbale, or in jungle operations.

c. Thickened Fuel. Thickened fuel increases the range of flamethrowers, imparts slower burning properties, gives clinging qualities, and causes flames to rebound off walls or other surfaces and to go around corners. It is used in all incendiary oil bombs as well as in flame field expedients. The target on which the fuel is employed and the means of dispersion used must be known for determination of the optimum mixture. More thickener is used in thickened fuel for incendiary oil bombs and mechanical flamethrowers than for portable flamethrowers.

d. Thickeners.

(1) *M1 thickener.* (Napalm) (Standard B) M1 thickener, known as Napalm, is a mixed aluminum soap in which approximately 50 percent of the organic acids are derived from coconut oil, 25 percent from naphthenic acids, and 25 percent from oleic acid. As issued, it is in small granular particles, variable in color from light tan to brown. The thickening qualities also vary. An undesirable feature of M1 thickener is that it absorbs moisture rapidly from the air; this moisture causes the properties to change so that the thickener may become unusable. When M1 thickener is stirred into gasoline at a temperature ranging from 16° to 29° C., it swells until the entire volume of gasoline becomes a more or less homogeneous gel. The gel may vary in consistency from a pourable fluid to a rubbery material, depending upon the proportion of thickener added. This type of gel, if allowed to set undisturbed, assumes a semirigid jellylike form. If the gel is shaken violently, stirred vigorously, or squirted through a small opening under pressure, it becomes almost liquid again, but resumes a jellylike form upon standing. The precentage of M1 thickener used in thickening fuels ranges from 2 percent for very thin fuels to 12 percent for the highest consistency likely to be required.

(2) *M2 thickener.* (Napalm) (Standard for Air Force use only.) M2 incendiary oil thickener is an intimate mixture of 95 percent M1 thickener and 5 percent devolatilized silica aerogel or other approved antiagglomerate. Moisture content may vary between 0.4 percent and 1.0 percent. M2 thickener is an improvement over M1 thickener for use in fire bombs, not only because of the free-flowing and faster setting characteristics, but also because the thickener itself and gel formed from it are more stable. M2 and M1 thickeners are used in the same manner.

(3) *M4 thickener.* (ISO) (Standard A) M4 incendiary oil thickener is a diacid aluminum soap of isooctanoic acids derived from isooctyl alcohol or isooctyl aldehyde obtained from the oxidation of petroleum. M4 thickener is a very fine white granular material. Moisture content is specified as no more than 1.2 percent, with chlorides not to exceed 0.3 percent. It contains 2 percent Santocel C or Attaclay SF which serves as an antiagglomerant. M4 thickener is much less susceptible to moisture in the air and has a higher density than the other thickeners, which gives it a decided logistic advantage. About one-half the amount of M4 thickener and about one-half to one-tenth mixing time is required for M4 thickeners as compared to M1 thickener for thickened fuels of comparable consistency. Peptizers are needed with M4 thickener at about 0° F. Fuels prepared with M4 thickener are superior in flamethrower firing performance with respect to range, burning, and target effects as compared with fuels prepared with other available thickeners.

(4) *Other thickeners.* Natural rubber and isobutyl methacrylate (polymer AE) are effective thickeners but are much more difficult to use than M1, M2, and M4 thickeners. IM incendiary oil, type I, is an example of the use of isobutyl methacrylate, polymer AE. The type I mixture has the following composition:

Ingredient	*Percent*
Stearic acid	3.0
Isobutyl methacrylate, polymer AE	5.0
Calcium oxide	2.0
Gasoline	88.75
Water	1.25

Three additional IM incendiary oil mixtures are obtained by varying the above ingredients.

e. Peptizers. A peptizer is any substance which hastens or facilitates the dispersal of a colloidal material in a dispersion medium. In addition, it lowers the final viscosity of the thickened fuel and facilitates the formation of a gel at lower temperatures than would otherwise be possible. At temperatures below 16° C., thickeners—which act as colloids in fuels—fail to disperse in gasoline or blended fuel, and either the fuel must be warmed or a peptizer must be employed. Usually it is much easier and safer to use a peptizer than to warm the fuel, unless a mechanical mixer equipped with heater is available. Water (at high temperatures), octoic acid, and cresylic acid (mixtures of xylenols and cresols) are the most common peptizers; cresylic acid is perferred. In general, one part of cresylic acid is used to four parts of M1, M2, or M4 thickener. However, there are wide variations in the properties and behavior of the several ingredients of thickened fuel. To determine the best proportions of thickener, peptizer, and fuel, samll experimental batches sohuld be prepared and tested before use.

f. Ignition. In most cases, munitions containing oil incendiaries are equipped with white phosphorus igniters to insure ignition because the burstng charge may or may not cause ignition. Since ignition of white phosphorus is prevented by water, a sodium igniter is used in an oil incendiary munition to be dropped over water. Thickened and unthickened fuel in the portable flamethrower is ignited by a red phosphorus-tipped metal match which scratches an igniting mixture.

38. Metal Incendiaries

a. General. Metal incendiaries include those consisting of magnesium in various forms, and powdered or granular aluminum mixed with powdered iron oxide. Magnesium is a soft metal which, when raised to its ignition temperature, burns vigorously in air. In either solid or powdered form it is used as an incendiary filling; in alloyed form it is used as the casing for small incendiary bombs such as the M126 which has a casing of the following composition: aluminum 4.45 percent, zinc 1.24 percent, and magnesium 94.31 percent. This alloy has an ignition temperature of between 548.9° and 598.9° C.

b. Magnesium Incendiaries.

(1) *Symbol.* Mg.

(2) *Atomic weight.* 24.32.

(3) *Melting point.* 651° C.

(4) *Boiling point.* 1,110° C.

(5) *Ignition temperature.* 623° C.

(6) *Burning temperature.* 1,982° C. Burning temperature is variable as it depends upon rate of heat dissipation, rate of burning, and other factors.

(7) *Density.* 1.74.

(8) *Combustion product.* Magnesium oxide (MgO).

(9) *Burning characteristics.* Magnesium burns with a blinding white flame. It melts as it burns; and the liquid metal, burning as it flows, drops to lower levels, igniting all combustible materials in its path. Burning stops if oxygen is prevented from reaching the metal or if the metal is cooled below its ignition temperature. Magnesium does not have the highest heat of combustion of the metals but none of the other metals have been successfully used singly as air-combustible incendiaries. Certain other metals may be alloyed with magnesium without affecting its ignitability. The alloyed metal has strength to withstand distortion, whereas pure magnesium does not. In massive form, magnesium is difficult to ignite. This problem is overcome by packing a hollow core in the bomb with thermate and an easily ignited mixture which supplies its own oxygen and burns at a very high temperature.

c. Thermite and Thermate Incendiaries.

(1) *General.* Thermite is essentially a mixture of powdered iron oxide (Fe_2O_3) and powdered or granular aluminum. The aluminum has a higher affinity for oxygen than iron has and, if a mixture of iron oxide and aluminum powder is raised to the combustion temperature of aluminum, an intense reaction occurs:

$Fe_2O_3 + 2\ Al \rightarrow Al_2O_3 + 2\ Fe + heat$

Under favorable conditions, the thermite reaction produces temperatures of about 2,200° C. (3,922° F.). This is high enough to turn the newly formed metallic iron into a white hot liquid which acts as a heat reservoir to prolong and to spread the heat or igniting action.

(2) *Composition.* Thermite is composed of approximately 73 percent ferric oxide and 27 percent fine granular aluminum. The thermate mixture composed of thermite with various additives is used as a component in igniter compositions for magnesium bombs. A number of such compositions were developed before World War II. Three of these were Therm–8, Thermate–TH2 (formerly Therm–8–2) and Thermate–TH3 (formerly Therm–64–C). Therm–8 was the precursor of later and improved igniting formulations. TH2 differed from Therm–8 in that it contained no sulfur and slightly less thermite. TH3 was found to be superior to either Therm–8 or TH2 and was adopted for use in the incendiary magnesium bombs. The composition by weight of TH3 is as follows:

Ingredient	*Percent*
Thermite	68.7
Barium nitrate	29.0
Sulfur	2.0
Oil (binder)	0.3

The TH3 core is ignited by the primer; this burning core then melts and ignites the magnesium alloy body. The incendiary action is localized since there is little scattering action.

(3) *TH4.* A new thermate (TH4) filling has been developed to replace the original thermite (TH1) used since 1943. The action of TH4 is essentially the same as that of TH3. The principal differences are in the percentages of the basic ingredients, the addition of an oxidizer (barium nitrate), and the substitution of polyester resin for sodium silicate as a binder. The composition of TH4 is—

Ingredient	*Percent*
Iron oxide, magnetic	51
Barium nitrate	22
Aluminum, granular	19
Aluminum, grained	3
Polyester resin (Laminac 4116)	5

39. Oil and Metal Incendiary Mixtures

a. Composition.

(1) PT1 is a complex mixture based on "goop," a paste comprised of magnesium oxide, and carbon with a sufficient amount of petroleum distillate and asphalt to form the paste. The following formula has been adopted for use:

Ingredient	*Percent*
Type C "goop"	49.0 ± 1.0
IM polymer AE	3.0 ± 1.0
Coarse magnesium	10.0 ± 1.0
Petroleum oil extract	3.0 ± 0.2
Gasoline (QM issue)	30.0 ± 3.0
Sodium nitrate	5.0 ± 0.5

(2) PTV is an improved oil and metal incendiary mixture with the following composition:

Ingredient	*Percent*
Polybutadiene	5.0 ± 0.1
Gasoline	60.0 ± 1.0
Magnesium	28.0 ± 1.0
Sodium nitrate	6.0 ± 0.1
P-aminophenol	0.1

b. Functioning. Incendiary bombs containing PT1 or PTV mixture are easily ignited by nose and tail fuzes since they contain many combustible ingredients. The same type of disseminated incendiary effect is obtained as with oil incendiaries.

Section IV. SMOKES

40. Screening Smokes

a. Introduction.

(1) *General.*

(*a*) New means of smoke dispersion made it feasible to use screening smokes extensively in both offensive and defensive operations in World War II. Screening smokes were used to conceal all types of troop movements and installations, in both the combat zone and rear areas.

(*b*) The obscuring action of screening smokes is largely due to reflection and refraction of light rays by the individual suspended solid or liquid particles of which the smoke is composed. This obscuring action occurs to the greatest extent in the absence of light-absorbing particles, such as carbon; white smokes, therefore, have the greatest screening action. Actually, white smokes are made up largely of colorless particles, and the white appearance is due to reflection and refraction of all the visible light rays. The fewer undeviated light rays which pass through the smoke particles, the more effective the smoke screen becomes. Smoke particles exhibit irregular individual motions which cause the smoke to diffuse and spread; larger particles settle out. The life or persistency of a smoke cloud is determined chiefly by wind and convection currents in the air. Ambient temperature also plays a part in the disappearance of fog oil smoke.

(*c*) Water vapor in the air plays an important role in the formation of most smokes; and for this reason, high relative humidity improves the effectiveness of most smokes. The water vapor not only exerts its effects through hydrolysis, but also by assisting the growth to effective size of hygroscopic (deliquescent) smoke particles by a progress of hydration. If these particles are too small, they do not effectively scatter light rays and thus do not assist the screening action. Optimum size of smoke particles is 10^{-4} centimeters (1 micron).

(2) *Properties of screening smokes.* Table II gives a comparison of the properties of all the screening smokes except oil smoke.

(3) *Genertaion of smoke.* Smoke may be generated by mechanical or thermal means, or a combination of mechanical and thermal means.

(*a*) Screening smokes composed of liquids can be disseminated fairly satisfactorily by explosion—a mechanical method. A chemical reaction, however, usually accompanies or follows this form of dissemination. For example, FM may be disseminated by explosion, but smoke is not formed until hydrolysis has occurred as a result of reaction with water vapor in the air.

(*b*) Screening smokes composed of solids are usually disseminated by a thermal method; that is, they are vaporized by heat. This method can also be used for liquids. Subsequent cooling condenses the vapor of the solid or liquid into minute particles which form the smoke. A chemical reaction may accompany the thermal process; for example, HC is disseminated by the thermal process but smoke is not formed until certain chemical reactions take place (*d*(3) below).

(4) *Protective measures.* Smoke is injurious if very heavy concentrations are breatehd for even a short time. (This is particularly true of HC.) Some men are more sensitive to smoke than others. Since use of the protective mask decreases visibility, masks are not usually adjusted in friendly smoke except during prolonged exposure. The mask should be worn when—

(*a*) Unpleasant effects are perceptible.

(*b*) The concentration is heavy.

(*c*) The individual is close downwind from source of smoke.

(*d*) Smoke is released in confined areas.

b. Tantanium Tetrachloride (FM).

(1) *General.* Since traces of moisture cause FM to solidify, making it hard to handle in spraying apparatus, it has been replaced to a large extent by FS.

(2) *Chemical name.* Titanium tetrachloride.

(3) *Formula.* $TiCl_4$.

(4) *Molecular weight.* 189.73.

(5) *Vapor density.* Not applicable since FM does not exert its effect in vapor form.

(6) *Liquid density.* 1.7 at 20° C.

(7) *Freezing point.* —30° C.

(8) *Boiling point.* 135° C.

(9) *Vapor pressure and volatility.* Not applicable because FM must be changed into a new compound by hydrolysis before the screening action is exerted.

(10) *Decomposition temperature.* Above the boiling point.

(11) *Latent heat of vaporization.* Not applicable because FM must be mechanically dispersed by spray or explosion.

(12) *Rate of hydrolysis.* Reacts immediately with water or water vapor. This behavior makes the use of FM in airplane smoke tanks difficult because of orifice clogging by solid hydrolysis products.

(13) *Hydrolysis products.* Solid $TiOCl_2$ and HCl, chiefly, but also $Ti(OH)_4$ if sufficient water is present.

(14) *Stability in storage.* Stable in steel containers if FM is dry.

(15) *Action on metals or other materials.* None on steel if FM is dry; vigorous action if FM is moist. FM smoke is definitely corrosive.

(16) *Odor.* Acrid.

(17) *Physiological action.* FM smoke is not toxic but the liquid burns the skin like a strong acid. The smoke is irritating to the nose and throat, but is only mildly so at the concentration usually found in a smoke cloud.

(18) *Protection required.* None for ordinary smoke clouds; protective mask for heavy concentrations.

(19) *Decontaminants.* Alakli in solid or solution form for liquid FM.

(20) *Munitions suitable for use.* Artillery shell, 4.2-inch mortar shell, airplane smoke tanks, bombs, and special munitions.

c. *Sulfur Trioxide-Chlorosulfonic Acid Solution (FS).*

(1) *General.* FS was developed during 1929 and 1930 to replace the more expensive and less effective FM. FS was used in the final phase of the Luzon Campaign (World War II), when smoke screens without fire hazard were desired.

(2) *Chemical name.* None: solution of sulfur trioxide (SO_3) dissolved in chlorosulfonic acid ($ClSO_3H$).

(3) *Formula.* 55 parts by weight of SO_3 and 45 parts by weight of $ClSO_3H$.

(4) *Molecular weight.* 96.47 (based on components).

(5) *Vapor density.* Not applicable since FS does not exert its effect in vapor form.

(6) *Liquid density.* 1.9 at 20° C.

(7) *Freezing point.* Below —30° C. A small increase in the proportion of sulfur trioxide raises the freezing point markedly.

(8) *Boiling point.* About 80° C. (Decomposes.)

(9) *Vapor pressure and volatility.* (Dependent upon air temperature and humidity.) When FS smoke is atomized in the air, the SO_3 quickly evaporates from the small drops and reacts with atmospheric moisture to form sulfuric acid (H_2SO_4) vapor which in turn condenses to form small drops of liquid or smoke particles. The water vapor in the air is the primary factor affecting evaporation of the SO_3 from FS drops. The absorption of moisture by the FS drops generates heat and causes the SO_3 to evaporate. The water vapor concentration in the air, therefore, determines the rate of evaporation and the total quantity of SO_3 evolved. Air temperatures have little direct effect except in the very early stages of evaporation; however, the air temperature indirectly controls the whole process, because it limits the amount of water vapor which can be present in the air. At very low temperatures

the chlorosulfonic acid component plays little part in smoke production because of its low volatility and because of the very low concentration of water vapor present in the air under such conditions. The effectiveness of $ClSO_3H$ depends upon the following reaction:

$$ClSO_3H + H_2O \rightarrow HCl + H_2SO_4 + \text{heat.}$$

This reaction must depend upon water vapor picked up by the FS drops. At low temperatures, the quantity of moisture held by the atmosphere is very small. For this reason, FS smoke is ineffective at low temperatures when mechanically dispersed. The defect can be overcome by means of thermal generation of FS smoke under low temperature conditions with addition of steam or by dropping the FS onto snow.

(10) *Decomposition temperature.* About 80° C.

(11) *Latent heat of vaporization.* Not applicable.

(12) *Rate of hydrolysis.* Instantaneous.

(13) *Hydrolysis products.* Sulfuric acid is produced by hydration rather than by hydrolysis, or sulfur trioxide. Chlorosulfonic acid is hydrolyzed to form hydrogen chloride and sulfuric acid.

(14) *Stability in storage.* Adequate if dry.

(15) *Action on metals or other materials.* None on metals if FS is dry; however, it is corrosive in the presence of moisture. Since FS smoke is made up entirely of acid components, it will destroy any material which is decomposed by acids. An example of such a material is nylon. Drops of FS of sufficient size will decompose the nylon plastic and weaken or sever the fibers at the points of contact. FS is also highly injurious to many types of paint. Therefore, FS should not be used where possible damage to nylon or auto finishes may occur.

(16) *Odor.* Acrid.

(17) *Physiological action.* Liquid FS is highly corrosive to the skin. The smoke causes a prickling sensation on the skin because of the minute acid particles of which it is composed. Splashes of liquid FS in the eye produce extremely painful acid burns. Exposure to heavy concentrations or prolonged exposure to ordinary concentrations may cause severe irritation of eyes, skin, and respiratory tract.

(18) *Protection required.* None for ordinary smokes; protective mask for high smoke concentration. Heavy rubber gloves should be worn for handling the liquid.

(19) *Decontaminants.* Any alkali in solid or solution form.

(20) *Munitions suitable for use.* Artillery shell, bombs, airplane smoke tanks, and special munitions.

d. HC Mixture (HC).

(1) *General.*

(*a*) During World War I, the greatest single advance in smoke was probably made by Captain Berger of the French Army when he developed a pyrotechnic mixture in which carbon tetrachloride (CCl_4) and a metal (Zn) reacted to produce a volatile hygroscopic chloride as a dense smoke. While neither the United States nor Great Britain used the Berger mixture during World War I, American scientists later improved it by adding an oxidizer for the carbon so that it would not darken the smoke.

(*b*) At the beginning of World War II a mixture of another composition was prepared and was designated HC smoke mixture. In this mixture CCl_4 was replaced by solid hexachloroethane. Ammonium chloride as a retarding agent and a perchlorate as an oxidizing agent were added. In 1940 after the fall of France, perchlorates were not available and chlorates were tested. These proved to be hazardous, however, because they often caused formation of free perchloric acid which ignited the smoke mixture spontaneously. Further experimentation led to the development of the present HC smoke mixture (type C) which consists of zinc oxide, aluminum, and hexachloroethane.

(2) *Composition.* HC is made up of mixture of grained aluminum (Al), zinc oxide (ZnO), and hexachloroethane (C_2Cl_6). Percentages by weight for ingredients of HC smoke mixture (type C) are as follows:

Ingredient	*Percent (approx.)*
Grained aluminum	6.68
Zinc oxide	46.66
Hexachloroethane	46.66

The ratio of zinc oxide to ehxachloroethane is held between the limits of 1.04 and 1.00, but the aluminum may be varied slightly to regulate the burning time as is illustrated below:

Aluminum content (percent)	*Burning time (seconds)*
9.0	55
8.4	64
8.0	65
7.5	71
7.0	84
6.5	96
6.0	107
5.5	147

(3) *Chemical action.* When the HC smoke mixture is heated, a self-propagating reaction is set up which is based, in part, upon the tendency of aluminum to split chlorine from chlorinated hydrocarbons, such as hexachloroethane, and form $AlCl_3$ as illustrated in the following equation:

$$2\ Al + C_2Cl_6 \rightarrow 2\ AlCl_3 + 2\ C + heat$$

The $AlCl_3$ reacts with ZnO to form $ZnCl_2$, as illustrated in the following equation:

$$2\ AlCl_3 + 3\ ZnO \rightarrow 3\ ZnCl_2 + Al_2O^3 + heat$$

A general summarizing reaction can be written

$$2\ Al + C_2Cl_6 + 3\ ZnO \rightarrow 3\ ZnCl_2 + Al_2O_3 + 2C + heat$$

By reducing the aluminum content, but keeping the proportions of hexachloroethane and zinc oxide constant in the smoke mixture, the amount of carbon appearing in the smoke is reduced, thus making the smoke whiter and diminishing the burning rate. The reaction where no carbon is liberated is

$$2\ Al + 9\ ZnO + 3C_2Cl_6 \rightarrow Al_2O_3 + 9\ ZnCl_2 + 6CO.$$

The amount of aluminum in the above reactions can be varied from 3.6 to 10.1 percent. When the aluminum content is reduced below 5 percent, however, the burning time becomes erratic and other means must be employed to regulate the burning. For this purpose basic zinc carbonate, in a quantity not exceeding 7 percent of the zinc oxide, is used.

(4) *Ignition of HC smoke mixture.* The initial heat needed to start the burning of the HC smoke mixture is provided by a starter mixture. A typical starter mixture is composed of silicon, potassium nitrate, charcoal, iron oxide, grained aluminum, cellulose nitrate, and acetone. It has some of the burning properties of both thermate and black powder and, while burning, generates sufficient heat to start the HC smoke mixture burning.

(5) *Mechanism of smoke formation.* As the HC mixture burns, intense heat and smoke are produced. By far the greater proportion of the smoke is zinc chloride, which rapidly absorbs moisture from the air to form particles of effective size. Most of the aluminum remains behind as solid aluminum oxide. During the process of smoke formation, small amounts of

volatile aluminum chloride and hexachloroethane are lost as vapor.

(6) *Stability.* HC smoke mixture (type C) having a total moisture content of 0.6 percent is very stable.

(*a*) Decomposition may result from reactions involving soluble chloride impurities if—

1. The total moisture content exceeds 0.6 percent.

2. Salt water or fresh water gains access to the munitions during storage or transportation.

(*b*) The following appears to be the sequence of events when water (or salt water) reacts with HC smoke mixture (type C):

1. The water dissolves a certain amount of chloride from the chloride impurities in zinc oxide or hexachloroethane.

2. The aqueous chloride solution reacts with the aluminum. The hydrogen produced under these conditions reacts with the hexachloroethane.

$$H_2 + C_2Cl_6 \rightarrow HCl + C_2HCl_5$$

3. The hydrogen chloride produced from the hexachloroethane reacts further with the aluminum and promotes decomposition.

(7) *Physiological action.* As normally encountered, HC smoke has no physiological action. It has a slightly acrid odor. In high concentrations, such as might be encountered very near an operating munition, in an inclosed space, during exposure to dense HC smoke screens, and during prolonged exposures to ordinary field concentrations, a sufficient concentration of zinc chloride may be encountered to produce toxic effects, and the protective mask should be worn.

(8) *Munitions suitable for use.* Burning type only. These include grenades, candles, pots, and artillery shell.

e. White Phosphorus (WP).

(1) *General.* During World War II, WP was used both as a screening smoke and an incendiary in all theaters of operations. In attacks on fortified positions, the M15 WP hand grenade forced enemy abandonment after other methods had failed.

(2) *Disadvantages.* WP has several disadvantages—

(*a*) *Pillaring.* When hot smoke rises rapidly, it produces the effect known as pillaring. In still air, the pillaring of WP nullifies its screening effect. WP pillars because it has such a high heat of combustion (10 times that generated by the HC smoke mixture on the basis of weight).

(*b*) *Rapid burning.* Because WP is very brittle, the exploding munitions in which it is used cause it to be broken into small particles which burn very rapidly.

(*c*) *Poor storage characteristics.* Its low melting point sometimes causes WP to melt in stored munitions; and if these munitions are not stored on end, the center of gravity will shift and produce instability in flight. Many attempts have been made to correct these undesirable properties. This has been accomplished to a considerable degree by plasticizing WP (*f* below).

(3) *Chemical name.* White or yellow phosphorus.

(4) *Formula.* P4.

(5) *Molecular weight.* 124.11.

(6) *Density of solid.* 1.83 at 20° C.

(7) *Freezing point.* 44° C.

(8) *Boiling point.* 290° C.

(9) *Vapor pressure and volatility.* Not applicable.

(10) *Decomposition temperature.* None.

(11) *Action with water.* None; WP is stored under water in concrete tanks.

(12) *Stability in storage.* Stable if kept in an oxygen-free environment.

(13) *Action on metals.* None.

(14) *Oxidation products.* Phosphorus pentoxide (P_2O_5) which reacts with

water to form phosphoric acid (H_3PO_4).

(15) *Odor.* Like matches.

(16) *Physiological action.* Burning solid or liquid WP burns the flesh; such burns heal very slowly. Vapors of WP are poisonous, producing bone decay. (No vapors are found in smoke.)

(17) *Protection required.* None against smoke; flame-proof clothing against burning particles.

(18) *Decontaminants.* WP cannot be decontaminated. Water extinguishes burning WP, and copper sulfate solution prevents further burning.

(19) *Munitions suitable for use.* Grenades, artillery shell, mortar shell, bombs and rockets.

f. Plasticized White Phosphorus (PWP).

(1) *General.* PWP is prepared by a series of steps. WP is first melted and stirred into cold water; granules about 0.5 millimeter in diameter are produced. The slurry of granules and water is mixed with a very viscous solution of synthetic rubber (40 percent GRS rubber in an organic solvent). All of the granules become coated with a film of rubber and are thereby separated from each other. The mass is folded, stretched, and refolded until the composition is homogeneous. This rubbery mass is dispersed by an exploding munition but does not break up to such an extent as WP; therefore pillaring with PWP is much less marked than with WP.

(2) *Properties.* Properties are the same as for WP (see *e* above).

g. Oil Smoke.

(1) *Theory of oil smoke.* During World War II a new method of smoke generation was developed, based on production of minute oil particles by use of purely physical means. The most desirable drop size of these particles ranges from 0.5 to 1.0 micron (1 micron = 0.001 millimeter; 1 inch = 25.4 millimeters). The small drops of oil scatter light rays and produce a smoke which appears to be white. Actually, an individual drop would be transparent under magnification. These drops are produced as soon as the vaporized oil passes through the nozzle of a generator and is cooled by the surrounding air. The air cools the oil vapor so quickly that only very small drops are able to form. The average size of the final drops is controlled by the concentration of the condensing vapor and the rate of cooling. If the oil vapor emerges from the nozzle at high velocity, large volumes of air are sucked into the vapor stream by the rushing vapor. The resulting dilution and cooling produces an enormous number of condensation nuclei. Unless the cooling effect is rapid, the larger drops tend to pick up the vapor lost by the smaller drops which vaporize more quickly than the larger drops. This tendency disappears as soon as the drops are cooled because fog oil has negligible vapor pressure at ordinary temperatures. Thus, the whole process depends upon a high temperature followed by quick cooling. The final oil smoke cloud is stable and the life of the cloud is determined almost solely by meteorological conditions. (For information on smoke generator operation see TM 3–1040–202–12.)

(2) *Production of oil smoke.* The smoke generator employs ordinary low viscosity petroleum oil, referred to as SGF (smoke generator fog) No. 2. Below 32° F., a mixture of SGF oil No. 2 and paraffin(wax)-free kerosene is used. Properties of SGF oil No. 2 are as follows:

(*a*) *Pour point.* —40° F. (—40° C.).

(*b*) *Flash point.* 320° F. (160° C.).

(*c*) *Ignition temperature.* 405° F. (207.2° C.).

(*d*) *Viscosity.* 25 seconds at 100° F. (37.7° C.). This corresponds somewhat to an SAE 10 motor oil in viscosity. (SGF No. 2 is known as "100 pale oil" by the petroleum industry.) Ordinary motor oil is less suitable for use as fog oil because of additives which are usually present in it.

(3) *Physiological action of oil smoke.* Average field concentrations of oil smoke are harmless to personnel regardless of length of exposure. Breathing a high concentration of oil smoke for even extended periods produces no immediately apparent symptoms, but chest pains may develop later on. Oil in the lungs may be a causative factor in development of pneumonia and possibly other diseases. Operating personnel exposed to prolonged high concentrations of oil smoke should wear protective masks as much of the time as possible.

41. Signaling Smokes

a. General. Smoke signals were utilized in ancient times in circumstances when hand and flag signals were not visible and where the sound of voice or horn was not audible. However, during the gunpowder era when battlefields were always enveloped in a thick haze, smoke could be used for signaling. With the advent of smokeless powder, smoke signals again became feasible and are now an important means of communication. By prearrangement, colored smoke can be used to identify friendly units; to control the laying and lifting of artillery, mortar, and small arms fire; to identify targets; and to coordinate fire and maneuver of combat arms engaged in local assault operations. Colored smokes are nontoxic in ordinary field concentrations.

b. Characteristics of Signaling Smokes.

(1) *General.* Four characteristics of signaling smokes determine their value for military use—color, visibility, duration, and volume.

(2) *Color.* A signaling smoke must be clearly distinguishable from the smoke incident to battle; this limits the utility of white, gray, or black smoke. The standard smokes: red, green, yellow, and violet (table III), afford good visibility and unmistakable identity.

(3) *Visibility.* At great distances all colors become gray and indistinguishable. A minimum visual range against a contrasting background is specified for each signaling munition. With munitions now in use, the visual range varies from 3,000 feet for the M22 rifle grenade to 10,000 feet for the M18 grenade.

(4) *Duration.* On the basis of duration, colored smoke munitions may be divided into two classes—fast-burning, which last about 1 minute; and slow-burning, which last about 2 minutes.

(5) *Volume.* Smoke volume can be expressed as the cross-sectional area of a cloud presented to the observer. For example, a horizontal area of at least 400 square feet has been the proposed military characteristic for the 105-mm and the 155-mm colored smoke shell.

c. Means of Producing Signaling Smokes. Of four possible methods for producing signaling smoke, only one has been found feasible—that of volatilizing and condensing a mixture containing an organic dye. Of the dyes tested, the most satisfactory are the general types of azo, anthraquinone, azine, or diphenylmethane dyes. The filling for a colored smoke munition is essentially a pyrotechnic mixture of fuel and a dye, with a cooling agent sometimes added to prevent excessive decomposition of the dye. The heat produced by the fuel volatilizes the dye which then condenses outside the munition to form the colored smoke. The fuel is made up of a mixture of an oxidizing agent, such as potassium chlorate ($KClO_3$) and a combustible material, such as sulfur or sugar. The burning time can be regulated by adjusting the proportions of oxidant and combustible material, and by use of coolants such as baking soda.

d. Grenade Fillings. Each grenade contains a starter mixture and a colored smoke mixture. Table III gives the ingredients and the percentage of each used in currently standard color mixtures and in the starter mixture for the M18 hand grenade. (Other colored smoke grenades have approximately the same composition as the M18.) The starter mixture is the same for each color.

Table III. Colored Smoke Fillings

Type mixture	Ingredient	Percent (approximate)
Red smoke	Dye: 1—methylaminoanthra-. quinone: 90%, Drextrine: 10%	40.0
	Baking soda	18.0
	Potassium chlorate	30.2
	Sulfur	11.8
Green smoke.	Dye: 1, 4—di-p-toluinoanthraquinone: 87.5%, Auramine: 12.5%	32.0
	Baking soda	24.0
	Benzanthrone	8.0
	Potassium chlorate	26.0
	Sulfur	10.0
Yellow smoke.	Dye: Auramine	38.0
	Baking soda	31.5
	Potassium chlorate	22.0
	Sulfur	8.5
Violet smoke.	Dye: 1, 4–diamino–2, 3–dihydroanthroquinone: 80%, 1–methylaminoanthraquinone: 20%	42.0
	Baking soda	18.0
	Potassium chlorate	82.8
	Sulfur	11.2
Starter	Potassium nitrate	37.8
	Silicon	28.0
	Charcoal	4.2
	Cellulose nitrate	1.2
	Acetone	28.8

CHAPTER 4

DETECTION AND IDENTIFICATION OF CHEMICAL AGENTS

Section I. GENERAL

42. Requirements

The essential requirements of a method of detection suitable for field use are that it be rapid, simple, specific, sensitive, easily read, and stable.

43. Methods

The methods available for the detection of chemical agents are considered under two heads—subjective and objective—according to whether the detection is by the senses alone or whether use is made of some external physical or chemical aid. Actually the subjective detection of chemical agent should be used only as a warning of the presence of agent, to be followed by immediate masking; and the objective method of detection should then follow. Moreover, the objective method should be used at any time it is believed that a chemical agent might be present whether the senses can detect its presence or not. The chief value of subjective detection is in surprise situations. All men should be familiar with the subjective methods of identification, and those who are primarily responsible for agent detection and identification should be trained in the objective methods. When taken singly, the known detection methods are not always entirely satisfactory; but when taken together, the methods usually will afford a reliable indication of the nature of any chemical agent which might be present. The fact must not be overlooked that in the field rapidity is essential.

Section II. SUBJECTIVE METHODS OF DETECTION AND IDENTIFICATION

44. By Visual Evidence

a. Liquid Chemical Agents. Contamination of grounds and/or buildings by liquid chemical agents sometimes affords visual evidence of the presence of the agent. The possibility must not be overlooked that bombs with high bursting charges can be used to disperse a liquid chemical agent, so that the greater portion of the agent forms a highly concentrated cloud of vapor which does not leave enough surface contamination to be visually detected.

(1) *Heavy concentration.* On dry, porous surfaces such as brick, cement, stone, dry roads, dry earth, and the like, some liquid toxic chemical agents are rapidly absorbed and leave only dark oily stains. On wet surfaces, some liquid agents may spread and give a slightly iridescent film on the surface for a time.

(2) *Light contamination.* Light contamination and also the contamination resulting from aircraft spray, takes the form of small (sometimes pin-point) drops; and is difficult to detect visually. In the form of a mist, these minute drops may drift for considerable distances downwind from the point of release.

b. Nonliquid Chemical Agents. Phosgene and diphosgene form white clouds when air is damp but are colorless and invisible when air is dry; GB when dispersed from high burst munitions forms white clouds which finally evaporate. The arsenicals are white and opaque if sufficiently concentrated, but are invisible when diluted. A white cloud may be only a smoke produced for screening purposes, or incidental smoke arising from the use of incendiary and high-explosive bombs. All clouds and smokes should be considered as possible agent-containing clouds or smokes and protective measures should be taken promptly. After a chemical-agent cloud has dissipated, there may be other visual evidence of it in the form of rotted clothing, bleached vegetation, or corroded metals.

45. By Irritation or Injury

a. When a chemical agent causes immediate irritation or injury to the body, the bodily effect affords a warning of the presence of the chemical agent. Tear agents, for example, are readily recognized by their immediate irritant effect on the eyes at concentrations as low as 0.1 mg/m^3. Vomiting agents in concentrations of 0.13 to 0.19 mg/m^3 or less irritate the nose, throat, and chest. The vomiting agents are practically odorless. The arsenicals (except SA) have an immediate irritating effect on the nose and eyes, which can serve as a warning.

b. With CG and DP, on the other hand, the irritant effects are far less marked, and concentrations which are barely detectable by odor and only slightly irritating to the breathing passages may lead to serious results if breathed for any length of time. Furthermore, the intensity of the immediate effects affords little indication of the magnitude of the concentration and dosage involved. Agents such as AC, SA, and HD produce no immediately recognizable symptoms, except that in high concentrations AC stimulates breathing and death occurs rapidly.

c. The nerve agents, even in very low vapor concentrations, have pronounced immediate effects including running nose, tightness of the chest, and dimmed vision. Effects from liquid contamination on the skin are delayed up to 1 to 2 hours. However, decontamination should be accomplished immediately because eye disturbances occur promptly and others follow in rapid succession (par. 30).

Section III. OBJECTIVE METHODS OF DETECTION AND IDENTIFICATION

46. General

A variety of objective methods of detection have been proposed from time to time. However, many of them have failed to fulfill the six essential requirements referred to in paragraph 42. Objective methods are of two types—physical and chemical.

47. Physical Methods

Many methods of detection of chemical agents by strictly objective physical means have been investigated, and certain of these are in an advanced stage of development (automatic alarms). Some items are adapted for issue as portable units in forward areas and some are designed for use in fixed installations. The operation depends on a color change produced by the reaction of the chemical agent with an indicator solution. This color change is measured by a photoelectric circuit which in turn sounds an alarm. The sensitivity of these devices is well below the major symptom-producing dosage in man, and the rate of warning is good. However, if a chemical agent is placed directly upon a position, warning cannot be given by these devices before danger exists; and immediate masking will always be required under these conditions.

48. Chemical Methods

Most of the field tests which have been devised to detect chemical agents are based upon the change in color of a test paper, or of a test reagent. These tests generally are simple, sensitive, and rapid. Taken separately however, they are seldom specific and require confirmation and interpretation. The value of any color test depends largely on circumstances under which the test is made and the intelligence used in interpreting the results. No one qualitative color test is absolutely specific. Detection and identification procedures have been designed to meet a wide variety of field conditions. These procedures employ three separate methods—the silica gel detector tube, indicator paper, and liquid contact detector. The first two methods are for use principally in the detection and identification of vapors of highly volatile chemical agents. Tests of vapors are more accurate than those of liquids, because the danger of interference from other materials is less in vapor than in liquid. The third method and, to a lesser extent, the second are designed to test for surface contamination by liquid or solid chemical agents. The liquid contact detector is particularly valuable in testing for chemical agents having low vapor pressures. These three methods are discussed in *a* through *c* below.

a. Silica Gel Detector Tube.

(1) *Principle.* In this method, activated silica gel is both the adsorbent and the medium on which color reactions are performed. Air suspected of contamination is drawn through a small glass detector tube which contains a layer of silica gel held between two loosely woven cotton plugs. The quantity of air required depends upon the concentration of the vapors and the sensitivity of the chemcial test. The sensitivity of most of the tests is sufficiently high to permit sampling by means of a hand-operated suction pump or suction bulb. Air resistance of the tubes must be kept at a minimum to facilitate sampling. A power-operated suction pump may be useful where large samples of air are needed to produce a test. In such cases, suction is adjusted to draw not over 1 liter of air per minute through the detector tube.

(2) *Use.* The vapor test can be applied to any sample having the required volatility. This includes samples of the chemical agents themselves or soil or other material contaminated with them. Samples suspected of containing chemical agents with low vapor pressure are heated in a closed container and the air in the container is then tested. Adequate samples should be obtained from localities likely to have the maximum vapor concentration.

(3) *Theory of the silica gel vapor detector.*

(*a*) *General.* Certain types of silica gel have the capacity to absorb many kinds of substances. In a silica gel detector tube, the chemical agent vapor can be thought of as being held fast on the surface of the silica gel in the presence of a chemical which has the power to react with the chemical agent to produce a colored compound or a dye. Whether the chemical is added to the silica gel before or after the chemical agent is adsorbed, the principle is the same.

(*b*) *Detection of highly volatile toxic chemical agents.* Highly volatile agents are poorly adsorbed on silica gel and, in order to obtain reasonable sensitivity, and impregnated gel must be employed that will react directly with the substance to be detected. However, these detector tubes cannot be used for the quantitative or even semiquantitative estimate of vapor concentration of highly volatile toxic chemical agents.

(*c*) *Detection of low volatility toxic chemical agents.* Chemical agents of low volatility are readily adsorbed on unimpregnated silica gel, provided the absolute humidity is low. When absolute humidity is low, it is possible to make a semiquantitative estimate of the vapor concentration of the chemical agent present. With increasing absolute humidity the adsorption process becomes less efficient, and at high absolute humidities so much of the agent may fail to be adsorbed that it will be impossible to make a quantitative or even semiquantitative estimate of the vapor concentration.

b. Indicator Paper.

(1) *Principle.* In this method, filter paper is used instead of silica gel as the medium to hold the indicator chemicals (reagents). Indicators paper are easier to use than silica gel detector tubes, but usually are not as sensitive. Indicator papers are used chiefly for detection of highly volatile chemical agents whose vapor concentrations are usually high enough to give a satisfactory test. Some indicator papers are of value as contact

detectors for the low volatility chemical agents. Indicator paper tests are usually of little value when only traces of chemical agents are present. If the reagents are nonvolatile and stable, the test papers can be impregnated in advance and stored until needed. When only part of the reagents are nonvolatile and stable, the test papers can be impregnated in advance with the stable ingredients and just before the test with the less stable ones. If none of the reagents has the required stability, the test papers must be impregnated just before use. This is more easily done by using reagents dissolved in volatile solvents.

(2) *Limitations.* If indicator paper tests are to be properly interpreted, certain precautions must be observed. Slight color changes are difficult to recognize, and doubtful readings must be compared with an unexposed portion of the same test paper. If the test reagents are colorless, it is better to apply them to the paper in spots, to obtain good contact with the unsensitized background after a faint test develops.

c. Liquid Contact Detectors.

(1) *General.* Liquid contact detectors are applied directly to liquid chemical agents or to materials contaminated with them. The principles of liquid contact detectors have been used in developing a paper and a crayon, each of which can be used in the detection of liquid blister agents. Detector paper is heavy paper which has been coated with an indicator sensitive to liquid blister agents. (Both the paper and crayon are discussed in FM 21-48 and TM 3-306.)

(2) *Principle.* Many of the same reagent solutions are used in the detection of liquid chemical agents as are used in the detection of vapors. Only the method varies.

(3) *Method.* To use a test solution for liquid detection, apply the solution directly to the surface suspected of being contaminated by the liquid chemical agent. If the surface would be harmed by this treatment or if surface is too highly colored to show a direct color test, place a strip of filter paper in contact with the contaminated surface for a short time and then remove the paper and apply the test solution to it; or apply filter paper, saturated (and still wet) with the test solution, to the surface. To rule out the possibility of a color reaction being due to an inherent quality of the material being tested or to chemicals being used, test a sample of like material *known* to be uncontaminated, following exactly the same procedure as for the material suspected of being contaminated, and compare the results.

(4) *Limitations.* In liquid contact testing the possibility must be considered that hydrolysis products or other reaction products cause the same color reactions as a chemical agent.

Section IV. FIELD DETECTION, IDENTIFICATION, AND SAMPLE COLLECTION

49. General

a. Special kits have been developed for detecting and identifying the chemical agents encountered in the field and for collecting samples of chemical agents for identification in the laboratory. See TM- 3-306, TM 3-6665-211-12, TM 3-6665-212-12, TB CML 43, and TB CML 44 for information on use of kits discussed in this section.

b. Automatic alarms are being developed and produced for early warning of point detection and area detection of chemical agents. For information on the automatic field VG-agent alarm, see TM 3-6665-210-12.

50. Chemical Agents Detector Kit M9A2

a. Development. Since most present-day chemical agents are colorless and odorless, or nearly so, rapid and reliable detection of their presence can be made by chemical test only. The chemical agent detector kit was devised for use by combat troops. The M9A2 chemical agent detector kit is presently a standard C item.

b. General. The chemical agent detector kit M9A2 is small, compact, and easily carried. The complete kit weighs about 2½ pounds and consists of the items listed in *c* below, contained in an olive drab, 8½- by 5½- by 3-inch duck carrier. The kit enables one operator to detect vapors of HD, HN's, L, ED, AC, CG, CK, CX, MD, and G-series chemical agents. The tests reveal contamination by producing color changes in chemically treated silica gel tubes through which contaminated air is drawn by means of a pump (par. 48*a*). Negative tests are also of value since they may be used to indicate when it is safe to remove protective masks or when decontamination has been accomplished following a chemical agent attack.

c. Contents. The kit contains the following items:

(1) *Lead-foil-covered glass detector tubes.* Quantities, markings, and uses of tubes are indicated in (*a*) through (*e*) below.

(*a*) *Twenty, with brown dot on tube; dot and one stripe on wrapper.* Used in testing for AC. These tubes contain silica gel imgregnated with tetramethyldiaminodiphenylmethane and a copper salt. This gel layer is protected by a layer of activated charcoal.

(*b*) *Twenty, with green dot on tube; dot and two stripes on wrapper.* Used in testing for CG. These tubes contain silica gel impregnated with a mixture of para-dimethylaminobenzaldehyde and phenyl alpha-napthylamine.

(*c*) *Forty, with blue dot on tube; dot and three stripes on wrapper.* Used in testing for CK, HD, CX, and HN. These tubes contain silica gel impregnated with DB–3 reagent. DB–3 is 4-(p-nitrobenzyl) pyridine. This reagent reacts with various chemical agents to give characteristic colors.

(*d*) *Twenty, with yellow dot on tube; dot and four stripes on wrapper.* Used in testing arsenicals. These tubes contain silica gel impregnated with ammonium molybdate and zinc sulfate.

(*e*) *Twenty, with white dot on tube; dot and five stripes on wrapper.* Used to test for G-agents, for carrying out a confirmatory test for nitrogen mustards in case the blue dot tube test for mustards is positive, and for collecting and preserving samples of vapors of unknown toxic chemical agents for later identification. These tubes contain silica gel only.

(2) *Reagent solutions.*

(*a*) *Blue-top bottle.* This bottle contains a solution prepared by dissolving 10 grams of sodium hydroxide and 20 grams of sodium perchlorate in 100 milliliters of distilled water. The sodium hydroxide is used to develop the test for L in the yellow dot tube and for HD or HN in the blue dot tube. The perchlorate is added to bleach out an interfering brown color sometimes obtained when sodium hydroxide solution is added to DB–3 reagent on silica gel.

(*b*) *Aluminum-top bottle.* This bottle contains a solution of 30 grams of anhydrous cupric chloride in 70 milliliters of water. This solution reacts with the aluminum foil wrapping on the blue dot detector tubes to produce the heat needed to develop the DB–3 test.

(*c*) *Red-top bottle.* This bottle contains Dragendorff reagent, which is a well-blended mixture of 3 grams bismuth oxychloride, 8.6 grams sulfamic acid, and 38.2 grams of potassium iodide. One gram of Dragendorff reagent is dissolved in 45 milliliters of distilled water to make the reagent solution. When newly prepared, this solution has a bright yellow color. The solution is somewhat unstable and should be replaced if its color changes to orange or brown. Used with white dot tube for confirmation of HN.

(*d*) *Green-top bottle.* This bottle contains an aqueous solution of sodium pyrophosphate peroxide and sodium-2-ethoxy-3-amino diphenylamine-2-sulfonate. A fresh solution should be prepared in the green-top bottle each 24 hours the kit is in use, and it should be made up before the test is begun. (For instructions on preparations of reagent solutions, see TM 3–306). Preparation time required is about 10 minutes. The green-top bottle should be emptied and washed out with pure water at the end of each day's operation. Used with white dot tube for detection of G-agent.

(3) *Dry chemical refills.* These are stored in the hollow pump handle and contain solid reagent for replenishing the solutions in all but the green-top reagent bottles. The contents of one of the red, aluminum, and blue vials are enough to make one solution for each of the correspondingly colored bottles. Distilled water is added up to the edge of the paint on the bottle and the solutions shaken vigorously. One tablet of reagent from the green vial and one tablet from the white vial are crushed together in one reagent bottle of water to fill the green-top bottle.

(4) *Blister agent detector crayon.* An aluminum vial contains three detector crayons which can be used as crayons or pulverized and used as power to detect surface contamination by blister agents, with the exception of HN.

(5) *Air sampling pump.* The pump is manually operated; it draws in about 100 cubic centimeters of air per stroke.

(6) *Flashlight.* A one-celled flashlight is built into the pump handle.

(7) *Absorbed agent sample report forms.* A set of data cards is included in the kit for reporting information concerning unidentified chemical agents. These cards accompany vapor samples collected and preserved in the white dot detector tubes.

(8) *General instructions for use of kit.* Instructions are on ten plastic-coated cards and give contents of kit, directions for use, and other pertinent information.

51. Chemical Agent Detector Kit, M18 (Standard B)

a. General. This kit consists of a canvas carrying case containing all of the reagents and accessories listed in *b* below. The kit weighs approximately 2½ pounds, and is approximately 8½ inches by 5½ inches by 3 inches. With this kit a trained operator can detect field concentrations of the blister agents (H, HD, HN, HT, L, MD, CX, ED), the nerve agents (G-series), the blood agents (AC, CK), and the choking agent CG. Like the M9A2 kit discussed previously (par. 50), contamination is detected by the use of silica gel detector tubes through which air is drawn by means of an air-sampling bulb. Negative tests are of value in determining when it is safe for personnel to remove their protective masks, or when decontamination has been successfully completed, after a chemical-agent attack.

b. Contents. This kit consists of:

(1) *Lead-foil-wrapped detector tubes and sampling tubes.* Quantities, markings, and uses are as indicated below.

(*a*) *Forty; blue dot on tube; dot and 1 band on wrapper.* Used for testing for G, CK, H, HD, HT, HN, ED, and CX. These tubes contain silica gel impregnated with DB–3 test reagent and mercuric cyanide. DB–3 is alpha-4- (p-nitrobenzyl) pyridine.

(*b*) *Twenty; brown dot on tube; dot and 2 bands on wrapper.* Used for testing for AC. These tubes contain silica gel impregnated with tetramethyldiaminodiphenyl methane and a copper salt.

(*c*) *Twenty; green dot on tube; dot and 3 bands on wrapper.* Used for testing for CG. These tubes contain silica gel tubes impregnated with p - dimethylaminobenzaldehyde and phenylnapthylamine.

(*d*) *Twenty; yellow dot on tube; dot and 4 bands on wrapper.* Used for testing for L and ED. These tubes contain silica gel impregnated with ammonium molybdate and zinc sulfate.

(*e*) *Twenty; white dot on tube; dot and 5 bands on wrapper.* Used for sampling and preserving unknown toxic chemical agents for future identification and the detection of G-agents if blue dot tubes are not available. These tubes contain silica gel without any chemical impregnite.

(2) *Two air sampling bulbs-manually operated.* Approximately 3½ inches overall length and 1½ inches at their greatest diameters. One end of the bulb contains a ball check valve which permits air to escape but not to enter. The other end has an opening to accommodate a detector tube.

(3) *Reagents.* The reagents listed below are all packed in a plastic package in the kit:

(*a*) 1 green vial of solid reagent—contains 14 tablets of "compound 34," which is sodium-2-ethoxy-3-amino diphenylamine-2-sulfonate.

(*b*) 1 blue vial of solid reagent—contains a sufficient amount of sodium hydroxide to prepare one bottle of the reagent solution.

(*c*) 14 plastic packets of powdered reagent—contain sodium pyrophosphate peroxide.

(4) *Reagent solutions.* Two screw-cap glass dropper bottles are included for solutions required for testing for the various agents. They are prepared as follows:

(*a*) *Green-top bottle.* To prepare this solution, one tablet from the green vial ((3) (*a*) above) is mixed with the contents of 1 plastic packet ((3) (*c*) above) and enough water added to this mixture to fill the bottle to the mark. This solution is used in the test for G-agent.

(*b*) *Blue-top bottle.* This bottle is originally packed with enough solid reagent to make one solution by adding just enough water to fill the mark. To refill it, the contents of the blue vial ((3) (*b*) above) are emptied into the bottle which is then filled to the mark with water. This solution is used in the tests for H, HD, HT, HN, CX, L, MD, and ED.

(5) *M7A1 Vesicant Detector Crayon.* This aluminum can contains three crayons sealed in individual plastic bags. They may be used as crayons or crushed into powder to detect surface contamination by blister agents, with the exception of HN.

(6) *M6A1 Liquid Vesicant Detector Paper.* This book contains 25 sheets of heavy paper which have been coated on one side with a substance sensitive to the blister agents.

(7) *Accessories.* Miscellaneous accessories also found in the kit include five report forms and envelopes (for use in the preservation of silica-gel-tube samples taken when and unknown chemical agent is suspected). These tubes plus the completed forms in an envelope are sent back to the chemical laboratory.

52. Chemical Agent Detector Kit, M18A1 (Standard A)

a. General. The M18A1 chemical agent detector kit consists of a canvas carrying case 8½ inches by 5½ inches by 3 inches. It weighs approximately 2½ pounds. This kit is designed to detect dangerous vapor concentrations of the blister agents (H, HD, HN, HT, L, CX, MD, ED), the nerve agents (G- and V-series), the blood agents (AC, CK), and the choking agent CG. The kit may also be used to collect samples of unknown agents which cannot be detected with the kit. Toxic chemical agents are detected by the use of either silica gel detector tubes or enzyme tickets through which air is drawn by means of an air sampling bulb.

b. Contents.

(1) Detector tubes and sampling tubes are glass tubes which are heat sealed at

both ends. The tubes are 3 inches long and have an outside diameter of approximately three-sixteenths of an inch. Silica gel is held in the mid portion of each tube by fabric plugs. The tubes are lightly scored about five-eighths of an inch from each end to permit the sealed ends to be broken by finger pressure. Each detector or sampling tube is marked with two colored bands. Quantities, markings, and uses for tubes are indicated below:

(*a*) Fifty blue band tubes used to test for G, CK, CX, H, HD, HT, and HN.

(*b*) Twenty-five green band tubes used to test for CG.

(*c*) Twenty-five red band tubes used to test for AC.

(*d*) Twenty-five yellow band tubes used to test for L and ED.

(*e*) Twenty-five white band tubes used to collect samples of agents which cannot be identified.

(2) Forty detector tickets are contained in a strip of sealed individual plastic envelopes. Each detector ticket consists of a plastic holder which is squared at one end and rounded at the other end. Two enzyme-impregnated plugs are set into the holder. The plug near the rounded end of the ticket has a plastic backing and is used as a control. The plug near the squared end has no backing and is used in sampling the air.

(3) Fourteen plastic packets of powdered reagent (in plastic container).

(4) One green vial filled with fourteen reagent tablets.

(5) 1 bottle (green dot, empty).

(6) 1 bottle of sodium hydroxide (blue dot).

(7) 1 bottle of tris(hydroxymethyl)aminomethane solution, pH 8.0 buffered (white dot).

(8) M7A1 vesicant detector crayon.

(9) Air-sampling bulb with adapter.

(10) Inspection date record card.

(11) Pack of envelopes and report forms.

(12) Book of M6A1 liquid vesicant detector paper.

(13) Instructions for use of kit.

(14) Pencil.

(15) Red-marked aerosol-type disperser containing 2.6 dichloroindophenylacetate substrate solution.

(16) Strip of 40 plastic bags.

c. Air-Sampling Bulb and Adapter. Air to be sampled is drawn through a detector tube, sampling tube, or detector ticket by an air-sampling bulb. The bulb has a one-way valve in its discharge end. A plastic adapter is inserted in the air-intake end of the bulb. The adapter remains attached to the bulb at all times. The adapter is designed to hold detector ticket or a detector sampling tube in position. (Detector tickets are used to test for V and G agents.) For additional information, see TM 3–6665–212–12.

d. Uses. The M18A1 kit may be used—

(1) For agent reconnaissance in areas where contamination is suspected.

(2) To indicate when it is safe to remove masks after an agent attack.

(3) To test for the presence of a toxic chemical agent after decontamination.

(4) To delineate areas of contamination.

It is not to be used as an alarm.

e. Refill Kits. Refill kits for the M18A1 chemical agent detector kit are the C18R1 chemical agent detector refill kit and the M30 V–G components chemical agent detector refill kit.

53. Chemical Agent Detector Kit, M15A1A

a. Development. The M15A1A detector kit was developed as an improved simplified model that would detect and differentiate between V, G, HD, HN, HT, CK, and CX, and replace the earlier M15 kit. See TM 3–6665–211–12.

b. General. This kit consists of a 5 by 5½ by 2¾ inch OD canvas carrier, equipped with "Type X" hardware so that kit can be placed on a load-carrying belt and moved to any comfortable position without removal from the belt. Weight is approximately 1 pound 2 ounces when filled and ready for use.

c. Contents. The kit contains:

(1) Dispenser of sealed glass blue band tubes for detection of G, H, HD, HN, HT, CX, and CK.

(2) Compartment containing sodium pyrophosphate peroxide packets and green top vial with tablets of compound 34.

(3) Forty plastic G- and V-agent detector tickets in sealed plastic envelopes and separate belt of 40 plastic envelopes.

(4) Red marked aerosol dispenser for the substrate solution.

(5) Blue, green, and white dot plastic squeeze bottles for solutions.

(6) Rubber aspirator bulb with adapter.

(7) Instruction Cards.

d. Use. The M15A1A chemical agent detector kit is designed for the detection of dangerous concentrations of nerve agents (G and V), mustards (H, HD, HN, HT), and CK and CX by observation of color changes in detector tubes or detector tickets. (Uses are given in par. 52*d.*) It is to be employed by company and smaller units down to platoon level and also by higher-level headquarters.

(1) *Basis of issue (initial).* One per platoon or similar-size unit. One per company, battalion, brigade, or similar-size headquarters.

(2) *Maintenance.* This kit will be maintained by using units through use of refill kits listed in *e* below.

e. Refill Kits. Refill kits for the M15A1A chemical agent detector kit are the C15R1 chemical agent detector refill kit and the M30 V–G components chemical agent detector refill kit.

54. Chemical Agent Analyzing Kit M10A1

a. General. The analyzing kit was developed as a portable kit for use by laboratory teams (par. 59). It is used by technicians trained in the chemistry and use of chemical agents. The kit detects and identifies the common chemical agents (except VX, BZ, and CS) by use of detector tubes, detector papers, and detector solutions. The analyzing kit, like the mobile laboratory itself, is not usually located in the combat area. Since tests made with field detector kits are not always adequate, area commanders may ask for personnel and equipment from a mobile laboratory to make further tests. Also, commanders may request personnel of the mobile laboratory to make routine checks of field kit results to confirm reports from front-line personnel.

b. Description. The M10A1 chemical agent analyzing kit is divided into two sections.

(1) A shelf which contains dropping bottles for liquid reagents, clips of detector tubes, detector papers, aluminum foil chemical heaters, and a rubber sampling bulb.

(2) A bottom section which contains solid chemicals, liquid reagents, spatulas, extra paper strips, a funnel, a sampling pump, and a rubber aspirating bulb. The complete kit, in a metal carrying case, is 19 by 8 by 7 inches and weighs 26 pounds.

c. Testing Procedure. See TB CML 43 for information.

55. Chemical Agent Sampling Kit, M12

a. Development. The chemical agent sampling kit M12 was designed primarily for use by laboratory teams and technical service intelligence teams to provide a method of collecting samples of liquid or solid chemical agents from the soil, vegetation, or hard surfaces; and to permit the return of the agents to the field laboratory for analysis.

b. Description. This kit contains sampling bottles, an extraction apparatus, cleaning solvent, repair and replacement items, and a component carrier-type kit about 12 by 4 by 4 inches. The component carrier-type kit is divided into two compartments. The large compartment contains screwcap bottles, a scoop, pliers, cotton toweling, a notebook and pencil, and a small container of detector powder. The smaller compartment contains an impermeable envelope for rubber gloves. The complete kit, in an aluminum carrying case, is 15 by 15 by 9 inches and weighs 43 pounds. See TB CML 44 for further information.

Section V. LABORATORY IDENTIFICATION OF CHEMICAL AGENTS

56. General

a. The rapid and accurate identification of chemical agents used by enemy forces is necessary for the development of effective countermeasures. It is necessary to guard against the eventuality of the use not only of recognized agents but of new agents as well.

b. By providing means of identification at a number of organizational levels, identification can be expedited, although it is clear that only limited information can be expected from forward groups.

c. Thus, proper provisions for chemical intelligence should include semipermanent laboratory units capable of performing all tasks necessary for the complete identification of recognized and new chemical agents as well as portable kits of more limited applicability for use in forward areas, preferably by laboratory teams, type HA (TOE 3–500).

57. Laboratory Facilities

A military laboratory differs from a civilian laboratory in that it must be capable of being operated in regions devoid of the usual facilities provided in developed urban areas. A self-sufficient laboratory should—

a. Be of a semipermanent nature.

b. Be staffed by individuals skilled in the science and practice of chemistry, and continuously employed in the operation of the laboratory.

c. Contain equipment required for solving chemical operations problems of an analytical nature.

d. Be capable of operating for extended periods remote from sources of supply.

e. Follow procedures employing very small quantities of chemical reagents and agents for safety in working with noxious, toxic, or explosive substances.

58. Laboratory Procedures

Given sufficient time and facilities, there is little doubt that competent chemists can identify almost any substance. However, when there is need for rapid identification, operations must be expedited by means of specially developed procedures. These may be separated into several steps.

a. Procurement of Sample. Samples may be taken from unexploded and malfunctioned munitions or from contaminated materials such as soil, foliage, masonry, water, and air.

b. Separation and Purification of Sample. Micro and semimicro procedures are particularly advantageous in separation and purification of chemical agent samples because frequently only small amounts may be available and because small samples are less hazardous to work with. For most samples, distillation or sublimation are effective for purification. Other procedures are necessary for purification of very unstable agents. Such procedures make use of crystallization from suitable solvents and of partitioning between solvents. Determination of certain physical constants may be necessary before purification procedures can be selected.

c. Specific Tests. Methods have been developed which are specific for certain chemical agents (ch. 5). A chemical agent should be given specific tests unless it is known to be something so new that it cannot be identified without special analysis.

d. Functional Group Analysis. Methods have been developed for determination of elements or functional groups which have been found to be common to various groupings of chemical agents. Thus, if one of the elements or functional groups is found in an unknown substance, much will be known or can be postulated as to the probable properties of the unknown material. For example, the most powerful blister agents are characterized by the group—CH_2CH_2Cl; the structural formula for mustard is $ClCH_2CH_2\text{–}S\text{–}CH_2CH_2Cl$, and for HN–1 is $ClCH_2CH_2\text{–}N(C_2H_5)\text{–}CH_2CH_2Cl$. The carbon atoms in such a compound are designated by consecutive Greek letters starting from the point of attachment to the central atom (the sulfur atom in HD; the nitrogen atom in HN–1). Thus, the chlorine atom in each of the above groups is attached to the beta carbon, and is usually referred to as beta chlorine. The presence of this type of chlorine atom usually indicates a blister agent; the beta chlorine atom may be present, however, in some nonblistering compounds.

e. Derivative Preparation. Application of the techniques described in *a* through *d* above, to the identification of an unknown chemical agent usually results in limiting the unknown agent to a particular group of possible compounds. Positive identification can then be accomplished by preparation of a derivative (formation and identification of a known compound) and direct comparison or, if the compound has not been previously described, by transformation into known compounds. Work of this nature requires adequate library and laboratory facilities in addition to well-organized working procedures. These are only possible in a semipermanent installation.

f. Ultimate Analysis. If a chemical agent cannot be identified by any specific tests, it may be necessary to determine all the elements in the compound. This is determined by—

(1) Decomposing the sample in such a way that its constituent elements are brought into solution for easy identification. (Elements which are most likely to be encountered in typical chemical agents include boron, bromine, chlorine, chromium, fluorine, iodine, phosphorus, selenium, silicon, sulfur, tellurium, nitrogen, carbon, hydrogen, iron, titanium, manganese, nickel, cadmium, magnesium, barium, strontium, calcium, copper, lead, zinc, arsenic, beryllium, antimony, and tin.)

(2) Qualitative analysis.

(3) Quantitative analysis.

(4) Comparison of the results of analysis with the ultimate analysis of known compounds.

59. Base Chemical Laboratory M2

a. Description. The base chemical laboratory M2 consists chiefly of general laboratory equipment, chemical glassware, chemicals, library, special testing equipment, and auxiliary equipment. The laboratory requires a floor space of not less than 900 square feet; it is packed in 65 boxes (total weight 22,000 pounds; cubage not over 1,356 feet).

b. Function. The base chemical laboratory M2 is designed to provide a complete field laboratory which is operated by personnel of a chemical laboratory company. The principal work is—

(1) To collect and identify enemy chemical agents.

(2) To devise immediate methods of decontamination and protection of the troops, equipment, and terrain against new chemical agents.

(3) To determine the adequacy of friendly and enemy protective equipment.

(4) To provide miscellaneous technical advice whenever it is required.

(5) To keep an uninterrupted flow of chemical operations information from the theater of operations to the Defense Intelligence Agency and Army Materiel Command. The laboratory has instruments accurate enough to permit qualitative and quantitative analyses of small samples. Ordinarily, one chemical laboratory is assigned to each theater of operations. Transportation of the TOE 3–97 laboratory equipment over land requires three 40-foot flatcars and one railway boxcar or ten 2½-ton trucks in addition to organic vehicles. For further information, see TOE 3–97, FM 3–8 and FM 3–85.

60. Mobile Chemical Laboratory

a. Description. The transportation problems in connection with the mobile laboratory are such that the function of the laboratory can be best carried out when the equipment for it is made up into a series of kits, with each kit designed for a specific task. Each kit is composed of component kits of varying portability and scope. Other equipment consists of glassware, inorganic chemicals, organic chemicals, books, and special items. The mobile laboratory can be set up in a standard Army field tent. It is packed in 16 boxes (total weight about 3,150 pounds; cubage 145 cubic feet). The complete laboratory can be packed in a standard 6 × 6, 2½-ton cargo truck. The laboratory is operated by mobile laboratory teams, and is assigned chiefly to task forces.

b. Function. The mobile chemical laboratory, within limits or design capabilities, is to accomplish the following tasks:

(1) Identify organic compounds.
(2) Make qualitative and semiquantitative analyses.
(3) Test protective equipment.

61. Laboratory Team HA

a. Mission. The mission of laboratory team HA is laboratory examination, evaluation, and identification of materiel pertinent to chemical operations. This includes—

(1) Analysis and identification of enemy chemical agents and equipment.
(2) Inspection and testing of clothing, equipment, and chemical agents of friendly troops.
(3) Development of temporary devices and measures for chemical operations activities.
(4) Laboratory assistance, within its capabilities, in the solution of problems of a chemical nature submitted by the appropriate commander.

b. Equipment. Principal equipment of this team is a mobile laboratory. The team is also issued chemical agent sampling, analyzer, and detector kits, and photographic equipment. For further information, see TOE 3–500 and FM 3–85.

CHAPTER 5

SPECIFIC TESTS FOR DETECTION AND IDENTIFICATION OF CHEMICAL AGENTS

Section I. MUSTARDS

62. General

The mustards, which include Levinstein mustard (H), distilled mustard (HD), mustard–T mixture (HT), and the nitrogen mustards (HN–1, HN–2, and HN–3), are easily detected and identified by means of the specific tests described in paragraphs 63 through 65. All except the S. D. test employ materials from the M9A2, M15A1A, M18 or M18A1 chemical agent detector kits. All the tests can be made with the materials from the chemical agent analyzing kits, M10A1.

63. DB–3 Test

a. General. The DB–3 reagent is the most satisfactory test reagent for the mustards. DB–3 reacts with the mustards somewhat slowly at ordinary temperatures but rapidly at elevated temperatures (70° C. or higher) to form a colorless addition product. This colorless product will react with a strongly alkaline solution to form an intensely blue color which constitutes the test for the mustards. The best method of utilizing the DB–3 test in detecting HD or HN is by means of the DB–3 impregnated silica gel. The tube as found in the M9A2 kit is surrounded by a sleeve of aluminum which is used as a chemical heater. Tubes are supplied in individual lead containers and are mounted on cardboard in groups of 20. The containers and tubes are coded with either a dot or the blue bands for identification. In tubes from the M18, M18A1, or M15A1A kits, the aluminum heater sleeve is not needed, since mercuric cyanide, which acts as a catalyst, has been impregnated on the gel. The absorption of HD or HN is so complete that very low concentrations of the vapor can be detected. About 0.001 milligram of HD or HN can be detected readily and a lesser amount can be detected by careful manipulation and observation. Such small quantities are of little danger in the field since 0.001 milligrame per liter is only a milligram per cubic meter. Several hours at this concentration would be required even to produce eye casualties in unmasked personnel.

b. Method. The steps comprising the method are as follows.

(1) A suitable amount of contaminated air is drawn slowly through the blue dot or band tube by means of a rubber suction bulb or pump. The tube is then disconnected from the suction device. For the M9A2 kit a drop of copper chloride solution (from the aluminum-top bottle) is applied at each end of the sleeve to the exposed paper so that it thoroughly saturates the paper layer beneath the aluminum foil. (A large excess of solution should not be used as it would cool the tube.) The proper reaction will be indicated by the formation of steam. Heat is generated by the reaction

$$3\,CuCl_2 + 2Al \rightarrow 2AlCl_3 + 3\,Cu + \text{heat.}$$

Alternative methods of heating, such as by a flame or by a heating block, may be used. Charring of the fabric retainer plugs in the detector tube should be avoided. (If the detector tube has been allowed to stand for a half hour or more at 68° F. (20° C.) or above it is not necessary to heat it before adding the sodium hydroxide.)

(2) After the reaction has ceased and the heater has cooled somewhat, the heater sleeve is removed.

Note. This heating is not necessary when blue dot/band tubes from the M18, M18A1, or M15A1A kits are used.

Sodium hydroxide solution (from the blue-top bottle) is added to the undotted end of the tube for the M18 and to the blue band side in the M18A1 and M15A1 kits to thoroughly wet the contents of the tube. After 2 minutes the formation of a blue color in the tube from the M9A2 or M10A1 kits indicates the presence of H or HN in the sampled air. With tubes from the M18, M18A1, or M15A1A kits, a purple-blue color indicates the presence of the H or HN while an orange-red color indicates the presence of CX.

c. Uses. The DB–3 tube test is used—

(1) *For detection and identification of the mustards as a group.* By proper standardization of procedure, it can be used to determine the approximate degree to which air is contaminated with these agents and the hazard to personnel for any given period. This applies only to the vapor hazard and is not necessarily a guide to the degree of danger that may exist due to liquid contamination of soil or equipment. Not only the general atmosphere but also the soil, foliage, and other surfaces must be tested before it can be definitely stated that an area is safe.

(2) *For air sampling to test surfaces for contamination.* The air for the test sample is drawn directly from within ½ inch or less of the surface. Since the rate at which any of the mustards are volatilized is largely dependent upon temperature, degree of contamination, and, to some extent, on the type of surface examined, no attempt should be made to arrive at more than an approximate quantitative estimate of the degree of contamination of surfaces—that is, contamination should be reported only as heavy, moderate, or light.

d. Specificity. The DB–3 test responds—

(1) To chemical compounds that have the properties of alkyl halides and act as strong alkylating agents. In this class, in addition to the mustards, there are such compounds as methyl iodide (CH_3I), dimethyl sulfate ($(CH_3)_2SO_4$, and benzyl chloride ($C_6H_5CH_2Cl$). Chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), and acetylene tetrachloride ($CHCl_2CHCl_2$) do not have the properties of alkylating agents.

(2) To cyanogen chloride, cyanogen bromide, and bromobenzylcyanide, and gives a yellow or orange color either immediately or when heated, without the addition of sodium hydroxide. (Reactive compounds which require a higher temperature than is obtained with the chemical heater are not listed here.)

A partial list of chemical agents and reactive compounds with their color reactions is given below.

Agents or reactive compounds	*DB–3 Color reactions*
Mustard	blue
Nitrogen mustards	blue
Chloropicrin	brown
Chloroacetophenone	reddish violet
Ethyl bromoacetate	blue
Dimethyl sulfate	blue
Benzyl chloride	reddish violet
Xylyl bromide	blue
Sulfur chloride	brown

e. Interferences. Interfering substances that prevent the DB–3 test from developing in the presence of HD or HN are not ordinarily encountered in amounts sufficient to destroy the test completely, but may be present in sufficient amounts to reduce the sensitivity. L, FS, FM, and strong acids such as hydrochloric, have this effect.

(1) *Mustard.* Hydrochloric acid may be present in badly decomposed stored H and, if mixed with the test sample, will interfere with the test. This interference can be prevented by allowing the accumulated stale vapor to escape or by placing a small amount of the liquid agent in a fresh bottle and taking the vapor sample from the top of the bottle. The effect of acid on the DB–3 test can also be overcome by drawing a small amount of ammonia vapor from aqueous ammonia through

the DB–3 tube before developing the test. This procedure is necessary whenever tests with congo red or pH paper indicate the presence of a strongly acidic substance.

(2) *Nitrogen mustards.* The HN's are alkaline substances and readily form salts with strong acids or acidic substances. These salts are relative nonvolatile, and tests for HN's may fail where sufficient amounts of acidic substances are present. If tests with an acid indicator paper, such as litmus paper, show that acids or acidic substances are present and it is suspected that an HN is also present, a small amount of the sample should be mixed with moist sodium carbonate and then tested for vapor with the DB–3 tube.

f. Testing After Mustard Decontamination. Surfaces that have been contaminated by H and then decontaminated by chlorine or chlorine-containing materials contain chlorinated mustard and have a very powerful odor that is usually associated with the agent itself. Highly chlorinated H gives test colors in the DB–3 tube that vary from reddish blue through red to brown. Therefore, in attempting to use the DB–3 test to evaluate the effectiveness of decontaminating procedures, great care should be used in judging the color, and direct comparison should be made when possible with a true HD test. In general, the bluer the test color obtained, the more H present, and the redder or browner the test color the more complete the decontamination. No test is obtained with the DB–3 tube if decontamination has been effected by steam, hot water, or alkali because hydrolyzed H does not give a test with the DB–3 test.

64. The Spotted Disk (S.D.) Test

a. General. The S. D. test distinguishes H from the HN's by the detection with acid indicators of the free hydrochloric acid liberated when mustard reacts with cloroamines. The test is also sensitive to strongly acid substances. CC–2 is recommended as the best chloroamine to use in the test because of its relative stability. This test must not be confused with those that depend upon the hydrolysis of mustard.

b. Method. The procedure is as follows:

(1) The test is made on congo red paper. (This is merely an absorbent paper impregnated with congo red, which is a red dye that turns blue in the presence of acid.) Shortly before the test is to be made, a saturated solution of CC–2 in carbon tetrachloride is placed on the paper in the form of a spot about one-quarter of an inch in diameter. When dry, the spot should be almost invisible. Contact with liquid or with relatively high concentrations of vapor causes a blue spot to appear on the red background of the congo red paper because the reaction between CC–2 and H liberates acid. Free strong acids such as hydrochloric cause the whole paper to turn blue.

(2) Surfaces are tested by applying a piece of indicator paper to the contaminated material and allowing it to remain in contact with the material for a few minutes. It is not necessary to have the paper come in direct contact with the liquid to obtain a test. Heavy concentrations of H cause a blue-colored spot to penetrate the paper while light concentrations produce a test visible only from the contact side. The time required to develop color is roughly proportional to the concentration of H present.

Note. When hydrochloric acid or another acidic substance is mixed with the mustard contamination, an alkaline filter (filter paper impregnated with a 10 percent solution of sodium carbonate and dried) should be placed between the indicator paper and the material being tested for H penetration. This stops penetration of acid vapors without affecting H penetration.

c. Uses. The S.D. test is used—

(1) To differentiate between HD (which gives a positive test) and HN (which gives a negative test).

(2) To test the penetration of HD through fabrics or other protective material. For this purpose, the indicator paper, previously spotted with CC–2 solution, is placed in close contact with the protective material on the side opposite

the suspected HD vapor or liquid contamination.

(3) In routine testing for leaking shell and containers where high sensitivity is not required.

(4) In determining whether or not soil or materiel is contaminated with HD.

Note. These papers cannot be used to test for ordinary field concentrations as they are not sufficiently sensitive.

d. Specificity. As stated in *b* above, all strong acids or acidic substances capable of changing congo red dye to blue will give a test but will cause the whole paper to change color, whereas HD alone will cause only the blue spot to appear. This difference cannot always be relied upon to indicate mustard, since there may be enough free acid to cause a complete change in color, thus hiding the effect. This is particularly true when HD is tested from a newly opened container. HD in the presence of traces of strong acids will cause test paper to have dark blue spots against a lighter blue background.

e. Interferences. SA, AC, and certain organic sulfides used as HD simulants give a test resembling that of HD, that is, they produce a blue spot against a red background. Among the chemical agents that will cause the overall coloration of the S.D. paper are L, ED, MD, PD, CK, FS, and WP. Hydrochloric acid from hydrolysis of agents also will cause this coloration.

65. The Dragendorff Test

a. General. This test is used after a positive DB–3 test to determine whether the agent present is HD or HN. The HN's react with an acid solution of a bismuth iodide complex (Dragendorff's reagent) to form an insoluble bright orange-colored complex. The reagent used is a specially compounded modification of the Dragendorff reagent for alkaloids. The reagent is supplied in the red-top bottle as a dry, orange-colored powder which, when properly dissolved in water, produces a stable yellow test solution that shows a high sensitivity to the HN's. The reagent can be used to detect either HN vapor or liquid.

b. Nitrogen Mustard Vapor Detection. A plain, unimpregnated silica gel tube (white dot tube) is inserted in the sampling pump and a sufficient amount of contaminated air is drawn through the tube. After addition of the solution from the red-top bottle the appearance of an opaque orange-red band on a yellow background in the tube indicates presence of HN. If the orange-red color is not obtained in this test, but a blue color was obtained in the DB–3 test (blue dot tube), HN is absent and HD present. Observation of the orange-red color change should be made immediately after the solution is added.

c. Nitrogen Mustard Liquid Detection. A convenient method for the detection of liquid HN is to apply the test solution from the red-top bottle directly to a surface suspected of being contaminated and look for the immediate appearance of an opaque orange-red color. If the color of the surface tested interferes, a piece of white filter paper may be rubbed over the surface and the solution applied to the portion of the paper that has made contact.

d. Specificity. The test is specific when used to distinguish the HN's from HD, but cannot be used to differentiate among the HN's. The test gives a similar reaction with nearly all nitrogen ring bases and with a number of other substituted ammonia compounds related to the HN's. Tobacco smoke reacts with the reagent because it contains such compounds.

Section II. ARSENICALS

66. General

The tests described in paragraphs 67 through 70 can be used to determine the presence of arsenicals such a L, ED, MD, and SA. With the exception of the molybdenum blue test, reagents not found in the standard kits are needed. Table IV summarizes these tests.

Table IV. Tests for Arsenicals

Test	Color reaction				Reagents
	L	ED	MD	SA	
Molybdenum blue	Blue	Blue	Blue	--------------	Yellow dot tube. Blue-top bottle.
Cuprous acetylide	Brown to red	--------------	--------------	--------------	White dot tube. Cuprous iodide. Blue-top bottle.
ACU	Red	--------------	--------------	--------------	White dot tube. Arsenite-piperidine reagent.
Gold chloride	--------------	--------------	--------------	Purple to bronze	White filter paper. Gold chloride solution.
DT	Pink to red	Pink to red	Pink to red	Pink to red	Dithiophenyl-carbazone (DT) reagent and white dot tube.

67. Molybdenum Blue Test for ED and MD

a. General. The agents ED and MD (and under certain conditions, PD) react with molybdates to form molybdenum blue. The test is performed on detector tubes which contain silica gel impregnated with ammonium molybdate and zinc sulfate. The sensitive reagent is probably a silicomolybdate. When ED or MD vapors are adsorbed in these tubes, reduction takes place and a greenish-blue color develops in the forward end of the tube. The color formation is direct; that is, no further treatment is necessary. However, the color can be intensified by warming or by allowing the tubes to stand for several minutes after making the test. L and PD show a similar reaction under conditions of extremely low atmospheric humidity. The tube can be used to detect L and PD under any conditions if, after sampling the agent, it is heated to about 100° C. or if 10 percent sodium hydroxide solution is added.

b. Method. Draw a suitable amount of suspected air through the tube. Look for a bluish-green color in the forward end of the gel layer. If no color appears, ED and MD are absent. If it is suspected that L or PD may be present, warm the tube and look for the blue color or add a drop of alkali solution to the tube. A reddish-blue color appearing instantly indicates the presence of L; a blue color probably indicates PD.

c. Use. The molybdate test can be used as a general detector for dichloroarsines, but is not sufficiently specific to give conclusive proof of identity. Whenever possible, the agent should also be tested with the DT reagent.

d. Specificity. The molybdenum blue test appears to be fairly specific for the arsenicals among the chemical agents, although the test depends solely on their reducing properties. Other reducing agents such as SO_2, SA, and H_2S react only in high concentrations or in lower concentrations when a strong acid such as hydrochloric acid is also present. L and PD react only when atmospheric conditions are abnormally dry. This condition limits the usefulness of the reaction as a general test for the dichloroarsines.

68. Cuprous Acetylide Test for Lewisite

The cuprous acetylide test for L is conducted by using silica gel (white dot or band tube) impregnated with cuprous iodide. If as much as 3 to 6 micrograms of L are drawn into the impregnated silica gel and the silica gel is then moistened with 10 percent sodium hydroxide solution, a brownish red ring forms at the intake end of the silica gel layer. This color is due to formation of cuprous acetylide and is specific for an arsenical containing the vinyl group of which L is the only representative among the toxic chemical agents.

69. ACU Test for Lewisite

a. General. Brownish-red cuprous acetylide is formed when L or L-oxide is treated with strong caustic in the presence of a cuprous salt. L or the oxide breaks down with alkali to produce acetylene, which in turn reacts with reduced copper. Several materials affect the color of cuprous acetylide. Piperdine is the most noteworthy, forming a brilliant red complex with it. The ACU solution used below contains sodium hydroxide, a stabilized reduced copper complex, and piperidine.

b. Methods.

(1) *Vapor detection.* A plain silica gel tube is used for sampling the contaminated air. Add sufficient solution to wet the contents of the tube. A brilliant red color on the pads and gel indicates L. The amount of color formed in the tube is roughly proportional to the amount of L present.

(2) *Surface contamination.* To test surfaces for L contamination, apply a few drops of solution on the surface. Both L and L-oxide produce a red color. No differentiation can be made between them except when the amount of L is fairly large, in which case the reaction mixture fumes.

c. Application. L is readily decomposed by water or moisture, forming L-oxide, a solid of very low vapor pressure. Samples of contaminated material may contain most of the original L in the form of the oxide, particularly if the material contains much moisture. Test for vapors of L made by the detector tube method accordingly may not show a positive test, although the material may have been heavily contaminated with L originally. A contact test will be successful since direct contact is established between the developing solution and the L-oxide. Therefore, test the material by direct contact, if possible, and use the tube test to show the presence of unhydrolyzed L. On surfaces where it is not advisable to use the strongly alkaline solution, contact tests may be made by rubbing the surface with a piece of whilte filter paper or absorbent cotton and applying the solution to the absorbent. Liquid drops can be tested by first touching the drop with a clean matchstick and then applying the test solution to the end of the stick. The ACU solution can be used in place of caustic to develop the DB–3 tube. In so doing, there are three possible results.

(1) A blue color indicates H only.
(2) A red color indicates L only.
(3) A mixture of red and blue indicates a mixture of H and L.

If there is indication of a mixture, the presence of H can be confirmed by plain alkaline development. Confirmation of L can be obtained by not heating the DB–3 tube or by using a plain tube and adding the alkaline cuprous solution.

d. Specificity. The test is highly specific for L and L-oxide since no other known toxic chemical agents decompose with the evolution of acetylene. Nothing has been found to interfere with the test or prevent it from going to completion. Even when it is used as a contact detector, dirt or other materials seldom obscure the test.

70. Gold Chloride Test for Arsine

The most sensitive test for SA is a gold chloride solution which reacts with SA to form colors ranging from deep purple to bronze, due to the formation of metallic gold.

a. Method. A drop of gold chloride solution is added to a strip of white filter paper and the strip exposed, while wet, to the atmosphere suspected of being contaminated. The rate of formation of the purple to bronze coloration and the depth of color formed in a given time is proportional to the SA concentration.

b. Uses. The gold chloride test can be applied to the detection of SA in air or to identification of metallic arsenides which evolve SA on contact with water.

c. Specificity. Although the reaction between gold chloride and SA is due to the reducing power of the SA, other reducing agents, such as sulfur dioxide or hydrogen sulfide, do not react with the gold chloride under the conditions of the test.

Section III. BLOOD AGENTS AND NERVE AGENTS

71. General

Paragraphs 72 through 74 describe specific tests for CK, AC, and G-agents. Blood and nerve agents act so rapidly that physiological symptoms are often of more value for detection purposes than chemical methods, at least for the individual soldier under combat conditions. The G-series chemical agents, even at very low concentrations, produce characteristic symptoms in unmasked personnel.

72. DB–3 Test for Cyanogen Chloride

a. General. CK reacts with DB–3 to yield a yellow to orange color.

b. Method. Remove a blue dot band tube from its wrapper and remove the heater sleeve, if present. Insert in the sampling bulb or pump and draw suspected vapors through the tube. The presence of high concentrations of CK are indicated by the appearance of a yellow to orange coloration through the gel layer. Heating causes fading.

c. Application. This test is used in the M9A2, M15A1A, M18 and M18A1 detector kits, but is not as sensitive as the other tests discussed in this chapter.

d. Specificity. The test shows positive results with bromobenzylcyanide and xylyl bromide. Some DB–3 impregnated gel has yellowed on aging and is difficult to use in this test.

73. Brown Dot Red Band Tube Test for AC and GA

AC reacts with cupric salts to form cuprous cyanide and free cyanogen. The free cyanogen is capable of oxidizing a variety of aromatic substances, such as tetramethyldiaminodiphenylmethane to form deeply colored compounds. When AC is drawn through the brown dot tube (which contains cupric salts and the tetramethyldiaminophenylmethane) a deep blue color is produced. (Long exposure to air also causes a blue color reaction in the brown dot tube (red band tube in M18A1 kit) since tetramethyldiaminodiphenylmethane is oxidized slowly by contact with cupric salts without the aid of AC.) GA reacts similarly in high concentrations.

74. Dianisidine-Perborate Test for G-Agents

This test is based on the ability of the G-agent type molecule to react with peroxides and similar compounds to produce an active, intermediate compound capable of easily oxidizing certain amines such as dianisidine (also benzidine and substituted benzidines) and indole to colored and fluorescent compounds.

a. Method. Remove a white dot detector tube from its lead covering and insert the end marked with the white dot into the adapter at the end of the sampling pump or bulb, and take an air sample. (A total of 3–5 micrograms of a G-agent on the gel is required for a satisfactory test.) Remove tube from pump and pull out gauze plug from the upper end. Place this plug and the white granules from the detector tube in a small test tube. Add 6 drops of dianisidine and, after 15 seconds, add 10 drops of sodium perborate. The appearance of a distinct orange or amber color in the solution in the test tube 1 to 3 minutes after addition of the perborate indicates the presence of a G-agent. Disregard any color change that occurs after 5 minutes. When very low concentrations are being tested, run a blank test prior to the actual test. If the blank shows a marked coloration, discard the reagent solutions and make up fresh solutions.

b. Use. This test is used chiefly for establishing the presence of a G-type chemical agent. The color change is caused by all the known G-agents but not by their hydrolysis products.

Section IV. CHOKING AGENTS

75. PDB Test for Phosgene

The test for CG is made with the green dot tube and is called the paradimethylaminobenzaldehyde (PDB) test. CG reacts with the reagent PDB in the presence of certain compounds with active hydrogen atoms to form intensely colored compounds. The most satisfactory active hydrogen compound is phenyl-alpha-napthylamine (PAN) which, in the presence of CG, produces a pure green color.

76. Methods

a. The silica gel tube marked with a green dot/band contains silica gel impregnated with a mixture of PDB and PAN reagents. When air containing CG is drawn through the silica gel, a green color is formed immediately. The color will vary from a light green to an intense greenish black, depending upon the concentration of CG present.

b. The same test may be carried out with test paper. Strips of paper are dotted with small drops of sodium carbonate solution and dried. The entire strips are then impregnated with a solution of PAN and PDB and the solvent allowed to evaporate. (These papers may be kept for several days in a closed container, but they will gradually deteriorate.) When a test paper is exposed to CG, it assumes a green color with light reddish orange spots. In very high concentrations, the green color becomes intense and the orange spots may not appear until some time after exposure. If the paper assumes a yellow color with orange spots, the presence of CG mixed with a large amount of hydrogen chloride (hydrolysis product of CG) or other strongly acid substances is indicated. The production of a yellow color with white spots indicates an acidic substance alone.

77. Application

The silica gel tube has a somewhat higher sensitivity than the test papers and should be used when the chemical agent concentration is low. The papers are more convenient to use and can be employed to detect leaks in containers and for identification of CG when a sufficient amount of it is present. Neither type of test is as sensitive as the sense of smell, but the silica gel tube will detect concentrations less than those that are considered harmful for short exposures provided a sufficient amount of contaminated air is drawn through the tube.

78. Specificity

The characteristic test with both the silica gel tube and the test paper is given only by CG, DP, and triphosgene, and by a few seldom-encountered nontoxic compounds.

CHAPTER 6

PROTECTIVE ITEMS

Note. This chapter contains information on the chemical and physical actions involved in the functioning of some items of protective equipment. See the appropriate technical manual for further information on each item.

Section I. INDIVIDUAL AND COLLECTIVE PROTECTIVE EQUIPMENT

79. The Protective Mask

a. General. All of the component parts of the protective mask are included when the term "mask" is used. Information in this paragraph is applicable to M9A1 (M9) field protective masks. The M17 field protective mask, which is now the standard-A mask, utilizes filter elements contained in pouches in each cheek instead of an external filter element. For additional information on the various masks, see TM 3–4240–202–15 (M17 mask), TM 3–522–15 (M9, M9A1 masks), and TM 3–4240–221–15 (M14, M14A1 tank protective masks).

b. Composition of Filter Assemblies of the M17 and M9A1 Protective Masks. The filter element consists of a mechanical filter for the removal of solid and/or liquid particles, and a chemical filling for the disposal of toxic chemical agents by physical adsorption, chemical decomposition, or a combination of these means. The filter element assembly for the M17 protective mask consists of two layers of mineral fiber and charcoal. Each layer is faced front and back with a thin layer of fabric. The two layers of filter material are separated by a layer of corrugated screening and a plastic stiffener. The corrugations permit incoming air to disperse inside the filter element and to pass through all filtering areas of the element. The outer surfaces of the filter element are overlaid with plastic mesh screening. The two layers of filtering material are bonded together along their edges with vinyl plastic. An aluminum connector passes through the outer layer of filtering material. A flange at the external end of the connector projects through the side of the facepiece and makes close contact with the collar molded in the faceblank. The portion of the connector which extends through the side of the mask also serves as housing for the air inlet valve in the inlet valve assembly.

(1) *The mechanical filter.* The material used for the mechanical removal of toxic materials must be dense enough to hold back the extremely minute solid or liquid particles of certain chemical agents, screening smokes, and biological and radiological agents; and yet it must not be so dense that it unduly impedes the flow of air through it. Various types of filters have been used at various stages in the evolution of the filter element; materials used include carbon-impregnated wool felt, mineral fiber, asbestos, and paper. The present filter for the M17 protective mask is composed of a mixture of pulverized charcoal, plastic fibers, and very fine glass fibers.

(2) *The chemical filter.*

(*a*) *Requirements.* The effectiveness of an adsorbent in removing chemical agents depend upon three factors: the capacity of the adsorbent, the rate of adsorption, and amount of the adsorbent present. The protection increases linearly with the thickness of the layer of adsorbent through which the chemical agent air mixture passes. However, the thickness of this layer must be limited to keep down breathing resistance and size of the filter element assembly. The adsorbent used must be highly porous in order to provide within a small space a relatively enormous adsorptive surface; it must not be corrosive to the metal parts, nor seriously lowered in effectiveness by exposure to air of high humidity; it must remove toxic agents very rapidly, since any given portion of the incoming air is in contact with the filling for but a fraction of a second; it must have the capacity to purify large amounts of air, since the filter element cannot be frequently replaced, and it must not cause high resistance to breathing. Moreover, it must be of a fairly inexpensive material and available in large quantities. The best substance which fulfills the requirements of an adsorbent filling is activated charcoal in small granules. Charcoal is a highly porous substance consisting principally of carbon.

(*b*) *Activated* (*impregnated*) *charcoal.* Charcoal is usually made from coal, wood, or woodlike materials. The wood products consist of cellulose and other constituents. In wood charcoal manufacture, the cellulose is heated and thus converted to carbon while water and some other constituents are evolved. The residue is called primary charcoal. When primary charcoal is subjected to treatment with heat and steam, more of the constituents are driven off, leaving purer carbon. This activated charcoal is full of tiny spaces which were formerly occupied by the materials driven off by the treating processes, and has an extremely large surface area for the small amount of charcoal. Charcoal may also be processed in part by chemical action, and may be subjected to further special treatments by certain chemical catalysts to increase its adsorptive and neutralizing power for certain chemical agents.

(*c*) *Mechanism for removal of chemical agents by charcoal.* The various mechanisms by which the chemical filling acts to protect against chemical agents are illustrated in the action of the filling when any of the following chemical agents enter the filter element.

1. *Hydrogen cyanide.* The charcoal first adsorbs the AC and then catalytically destroys it.

2. *Cyanogen chloride.* The reaction is probably adsorption followed by slow hydrolysis.

3. *Arsine.* SA appears to be catalytically oxidized into solid arsenic trioxide.

4. *Phosgene.* Hydrolysis occurs on the charcoal surface to form carbon dioxide and hydrogen chloride. The hydrogen chloride then is either adsorbed by the charcoal or reacts with copper oxide present to form copper chloride. Some CG may react directly with copper oxide to form carbon dioxide and copper chloride (CG is typical of the easily hydrolyzed acidic chemical agents.)

5. *Distilled mustard.* HD is adsorbed.

6. *GB and other G-agents.* These agents are adsorbed.

c. Special Protective Masks. Special purpose protective masks are available to military and civilian personnel for use in the manufacture or handling of chemical agents. Some of these masks are listed in (1) through (4) below.

(1) *Mask, gas, acid and organic vapors, M10.* (See TM 3-4240-230-12.) Protects against any combination of acid gases and organic vapors, such as—

Acid gases

Formic acid
Hydrochloric acid
Hydrogen cyanide
Hydrogen sulfide
Phosgene
Sulfur dioxide

Organic vapors

Acetone
Alcohol
Aniline
Benzene
Carbon disulfide
Carbon tetrachloride.
Chloroform
Ether
Formaldehyde
Gasoline
Petroleum distillate
Toulene (other similar volatile organic compounds).

(2) *Mask, gas, all-purpose, M11A1.* (See TM 3-4240-231-12.) Protects against all substances listed in (1) above as well as carbon monoxide and ammonia.

(3) *Mask, gas, ammonia, M12.* (See TM 3-4240-232-12.) Protects against ammonia.

(4) *Breathing apparatus, compressed air, M15 and ABC M15A1 and breathing apparatus, oxygen generating, M13 and M20.* (See TM 3-310-15, TM 3-4240-224-12, and TM 3-4240-212-15.) Is for protection of wearer in oxygen-deficient or highly toxic atmosphere.

(5) *Mask, gas, rocket-propellant, M21.* (See TM 3-4240-218-15.) The M21 rocket propellant gas mask is worn by personnel handling liquid rocket propellant fuels. The mark affords protection against low concentrations of vapor from the fuels.

80. Protective Clothing

Two types of protective clothing, impermeable, and permeable, have been developed by the Chemical Corps in cooperation with the Quartermaster Corps. See AR 700-62.

a. Impermeable clothing resists penetration by liquid and gaseous chemical agents and biological agents for a reasonable length of time, but retards release of body heat and moisture and is therefore wearable for limited periods of time. Under warm weather conditions, the use of a cooling suit will extend the time that the impermeable suit can be worn.

b. Permeable clothing is impregnated with a chemical that neutralizes blister agents but does not interfere with body breathing. Items to be impregnated may be modified in design so as to assist chemical agent protection.

81. Impermeable Protective Clothing

This type of clothing (described in TM 3-304/TO 14P3-1-9) is designed to cover all of the body not covered by the mask and to protect it against liquid chemical agent contamination. Impermeable clothing protects by interposing a mechanical barrier between the body surface and a possible chemical agent, as contrasted with the chemical barrier presented by permeable protective clothing. Impermeable protective clothing offered the only available body protection in World War I. At that time it was made by coating cotton fabric with vegetable drying oils such as linseed oil. More recent impermeable clothing has been made from a variety of materials. Some of the warring powers in World War II employed all-rubber clothing. United States impermeable clothing is made from butylcoated fabric and is used in combination with butyl boots and gloves. It is issued by the Quartermaster Corps to special troops. It is decontaminated after use by mechanical removal of gross contamination, followed by aeration, or by any other method normally used for decontamination of the material.

Warning: **Personnel wearing impermeable protective clothing must take extreme care to avoid contact with open flame or objects which would ignite the coating. The material will burn when ignited and the flame is not self-extinguishing.**

82. Permeable Protective Clothing

a. General. The introduction of toxic chemical agents that generate significant concentrations of blistering vapors which persist over long periods of time indicated an imperative need for protective clothing that could be worn with reasonable comfort in the contaminated area. The development of an impregnating process for military clothing, by which a blister-agent-destroying chemical could be held in and on the fabric by means of an adhesive or binder, made it possible to prepare protective clothing of about the same porosity as untreated clothing, thereby dispensing with impermeable clothing to a large extent. While the binder employed is water-repellent, liquid perspiration is able to penetrate through the open pores of the fabric—to a certain extent even where both underwear and outer garments are of impregnated fabric.

b. Materials Used in Impregnite. The basic approach employed in making clothing protective against blister agent vapors is to fix a chlorine-bearing chemical in the cloth of the permeable protective garments by means of a binder. Contact of the agent with the chemical deposit liberates chlorine. This reacts with the agent vapor, converting it to a nontoxic vapor. Stabilizers are added to prevent rapid decomposition of the active ingredient.

(1) *Chlorinating chemicals.* Various chloroamides are suitable as chlorinat-

ing chemicals for blister agents, but activity of the chloroamide must be such that it does not injure the fabric and does not lose active chlorine at an excessive rate when the treated clothing is stored. The chloroamide known as CC–2 was chosen by the Chemical Corps and Quartermaster Corps prior to World War II as the most nearly satisfactory anti-blister agent impregnate for clothing.

(2) *Binder.* The binder is prepared by chlorinating paraffin wax or oil until the chlorine content is approximately 42 percent by weight of the final product. The final chlorinated paraffin is a sirupy liquid which shows little change in viscosity over the range of temperatures encountered from the arctic region to the tropics. This means that the clothing containing the binder will not stiffen at arctic temperatures nor become oily at tropical temperatures. The binder is merely a moistening substance which keeps the CC–2 impregnite from dusting out. A certain fraction of the CC–2 is actually dissolved in the chlorinated paraffin binder but the major portion is present as solid particles which are held on the surface of the cloth fibers by the binder. The binder content of the treated clothing may be adjusted up or down within rather wide limits without materially affecting the protective action of the CC–2; but if the binder content is increased too much, the clothing feels excessively clammy. Excessive binder makes the fabric more water-repellent and less comfortable. The proportion of chlorinated paraffin used in the past was higher than desirable for wearing comfort.

(3) *Stabilizers.* Since CC–2 can be decomposed by any of a number of factors, including the normal loss of chlorine, a stabilizer must be used with it to lessen decomposition of the CC–2 and to prevent the accompanying deterioration of the clothing itself. (Cotton is rapidly destroyed by acidity, and clothing impregnated before the introduction of stabilizers had very poor storage life.) CC–2 forms acid when it decomposes and this acid in turn encourages further decomposition. Thus, the decomposition of CC–2 is a self-catalyzing reaction. A marked increase in acidity is largely prevented if a substance is present which will absorb the acid as fast as it is liberated. Zinz oxide has been found to absorb the acid quite satisfactorily. The porportions used are 1 pound of zinc oxide to 10 pounds of CC–2. Zinc oxide may be replaced by calcium carbonate as a stabilizer if authorized, although the latter possess no important advantage over zinc oxide.

c. General Characteristics Required in an Anti-Blister Agent Impregnite.

(1) Even very low concentrations of the impregnite should react rapidly on contact with blister agent at concentrations as low as a few micrograms per liter.

(2) The compound and its hydrolysis and other reaction products should be of such physical and chemical characteristics as will permit the compound to retain its capacity for reacting with blister agent for long periods of time after clothing has been impregnated with it.

(3) The compound should be stable in storage.

(4) A chloroamide for use on clothing should not be reactive towards the fabric on which it is to be used (cotton, wool, or synthetic fiber), nor reduce the tensile strength of the fabric when it is subjected to the various conditions of temperature, humidity, perspiration, dirt, and laundering to which it normally will be subjected.

(5) The compound should cause minimum irritation to human skin, since impregnated clothing may have to be worn for weeks, or even months.

d. Fabrics Used for Impregnation. Prior to the instruction of stabilizers it was found that any chemical processing given cotton fabric before it was impregnated had an important bearing on its storage stability and also on the life of the CC–2. However, when stabilizers are present, the fabric is less important. The fabric used for impregnation by the Army during World War II weighed approximately 8 ounces per square yard and was of the weave known as herringbone twill, usually referred to as HBT. A heavier fabric could carry a higher percentage of impregnite than a light fabric without any greater decrease in porosity, but the heat load imposed by such fabric would be greater. See TM 3–304/TO 14P3–1–9 for type of clothing used for impregnation.

e. Impregnation Processes.

(1) *M1 solvent process.* Until 1941 the only clothing impregnating process available was based on the use of a hot tetrachloroethane (acetylene tetrachloride) ($C_2H_2Cl_4$) solution of CC–2 which also contained chlorinated paraffin in dissolved form. In this process calcium carbonate was used as a stabilizer in the ratio of 10 parts calcium carbonate for each 90 parts of CC–2, and soya lecithin was used as a suspension agent for the stabilizer. Zinc oxide was later substituted for calcium carbonate with improved results.

(2) *M2 suspension process.* This process was developed during World War II to avoid certain disadvantages of the M1 solvent process. The M2 process offers fewer difficulties in operation, in that water is used instead of solvent as a dispersing medium and either commercial laundry and dry cleaning equipment or portable, small-scale impregnation sets can be used for the process. In general, the M2 process makes possible more uniform impregnation of clothing because the essential ingredients are in suspension. Consequently, when the dispersing medium (water) is evaporated, the finely suspended drops of chlorinated paraffin and the minute particles of CC–2 and stabilizer are left in a state of uniform dispersion in the fabric. This occurs because the emulsion breaks up after it is introduced into the fabric and there is no tendency for the suspended particles to collect on the surface of the fabric as there is when a true solvent is used. Otherwise, there is little essential difference in the final results of the M1 solvent process and the M2 suspension process.

(3) *Foam impregnation process.* Late in World War II, work was started on an emergency impregnating process for protective clothing. This is a modification of the M2 process and differs from it only in that it utilizes a foam impregnation method of introducing the emulsion into the clothing. The foam process simplifies impregnating operations and seems to provide a more uniform CC–2 content than is obtained by any other method.

f. Functioning of CC–2 Protective Clothing.

(1) The protective action of CC–2-treated clothing is dependent upon the active chlorine content of the clothing. The chlorine in CC–2 combines with vapors of blister agents to form products having relatively no blistering power. Since the treated clothing contains active chlorine only to the extent of about 0.5 milligram (0.0005 gram) per square centimeter of area, a normal-size drop of liquid blister agent (about 0.05 gram) would react with all the CC–2 in the area and still leave a residue of undestroyed liquid agent of sufficient magnitude to produce a severe burn of the skin under the area. Thus, permeable protective clothing only partially protects against gross liquid blister agent contamination because it is not possible to have a sufficient amount of CC–2 present in any given area.

(2) The length of time for which personnel will be protected is dependent upon the number of layers of protective clothing worn, the air temperature, wind velocity, relative humidity, rate of perspiration and activity of the wearer, and previous history of the clothing, in addition to many variables connected with the preparation of the clothing.

g. Reimpregnation of Clothing.

(1) The M2 impregnite-in-clothing testing kit (which replaces the M1 kit, explained in the TM 3–303/TO 11D2–3–3–1) is used to determine whether permeable protective clothing contains sufficient impregnite (SSCC3) to protect the wearer against chemical agents. (Complete information about the M2 kit is contained in TB CML 68.) The normal effective life of permeable protective clothing during wear is relatively short because of loss of active chlorine from the CC–2. This loss results from the following causes:

(*a*) Perspiration.

(*b*) Sunlight.

(*c*) Contamination by blister or other agents.

(*d*) The destructive effects of wear.

(*e*) Storage conditions.

(*f*) Laundering.

(2) Any of the standard methods used for the initial impregnation of clothing may be used for reimpregnation. Steps must be taken, however, to avoid excessive binder buildup. If reimpregnation were carried out without the binder being first removed, or without an allowance being made for the amount of binder present, tackiness would become much more evident than after the initial impregnation, and after a second reimpregnation it would be so excessive as to make the clothing unwearable. In using the M1 solvent process for reimpregnation of clothing, the impregnating formula can be so adjusted that excessive buildup of chlorinated paraffin on the clothing is prevented. However, either of the aqueous methods (M2 suspension and the foam impregnation method) causes a buildup of binder content in the clothing. With the M2 suspension process only two reimpregnations are practicable, and with the foam process only one.

(3) In order to avoid the excessive buildup of binder, it has been proposed to reduce the ratio of chlorinated paraffin used in the CC–2. Reduction of the chlorinated paraffin would greatly improve the wearing qualities of impregnated clothing, and several reimpregnations could be carried out without rendering the clothing unwearable. Possible undesirable effects might include a more rapid loss of impregnite after the initial impregnation as a result of wear and a less efficient absorption of blister agent vapor. The mechanism of action of the binder is not understood well enough to permit prediction of all of the possible effects of reduction of binder content.

h. Reimpregnation as a Means of Decontaminating Clothing. It has been proposed that contaminated clothing might be decontaminated and reimpregnated simultaneously in a single operation. In practice, such a procedure is unworkable because acidity is generated by the decontaminating reaction, and a certain amount of zinc chloride is also formed. The presence of impurities of this nature would cause permature separation of the impregnating emulsion, corosion of equipment, and other difficulties. The decontamination of clothing is a Quartermaster Corps function. The method currently employed is laundering with synthetic detergents (TM 10–1680A); the most recent procedure at the QM laundry includes the use of bleach in the first wash cycle.

83. Impregnated Boots

a. General. Usually, the greatest hazard arising from liquid chemical agent contamination of terrain is to the feet of troops traversing such terrain. For this reason, it is absolutely necessary that a means be available to prevent chemical agent penetration of leather. It has been found that certain compositions or mixtures of substances which are completely immiscible with chemical agents are able to block the pores in leather and impede the passage of these agents. Before World War II, the composition developed for impregnating leather was called shoe impregnite. As a result of experiments conducted during World War II by the Chemical Corps in cooperation with the Quartermaster Corps and the Bureau of Standards, minor changes were made in the composition of shoe impregnite, and the procurement and issue of the amended formulation were taken over by the Quartermaster Corps. At the same time the name of the item was changed to protective dubbing. At present, the item is issued by the Chemical Corps and the nomenclature is "Leather Dressing, Vesicant Gas Resistant, M2." (See FM 21–40 for use of this item.)

b. Composition of Dressing. The composition of M2 Vesicant Gas Resistant Leather Dressing is as follows:

Ingredient	*Minimum parts*	*Maximum parts*
Microcrystalline wax	8.5	10.0
Paraffin wax	11.0	13.0
Animal oil	34.0	37.0
Aluminum stearate	0.8	1.2
Ester gum	29.0	31.0
Stoddard solvent	11.0	15.0

c. Operating Principles of Dressing. It appears that the repellent action of M2 vesicant gas resistant leather dressing is imparted chiefly by the ester gum component. Ester gum is the glyceroester of abietic acid, a complex organic acid which is the chief constituent of rosin. The exact nature of its action is not known. The dressing prevents the passage of chemical agents in vapor form, but liquid agents applied to the outer surface of leather treated with the dressing penetrate after some hours. Impregnated socks are worn for additional protection.

84. Self-Treatment Measures

a. General. Protective ointment (M5) is used against blister agents and is of value chiefly in neutralizing the agent and preventing it from being absorbed by the body. The method of use of M5 protective ointment is given in FM 21–41 for Army personnel and AFM 355–8 for Air Force personnel.

b. M5 Protective Ointment.

(1) *Formulation.* Since this type of ointment is most effective in preventing the passage of blister agent to and into the skin, it is desirable that the vehicle used in the ointment should possess the highest possible degree of persistency on the skin. The vehicle is the chief factor in determining the persistence of protective ointment, while the composition of the impregnite and the amount of impregnite in the ointment determine its protective efficiency. M5 protective ointment will permit normal perspiration. It is somewhat resistant to removal by water or mechanical action.

(2) *Chemical composition and functioning.* M5 ointment contains a substance which serves as a source of active chlorine. The active chlorine reacts with blister agent molecules and produces a more highly chlorinated compound which does not cause blisters. This active substance is blended with the vehicle to facilitate spreading and retention on the skin. The active substance is used prophylactically and is effective only insofar as it is able to prevent the blister agent from contacting and penetrating the skin. The ointment is applied in a thin layer to the more exposed or vulnerable parts of the body, such as the face, neck, and hands. It gives only limited protection against drops of liquid blister agent simply because of the limited amount of active compound present in the small areas covered by the drops and because of the high concentration of the blister agent represented by the drops. However, a film of the ointment will ordinarily contain sufficient active chlorine to detoxify all of the blister agent molecules impinging upon the surface during exposure of a few hours to vapor concentrations of from 20 to 30 micrograms per liter. Sufficient active chlorine for protection will remain upon the skin for a few hours, provided the subject does not perspire too freely and the ointment is not rubbed off. Even under optimum conditions, protective ointment can be expected only to reduce casualties and cannot

offer extended protection to the hands, neck, and face of a man in combat.

85. Collective Protective Equipment

The chemical principles involved in gas-particulate filter units (collective protectors) are the same as those employed in the protective mask. The filter units, however, require mechanical power to draw air through the purifying bed of activated charcoal. See TM 3-4240-207-12 and TM 3-4240-207-35 for information on filter units.

Section II. ANTIDOTES

86. General

The chemical aspects of antidotes for chemical agents are discussed in this section. See TM 8-285 for medical treatment of casualties.

87. Antidotes for Mustard and Nitrogen Mustards

An extensive search has been made for antidotes for poisoning by HD and the HN's, but no compound has been found which is significantly effective. The lack of success in this search is probably due to the fact that these toxic chemical agents react rapidly and irreversibly with all the tissues of the body. The lack of any antidote for HD poisoning accents the importance of protective clothing, protective ointment, and other expedients designed to prevent the penetration of the contaminant.

88. Antidote for Nerve Agent Poisoning (G- and V-Series)

Nerve agents inhibit secretion of the enzyme cholinesterase (par. 30) which hydrolyzes acetylcholine as it is built up at its normal sites of liberation throughout the body. Accumulation of acetylcholine at the nerve endings prevents the muscles of the body from functioning normally. Death is caused by anoxia (oxygen deficiency) due to respiratory failure resulting from weakness of the muscles of respiration, depression of the central nervous system, and airway obstruction by bronchial and salivary secretions. Atropine injected deep into a muscle counteracts the effects of nerve agents. If respiration is severely impaired, death will occur in a matter of minutes unless effective rescue breathing is begun immediately and maintained until spontaneous respiration is resumed. Casualties with severe poisoning may require several hours of continuous artificial respiration. While the administration of atropine facilitates respiratory exchange by suppressing bronchial and salivary secretion, bronchoconstriction, and perhaps diminished central depression of respiration, it does not alleviate the need for rescue breathing in cases of severe poisoning. See FM 21-41 for use of atropine and TM 8-285/NAVMED P-5041/AFM 160-12 for treatment of nerve agent poisoning.

Note. **Recovery is not complete until the cholinesterase level has returned to normal. This will require a period of days or weeks. While the cholinesterase level is low, susceptibility to nerve agents is increased and the effects of repeated exposure are cumulative.**

89. Antidote for AC and CK

The only antidote officially prescribed for AC and CK is amyl nitrite given by inhalation. Standard medical treatment is intravenous injection of sodium nitrite and sodium thiosulfate. The effects of AC poisoning are manifested so rapidly that other antidotes are usually impracticable. AC acts by combination with cytochrome oxidase, an enzyme essential for oxidative processes of the tissues. The central nervous system, particularly the respiratory center, is especially susceptible to this interference, and respiratory failure is the usual cause of death. In high concentrations of AC, the amount inhaled in a few breaths may be sufficient to cause immediate death without obvious symptoms. CK symptoms are a combination of those produced by AC and by CG.

Section III. TESTING OF PROTECTIVE ITEMS

90. Filter Elements Testing

In designing a new filter element it is necessary to know how long the filter element can be expected to be effective. It is also necessary to determine whether filter elements after some use or storage are still effective. Tests on new filter elements are discussed in base laboratory instructions. Field filter elements tests are discussed in surveillance procedures for the various filter elements.

97. Inspection and Testing of Impregnated Clothing

a. General. Impregnated clothing which has been prestored or in use but which has not been contaminated must frequently be tested for loss of impregnite and loss of tensile strength. When the impregnite content has dropped below a minimum of 3 percent, clothing must be reimpregnated to maintain its protective value. When the clothing has lost its tensile strength, it can no longer be worn safely and must be discarded. It is not necessary to test every piece of protective clothing but only selected samples from the various issues on hand. If protective clothing is to be laundered, testing for impregnite should be postponed until after laundering has been completed.

b. Schedule. The frequency of clothing inspection and testing varies with different climates. The following schedule is recommended:

Clothing	*Above 70° F.*	*Below 70° F.*
In storage	Every month	Every 3 months
In use	After 2 weeks and one laundering.	After 4 weeks and 2 launderings.

c. Tests. Tests for tensile strength and impregnite content are described fully in TM 3-303/TO 11D2-3-3-1 and TM 3-304/TO 14P3-1-9.

92. Analysis of CC–2

During the operation of an impregnating plant, the percentage of CC–2 must be determined as a general check for impregnation requirements. After a run is made in the impregnator and the unused suspension is returned to the suspension storage tank, the concentration of the CC–2 in the returned suspension must be determined so that its strength may be properly readjusted. The concentration of the protective chemical in clothing must be determined after impregnation and before reimpregnation. For complete details on the analysis of CC-2 see TM 3–409.

93. Analysis of Chlorinated Paraffin

a. Procedure. Each composite sample should be tested for acidity, calculated as HCl, by the following method:

(1) Transfer 20 milliliters of sample into a 250-milliliter separatory funnel, add 50 milliliters of benzene, and mix thoroughly by shaking.

(2) Add 30 milliliters of 95 percent ethyl alcohol to the mixture, shake; add 100 milliliters distilled water, and mix thoroughly by shaking.

(3) Allow mixture to stand until layers separate.

(4) Separate alcohol-water layer and to it add a few drops of mixed indicator solution, consisting of 0.050 gram of methyl red and 0.075 gram of bromocresol green dissolved in 100 milliliters of 95 percent ethyl alcohol.

(5) Titrate with 0.020 N NaOH (sodium hydroxide) to the intermediate purple end-point.

(6) Run a blank test using the same volumes of benzene, alcohol, and water as were used in testing the sample, and titrate in the same manner.

b. Formula. Calculate HCl by the following formula: $(\text{ml NaOH}-\text{Ml blank}) \times N \times 36.5 = \text{mg HCl per 20 ml of sample}$.

94. Analysis of Protective Ointment

M5 protective ointment is tested for active chlorine content in the following manner:

a. Preparation of Sample. From each kit selected for sampling, open one tube of M5 protective ointment along the entire length of tube. Transfer the contents of all the opened tubes from each lot (or combination group) to a beaker, and mix thoroughly as a composite sample. When the mass is homogeneous, weigh out approximately 1.000 gram of the ointment on a small square of "weighing paper" (glassine or equal).

b. Test.

(1) In rapid succession, place 25 milliliters of chloroform, 20 milliliters of a 5 percent KI solution, and 10 milliliters of glacial acetic acid in a 250-milliliter glass-stoppered Erlenmeyer flask.

(2) Immediately introduce the paper square and sample into the flask. Stopper the flask and shake thoroughly.

(3) Cool the flask below room temperature in a cold water bath before opening; remove the stopper and wash down the stopper and sides of the flask with distilled water.

(4) Titrate immediately with 0.1N $Na_2S_2O_3$ solution, swirling the flask constantly to prevent local excess of $Na_2S_2O_3$. When the aqueous layer becomes pale yellow, stopper the flask and shake vigorously before continuing the titration. (Do not permit an excess of $Na_2S_2O_3$ to be present in the aqueous layer while there is still any iodine dissolved in the chloroform.)

(5) When most of the iodine has been titrated, add 2 milliliters of 1 percent starch solution and continue the titration to the end-point; shake after each addition near the end-point.

(6) Run a blank test using the same weight of "weighing paper" and the same quantities of the reagents used in the test.

(7) Subtract the blank titer from that required for the titration of active chlorine and use the difference in the following calculation:

$$\frac{\text{ml } Na_2S_2O_3 \times N \times 1.773}{\text{wt of sample}} = \text{percentage of active chlorine}$$

95. Chemical Tests of Detector Tubes

a. General. Solutions from the M9A2 chemical agent detector kit are normally used in making the chemical tests outlined in *b* through *e* below. Similar tests are made with detector tubes of the M15A1A, M18, or M18A1 kits. If the inspector has cause to suspect deterioration of any of the solutions, or if only solid reagents accompany the kit, he should prepare fresh solutions by dissolving the contents of the vials in accordance with printed instructions attached to the kit. A certain number of detector tubes from each lot are tested for container leakage and for sensitivity as follows:

(1) *Tube container leakage test.* Detector tubes of the M9A2 and M18 kits are lead-foil encased and are furnished in clips. Each lead-foil wrapper is marked not only with a dot but also with a specific number of stripes. Detector and sampling tubes of the M15A1A and M18A1 kits are glass tubes heat sealed at both ends. They are lightly scratched with a file about five-eighths of an inch from each end to permit the sealed ends to be broken off by finger pressure. The purpose of this test is to determine whether the containers can be depended upon to offer complete protection to the tubes in the presence of chemical agents or other chemicals to which the tubes are sensitive. In the test, sealed containers of tubes are exposed to chemicals to which tubes are sensitive, and the tubes are then developed. A negative reaction indicates complete protection by lead containers or sealed tubes.

(2) *Blank sensitivity test.* Tubes which have not been exposed to chemical agent are developed. The absence of a positive test indicates that the detector tubes and reagents are pure and would not give a misleading positive test in actual use. Blank sensitivity tests are not run on the yellow and green dot tubes, as chemical agents cause color reactions in these tubes without the addition of reagents.

(3) *Positive sensitivity test.* The contents of the tubes are exposed to a chemical agent or reactive chemical. This test is designed to determine whether the detector tube, when exposed to a chemical agent or other reactive chemical and then developed, will give a positive test for the chemical agent as expected. Positive reaction indicates tubes are sensitive.

b. Blue Dot Tubes.

(1) *Tube container leakage test.*

(*a*) Suspend one of the two blue stripe (band) clips from kits selected for sampling in the vapor space of a wide-mouth, 1-gallon jar containing 8 ounces of dimethyl sulfate, and close the jar.

(*b*) After 30 minutes, remove the clips from the jar and rinse them in acetone, alcohol, benzene, or petroleum ether to remove residual dimethyl (*b*) The tube has normal sensitivity if it shows a pink band or ring on the gel within 30 seconds and if, following the first observation, it shows an orange-red band or ring on the gel within 30 seconds after a few drops of liquid (sufficient to wet the gel) are added from the red bottle. (The colors obtained will normally be less intense than those shown on the color card of the kit.)

d. Yellow Dot (Band) Tubes.

(1) *Tube container leakage test.*

(*a*) Suspend one yellow stripe clip from each sample kit in the vapor space of a wide-mouth, 1-gallon jar containing 8 ounces of ED, and close the jar.

(*b*) After 30 minutes, remove the clip from the jar; rinse the clip in acetone, alcohol, benzene, or petroleum ether to remove residual ED; dry; and remove the detector tubes from the individual containers.

(*c*) Lack of any blue or blue-green color indicates absence of container leakage.

(2) *Positive sensitivity test.*

(*a*) Insert each yellow dot tube which showed no reaction in the container leakage test in an air sampling pump, and draw through the tube one full pump stroke of saturated air from over a solution of 1 milliliter ED in 100 milliliters of mineral oil in a 1-liter bottle. (Shake the bottle before each sampling to insure saturation of the air in the bottle.)

(*b*) The tube has normal sensitivity if it shows a blue or blue-green band or ring on the gel within 30 seconds. (The color obtained will normally be less intense than that shown on the color card of the kit.)

e. Green Dot (Band) Tube Tests.

(1) *Detector tube container leakage test.*

(*a*) Suspend the one green stripe clip from each sample kit in the vapor space of a wide-mouth, 1-gallon jar containing 1 ounce of solid triphosgene, and close the jar.

(*b*) After 30 minutes, remove the clip from the jar; rinse the clip in acetone, alcohol, benzene, or petroleum ether to remove residual triphosgene; dry; and remove the detector tubes from the individual containers.

(*c*) Lack of any gren color indicates absence of container leakage.

(2) *Positive sensitivity test.*

(*a*) Insert each green dot tube which showed no reaction in the container leakage test in an air sampling pump or bulb and draw through the tube a sample of saturated air from over a solution of 1 gram of triphosgene in 100 milliliters of mineral oil in a 1-liter bottle.

(*b*) The tube has normal sensitivity if it shows a light to dark green color on the gel within 30 seconds.

CHAPTER 7
DECONTAMINANTS

96. General

This chapter discusses various types of decontamination, and is primarily concerned with those which involve a chemical reaction. These reactions are oxidation (including burning), chlorination, reduction, or hydrolysis. Chemicals used as decontaminants may be either inorganic or organic compounds which contain chlorine readily available for use as an oxidizing or chlorinating agent. Inorganic compounds include bleach in various forms, calcium hypochlorite, and chlorine itself. They decontaminate by oxidation and are used for large-scale decontamination. Organic compounds include the chloroamides and closely related compounds. They decontaminate in the absence of moisture, by chlorination and, in the presence of moisture, by oxidation. These compounds are usually dissolved in an organic solvent such as carbon tetrachloride or acetylene tetrachloride; they are expensive, however, and are used only for small-scale operations such as for destroying a blister agent on equipment.

97. Natural Decontaminants

All effective agents, including the blister agents, are volatile to a certain degree. Wind accelerates their natural evaporation and hastens their dissipation. Rain and dew cause a more or less rapid hydrolysis of chemical agents. Sunlight causes chlorine to split from many chlorinated organic compounds in the form of hydrogen chloride. As a result, the chemical nature of such compounds is completely altered. It is evident that natural processes will eventually destroy all chemical agents which have been disseminated.

98. Supertropical Bleach (STB)

a. General. STB may be referred to as bleach, supertropical bleach, bleaching powder, bleaching material, and chlorinated lime.

b. Characteristics. STB is a white powder containing about 30 percent available chlorine. It is an inexpensive material which can be made available in large quantities, and is easily spread over contaminated surfaces by means of mechanical equipment. It is estimated that bleach, if spread on the ground at a coverage of about 1 pound per square yard, would prevent formation of vapor concentrations, but would not destroy HD (or other liquid blister agents) completely. Destruction of liquid contamination within the soil is a difficult matter since a liquid easily penetrates beyond reach of a solid spread over the surface of the soil, no matter how finely the solid is divided. If sufficient bleach is disked or worked into the soil, however, decontamination can be completed. STB is an effective decontaminant for H, L, and ED. STB containing calcium hydroxide and hypochlorite is as effective against G- and V-agent as it is against H. Where contact can be made, the reaction destroys both types of nerve agents. The reaction between bleach and H can be violent (may cause fire), and proper caution should be exercised in carrying out decontamination procedures.

c. Slurry. STB may be mixed with water to form a wet mixture called slurry. There are two types of slurry, one for manual application and the other for application by means of a decontaminating apparatus. For manual application with swabs, brushes or brooms, the most effective slurry consists of approximately equal parts (by weight) of STB and water, and is prepared by mixing 6 shovelsful of bleach with one 14-quart bucketful of water. For use in a power-driven decontaminating apparatus, slurry is composed of 40 parts of bleach and 60 parts of water. When antiset is added to slurry, it holds the ingredients in suspension and prevents settling out of calcium which would clog the pipes and strainers. Therefore, antiset facilitates the flow of slurry, increases its sprayability, and helps prevent the foaming of slurry during hot weather and the premature settling of slurry during very cold weather. See TM 3–220.

d. Preparation. Sufficient calcium oxide is mixed with the calcium chlorohypochlorite to reduce the moisture content of STB to less than 3 percent. This results in greatly increased stability; and the product, supertropical bleach, will withstand 6 weeks of storage at 158° F (70° C.) with very little loss of available chlorine. STB loses about 2 percent available chlorine per year at 158° F. Therefore, under these conditions, it would last several years.

e. Reaction With Mustard. In the presence of an active material such as HD, STB reacts as follows:

$$2CaCl(OCl) + (ClCH_2CH_2)_2S \rightarrow 2CaCl_2 + (ClCH_2CH_2)_2SO_2$$

The reaction between bleach and HD is largely one of oxidation which, in the case of dry bleach and gross liquid contamination, may generate sufficient heat to produce flaming. Decontamination of HD by bleach is believed to be by oxidation of the HD to the sulfone as shown in the equation above. The sensitivity to mustard sulfone $(ClCH_2CH_2)_2SO_2$ varies with the individual. Mustard sulfone exists as a white crystalline material which adheres easily to the skin. If left on the skin, it often produces severe burns. Mustard sulfoxide $(ClCH_2CH_2)_2SO$, a product having no blistering power, is probably also formed.

f. Activity. STB does not contain as much active chlorine as the formula CaCl(OCl) would indicate. STB contains 30 to 35 percent available chlorine initially and gradually loses this in storage. For this reason, bleach is decidedly corrosive to metal containers.

g. Test for Chlorine Content.

(1) *General.* The available chlorine in bleach determines its oxidizing power. The available chlorine of bleach is one-half the actual chlorine content of the CaCl(OCl) contained in bleach.

(2) *Arsenious oxide titration method.* The following method is used to determine available chlorine in calcium hypochlorite and bleaching powder. (See (3) below for preparation of reagents.) Weigh 5 to 10 grams of thoroughly mixed sample into a porcelain mortar, add 30 to 40 milliliters of water, and triturate until smooth cream is obtained. Add more water, stir well with pestle, and allow residue to settle for a few minutes. Pour off the supernatant suspension into a 1-liter volumetric flask, add more water to the residue, and thoroughly triturate and pour off into flask as before. Repeat operation until all of sample has been transferred to flask. Rinse mortar and pestle, catch wash water in flask, dilute solution to mark, and mix. Without allowing material to settle, transfer a 25- to 50-milliliter aliquot into a 250-milliliter Erlenmeyer flask. Add 0.1 N As_2O_3 solution in excess and then add a decided excess of $NaHCO_3$, titrate excess of As_2O_3 with standard I_2 solution, corrected to 0.1 N, from volume of As_2O_3 solution used, and calculate percentage of available chlorine. One milliliter of 0.1 N As_2O_3 equals 0.003546 gram of available chlorine.

(3) *Preparation of reagents for titration method.*

(*a*) *Arsenious oxide solution, 0.1 N.* Dissolve exactly 2.474 grams of pure As_2O_3 in a beaker by boiling it with 150 to 200 milliliters of water containing 10 milliliters of H_2SO_4. Cool, add phenolphthalein indicator, neutralize acid with NaOH solution, adjust to faint acid reaction, transfer to a 500-milliliter volumetric flask, and dilute to mark.

(*b*) *Standard iodine solution (approx. 0.05 N).* Mix 6.35 grams of pure I_2 with twice this weight of pure KI, dissolve in a small quantity of water, filter, and dilute filtrate to 1 liter in volumetric flask. Standardize against standard arsenious oxide solution ((*a*) above) as follows: Transfer 50.0 milliliters of standard As_2O_3 solution to a 250-milliliter Erlenmeyer flask, dilute to the same volume as that obtained from the addition of excess 0.1 N As_2O_3 to the aliquot used for titration in actual determination ((2) above), neutralize with $NaHCO_3$, and then add 4 to 5 grams in excess. Slowly add the standard I_2 solution from a burette, shaking flask continuously until yellow color disappears. Add 5 milliliters of the starch indicator ((*c*) below) and continue adding the I_2 solution ((*c*) above) drop by drop until a permanent blue color is obtained. Calculate value of the standard I_2 solution in terms of As_2O_3 and As_2O_5. For conversion of As_2O_3 to As_2O_5, multiply by 1.1617. Occasionally restandardize the I_2 against AS_2O_3 solution.

(*c*) *Starch indicator.* Mix approximately 2 grams of finely powdered potato starch with cold water to form a thin paste; add to approximately 200 milliliters of boiling water, stirring constantly; and immediately discontinue heating. Add approximately 1 milligram of HgI_2; shake, and allow starch to stand over HgI_2.

99. DANC Solution

a. General. This is a 6.25 percent solution of RH–195 in acetylene tetrachloride. This decontaminant is decidedly corrosive to metals (but considerably less so than bleach) because the decontamination reaction is accompanied by the formation of acid. Because of the corrosive nature of the DANC solution the components of the solution are packaged separately in a dual-compartmented container and are combined just before use.

b. RH–195. This compound was developed prior to World War II and, in acetylene tetrachloride solution, was adopted as a satisfactory HD decontaminant in small-scale operations. It is not a decontaminant for nerve agents and should not be used for that purpose. The compound is 1,3-dichloro–5, 5-dimethylhydantoin. It is an effective decontaminant for arsenicals, if sufficient time is allowed for it to react.

c. Acetylene Tetrachloride. This solvent, used in DANC solution, is probably the most toxic chlorinated organic solvent known. It is about 10 times as toxic as carbon tetrachloride. Less than 20 drops ingested can cause death.

(1) *Toxicity.* Personnel who are exposed to detectable concentrations of acetylene tetrachloride vapor for more than a few minutes are required to wear protective masks. Two types of poisoning may be caused by acetylene tetrachloride. An individual may have both types at the same time.

(*a*) The more commonly observed type of poisoning is gastrointestinal, with special effect on the liver. Chronic poisoning of this type shows up as jaundice and other symptoms arising from the liver. The immediate effects of this form of poisoning are nausea and vomiting, accompanied by various other symptoms. Chronic exposure may lead to permanent liver damage.

(*b*) The less common form of poisoning localizes in the central nervous system, that is, the brain centers. As with any form of injury to the nervous system, the effects may run through a succession of symptoms, perhaps starting with blurred vision, followed after a few days by daily headaches for several days. This may be succeeded by temperature derangement such as nocturnal fever and by general nervous exhaustion, accompanied by temporary partial loss of memory and other symptoms. These symptoms gradually subside, but even moderate poisoning has been known to produce effects lasting over a period of several months. Symptoms vary with the individual.

(2) *Chemical testing.* Test each composite sample of acetylene tetrachloride for acidity, calculated as HCl, as follows:

(*a*) Pipette 25 milliliters of the sample into a 100-milliliter separatory funnel. Pipette 25 milliliters of distilled water into the separatory funnel, shake vigorously for at least 1 minute, allow the two liquids to separate, and draw off and discard the acetylene tetrachloride.

(*b*) Run a blank test according to the following procedures: Pipette 25 milliliters of distilled water into a second 100-milliliter separatory funnel, add 2 drops of phenolphthalein indicator, and titrate with 0.02

N NaOH (sodium hydroxide) to a faint pink end point.

(*c*) Add 2 drops of phenolphthalein indicator to the water in the first separatory funnel and titrate with 0.02 N NaOH until a pink color, matching that of the blank test, is obtained.

(*d*) Subtract volume of 0.02 N NaOH used in the titration of the blank test from that used in the test of the sample and use the difference in the following calculation:

$$\frac{\text{mlNaOH} \times \text{N} \times 3.65}{25 \times \text{sp. gr. of sample}} = \text{Percent of acidity, calculated as HCl}$$

100. DS2 Decontaminating Agent

DS2 is a clear solution consisting of 70 percent active agent (diethylenetriamine), 28 percent solvent (ethylene glycol monomethyl ether), and 2 percent active agent booster (sodium hydroxide). DS2 is a general-purpose decontaminant that reacts with GB and HD to effectively reduce their hazards within 5 minutes of application. It is effective for all toxic chemical agents, to include V-agents. It is available in 1⅓-quart cans and 5-gallon drums in ready-to-use solution. The 1⅓-quart cans are for filling the M11, portable decontaminating apparatus. The 5-gallon drums of DS2 may be applied by means of brooms, swabs, or brushes. The solution is effective at temperatures from —25° F. (—31.6° C.) to + 125° F. (51.6° C.). One application is used on contaminated surface followed in 30 minutes by flushing with water. DS2 is flammable. It is irritating to the skin, and contact with the skin should be avoided. It can be readily removed from the skin without harmful effect by immediately washing with water. Inhalation of vapors should be avoided. DS2 is noncorrosive to most metals. It removes and softens new paint and may discolor old paint. DS2 will also soften leather. See TM 3–220 for further information.

101. Miscellaneous Decontaminants

a. Alkalies. All alkalies are effective decontaminants for the nerve agents. Alkalies are of little value as decontaminants for L, as the L hydrolyzes so rapidly with water alone that the additional assistance of alkali is of little importance.

b. Sodium Hypochlorite. Sodium hypochlorite solution liberates HOCl and, upon contact with chemical agents, changes them to less toxic chemicals. Although normally used full strength, standard sodium hypochlorite solution may be diluted with water.

c. Soap. Soap is no more effective than alkali in decontaminating blister agents on surfaces, except for decontamination by physical removal of the blister agent.

d. Water. Water hydrolyzes many chemical agents, and flowing water mechanically washes chemical agents from surfaces. Addition of soap or other cleansing chemicals usually makes water a more effective decontaminant. Effectiveness of water depends to some extent on its temperature, hot water usually being most effective.

e. Steam. Wet steam is effective as an HD decontaminant. Superheated steam is not effective, except to volatilize agents. The reason for this is that water must be present to bring about the hydrolysis of HD by first dissolving it, and superheated steam contains no condensed water. Steam has an action similar to that of hot water. Steam is not a good decontaminant for contaminated clothing because the hydrochloric acid liberated from HD by hydrolysis reduces the tensile strength of the clothing.

f. Oxidizing Compounds. A variety of oxidizing compounds react with HD to form mustard sulfone. Among these are potassium permanganate and potassium persulfate. Sodium peroxide oxidizes HD and removes the chlorine atoms simultaneously. Hypochlorous acid, formed when chlorine is passed into water, decomposes HD and also forms some mustard sulfoxide. Sodium hypochlorite acts similarly.

g. M5 Protective Ointment. M5 ointment is used primarily for decontaminating the skin. It may be used on a limited scale for emergency decontamination of small areas of clothing and personal equipment (FM 21–41). The mechanism of action of M5 ointment is the same as that of the chloroamide type of decontaminants in general. The chloroamides release chlorine which enters the HD (or similar) molecule and changes its chemical nature in such a way as to negate its blistering power.

h. Burning. This method of decontamination is applicable to vegetation, debris, rubbish, and so forth. Burning accomplishes decontamination partly by thermal decomposition and partly by volatilization. This method may, therefore, set up blistering concentrations of vapor in downwind areas and this possibility must be given proper consideration.

i. Chlorine. In general, chlorine is of little value as a decontaminating chemical. If it is dissolved in carbon tetrachloride, it may be used for decontaminating laboratory equipment with satisfactory results.

j. Burying. Burying is applicable to debris and rubbish; however, the area where the contaminated material has been buried should be clearly marked.

APPENDIX I

REFERENCES

AR 320-5	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations and Brevity Codes.
AR 700-62	Chemical Protective Clothing Policy and Utilization of Certain Chemical Corps Units and Equipment in Combat Areas.
DA Pam 108-1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310-1	Index of Administrative Publications.
DA Pam 310-2	Index of Blank Forms.
DA Pam 310-3	Index of Doctrinal, Training and Organizational Publications.
DA Pam 310-4	Index of Technical Manuals, Technical Bulletins, Supply Manuals (types 4, 6, 7, 8, and 9), Supply Bulletins, Lubrication Orders, and Modification Work Orders.
DA Pam 310-7	Index of Tables of Organization and Equipment, Type Tables of Distribution, and Tables of Allowances.
TOE 3-97E	Chemical Laboratory.
TOE 3-500E	Chemical Service Organization.
FM 3-8	Chemical Corps Reference Handbook.
FM 3-10	Chemical and Biological Weapons Employment.
FM 3-50	Chemical Smoke Generator Battalion and Chemical Smoke Generator Company.
FM 3-85	Chemical Service Units.
FM 21-5	Military Training.
FM 21-30	Military Symbols.
FM 21-40	Small Unit Procedures in Nuclear, Biological, and Chemical Warfare.
FM 21-41	Soldier's Handbook for Nuclear, Biological and Chemical Warfare.
FM 21-48	Chemical, Biological, and Nuclear Training Exercises and Integrated Training.
(C) TM 3-200A/TO 42C-1-6	Employment of Toxic Chemical Agents (U).
TM 3-220/TO 00-110-1	Chemical, Biological and Radiological (CBR) Decontamination.
TM 3-240/AFM 105-7	Field Behavior of Chemical, Biological, and Radiological Agents.
TM 3-250	Storage, Shipment, and Handling of Chemical Agents and Hazardous Chemicals.
TM 3-281/TO 39C-10CCB-6	Impregnating Plant, Clothing, M2.
TM 3-300	Ground Chemical Munitions.
TM 3-303/TO 11D2-3-3-1	Impregnating Set, Clothing, Field, M3; Impregnating Outfit, Clothing, Field, M1 Kit, Testing Impregnite-in-Clothing, M1.
TM 3-304/TO 14P3-1-9	Protective Clothing and Accessories.
TM 3-306/TO 11H2-1-2	Detector Kits, Chemical Agent, M18, M9A2, M15.
TM 3-310-15	Breathing Apparatus, Compressed Air, M15; Adapter, Compressed Air-breathing Apparatus, M4; and Detector Kit, Carbon Monoxide, Calorimetric, M23.
TM 3-376/TO 39C-10AA-1	M2A1 Portable Flame Thrower.
TM 3-400/TO 11C2-1-1	Chemical Bombs and Clusters.

TM 3–409	Impregnating Plant, Clothing, M2A1.
TM 3–522–15	Mask, Protective, Field, M9 and Mask, Protective, Field, M9A1.
TM 3–1040–202–12	Operator and Organizational Maintenance Manual, Generator, Smoke, Mechanical, Pulse Jet, M3A3.
TM 3–4240–202–15/ TO 14P4–9–1	Operator, Organizational, Field and Depot Maintenance Manual: Mask, Protective, Field, M17.
TM 3–4240–207–12	Operator and Organizational Maintenance Manual: Filter Units, Gas-particulate, 300 cfm, ged, ABC–M16 and 300 cfm, emd, ABC–M6.
TM 3–4240–207–35	Filter Unit, Gas Particulate, 300 cfm, ged, ABC–M6 and 300 cfm, emd, ABC–M6.
TM 3–4240–212–15/ TO 14S5–4–1	Operator, Organizational, Field and Depot Maintenance Manual: Breathing Apparatus, Oxygen Generating, M20.
TM 3–4240–218–15	Operator, Organizational, Field and Depot Maintenance Manual: Mask, Gas, Rocket Propellant, M21.
TM 3–4240–221–15	Operator, Organizational, Field and Depot Maintenance Manual: Mask, Protective, Tank, ABC–M14A1 and Mask, Protective, Tank, M14.
TM 3–4240–224–12	Operator and Organizational Maintenance Manual: Breathing Apparatus, Compressed Air, ABC–M15A1 (end item Code 404).
TM 3–4240–230–12	Operator and Organizational Maintenance Manual: Mask, Gas, Acid and Organic Vapors, M10.
TM 3–4240–231–12	Operator and Organizational Maintenance Manual: Mask, Gas, All-Purpose, M11A1.
TM 3–4240–232–12	Operator and Organizational Maintenance Manual: Mask, Gas, Ammonia, M12.
TM 3–6665–210–12	Alarm, VG-Agent, Automatic Field, E41R3.
TM 3–6665–211–12	Operator and Organizational Maintenance Manual: Detector Kit, Chemical Agents, VGH, AN–M15A1 and AN–M15A1A.
TM 3–6665–212–12	Operator and Organizational Maintenance Manual: Detector Kit, Chemical Agent, ABC–M18A1.
TM 8–285/NAVMED P–5041/AFM 160–12	Treatment of Chemical Warfare Casualties.
TM 9–1300–203	Ammunition for Antiaircraft, Tank, Antitank and Field Artillery Weapons.
TM 9–1901–1/TO 11A–1–39	Ammunition for Aircraft Guns.
TM 10–1680A	Laundry Unit, Trailer-mounted Washer, Trailer TLMW–51, PLMW–51A, TUA–1, and TLMW–55; Tumbler Trailer TLMT–51, PLMT–51A, TUA–2, and TLMT–55.
TC 19–1	Operation and Employment, Irritant Gas Dispensers.
TB CML 43	Kit, Chemical Agent Analyser, M10A1.
TB CML 44	Kit, Agent Sampling, M12.
TB CML 68	Testing Kit, Impregnite-in-clothing, M2 Safety Guide for Processing, Filling, Handling, and Decontamination of CS and CS1.

Note. Army publications referred to in this manual are applicable to the Air Force only in those instances where the Air Force publication number is also indicated. Army publications not applicable will not be requisitioned by Air Force Activities.

APPENDIX II

METRIC UNITS

Length

1 kilometer = 1,000 meters
1 meter = 100 centimeters
1 centimeter = 10 millimeters
1 micron (μ) = 10^{-4} centimeters
1 millimicron (mμ) = 10^{-3} microns
1 angstrom (A) = 10^{-1} millimicrons

Volume

1 kiloliter = 1 cubic meter = 1,000 liters
1 liter = 1,000 cubic centimeters = 1,000 milliliters
1 milliliter = 1 cubic centimeter (exactly 1.000027)
1 microliter or 1 Lambda (λ) = 10^{-6} liter

Weight

1 kilogram = 1,000 grams
1 gram = 1,000 milligrams
1 microgram or gamma (γ) = 10^{-6} grams

APPENDIX III

TABLE OF EQUIVALENTS

Length

1 inch = 2.54 centimeters = 25.4 millimeters
1 foot = 30.48 centimeters
1 yard = 0.9144 meter
1 mile = 1.61 kilometers
1 centimeter = 0.3937 inch
1 meter = 3.28 feet = 1.093 yards
1 kilometer = 0.6214 mile

Volume

1 quart = 0.946 liter
1 gallon = 3.785 liters
1 cubic foot = 28.32 liters
1 liter = 1.057 quarts
1 cubic meter = 35.31 cubic feet = 1.38 cubic yards

Weight

1 ounce = 28.35 grams
1 pound = 453.6 grams
1 gram = 0.03552 ounce avoirdupois
1 kilogram = 2.20 6 pounds avoirdupois

APPENDIX IV
1963 INTERNATIONAL ATOMIC WEIGHTS

Chemical Element	*Symbol*	*Weight*
Actinium	Ac	227
Aluminum	Al	26.98
Americium	Am	*243
Antimony	Sb	121.76
Argon	Ar	39.944
Arsenic	As	74.91
Astatine	At	210
Barium	Ba	137.36
Berkelium	Bk	*249
Beryllium	Be	9.013
Bismuth	Bi	209.00
Boron	B	10.82
Bromine	Br	79.916
Cadmium	Cd	112.41
Calcium	Ca	40.08
Californium	Cf	*249
Carbon	C	12.011
Cerium	Ce	140.13
Cesium	Cs	132.91
Chlorine	Cl	35.457
Chromium	Cr	52.01
Cobalt	Co	58.94
Copper	Cu	63.54
Curium	Cm	*247
Dysprosium	Dy	162.51
Einsteinium	E	*254
Element 102	–	*254
Erbium	Er	167.27
Europium	Eu	152.0
Fermium	Fm	*255
Fluorine	F	19.00
Francium	Fr	*223
Gadolinium	Gd	157.26
Gallium	Ga	69.72
Germanium	Ge	72.60
Gold	Au	197.0
Hafnium	Hf	178.50
Helium	He	4.003
Holmium	Ho	164.94
Hydrogen	H	1.0080
Indium	In	114.82
Iodine	I	126.91
Iridium	Ir	192.2
Iron	Fe	55.85
Krypton	Kr	83.80
Lanthanum	La	138.92
Lawrencium	Lw	*257
Lead	Pb	207.21
Lithium	Li	6.940
Lutetium	Lu	174.99
Magnesium	Mg	24.32
Manganese	Mn	54.94
Mendelevium	Mv	*256
Mercury	Hg	200.61
Molybdenum	Mo	95.95
Neodymium	Nd	144.27
Neon	Ne	20.183
Neptunium	Np	*237
Nickel	Ni	58.71
Niobium (Columbium)	Nb	92.91
Nitrogen	N	14.008
Osmium	Os	190.2
Oxygen	O	16.000
Palladium	Pd	106.4
Phosphorus	P	30.975
Platinum	Pt	195.09
Plutonium	Pu	*242
Polonium	Po	*210
Potassium	K	39.100
Praseodymium	Pr	140.92
Promethium	Pm	*147
Protactinium	Pa	231
Radium	Ra	226.05
Radon	Rn	222
Rhenium	Re	186.22
Rhodium	Rh	102.91
Rubidium	Rb	85.48
Ruthenium	Ru	101.1
Samarium	Sm	150.35
Scandium	Sc	44.96
Selenium	Se	78.96
Silicon	Si	28.09
Silver	Ag	107.880
Sodium	Na	22.991
Strontium	Sr	87.63
Sulfur	S	+32.066
Tantalum	Ta	180.95
Technetium	Tc	*99
Tellurium	Te	127.61
Terbium	Tb	158.93
Thallium	Tl	204.39
Thorium	Th	232.05
Thulium	Tm	168.94
Tin	Sn	118.70
Titanium	Ti	47.90
Tungsten (Wolfram)	W	183.86
Uranium	U	238.07
Vanadium	V	50.95
Xenon	Xe	131.30
Ytterbium	Yb	173.04
Yttrium	Y	88.92
Zinc	Zn	65.38
Zirconium	Zr	91.22

* Starred values are the mass numbers of the longest-lived of the known available forms of elements, usually synthetic, which are radioactive in all forms.

+ Because of natural variations in relative abundance of the sulfur isotopes, its atomic weight has a range of 0.003.

APPENDIX V

TEMPERATURE CONVERSION TABLE °C. TO °F.

$$F = 1.8C + 32$$

$$C = \frac{F - 32}{1.8}$$

°C.	°F.	°C.	°F.	°C.	°F.
—60	—76	45	113	155	311
—55	—67	50	122	155	302
—50	—58	55	131	160	320
—45	—49	60	140	165	329
—40	—40	65	149	170	338
—35	—31	70	158	175	347
—30	—22	75	167	180	356
—25	—13	80	176	185	365
—20	—4	85	185	190	374
—15	5	90	194	195	383
—10	14	95	203	200	392
—5	23	100	212	205	401
0	32	105	221	210	410
5	41	110	230	215	419
10	50	115	239	220	428
15	59	120	248	225	437
20	68	125	257	230	446
25	77	130	266	235	455
30	86	135	275	240	464
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40	104	145	293	250	[illegible]

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For explanation of abbreviations used, see AR 320–50.

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