To 1st mate

1 April 1967
Date of Transmittal

Extra copy

Complete Revision

to

Chapter 9770

NAVAL SHIPS TECHNICAL MANUAL

NAVSHIPS 0901-977-0000

Chapter 9770

Shipboard BW/CW Defense and Countermeasures

List of Effective Pages

PAGE NUMBERS	CHANGE IN EFFECT
1-49	Original

Original: 1 April 1967

NAVAL SHIPS TECHNICAL MANUAL
formerly
Bureau of Ships Technical Manual

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NAVSHIPS 0901-977-0000

NAVAL SHIPS TECHNICAL MANUAL

CHAPTER 9770 - SHIPBOARD BW/CW DEFENSE AND COUNTERMEASURES

2/1/67

This printing supersedes Chapter 9770 of 11/1/65 and includes all changes prior to this date.

CONTENTS

SECTION I. GENERAL

Part 1. Purpose of this Chapter

9770.1.

It is necessary that all officers and men of the Fleet be supplied with practical, accurate, and up-to-date information on biological and chemical warfare (BW/CW) defense at sea. A wide variety of manuals and other documents issued by the Navy, Marine Corps, and other services furnishes general or specialized data on many aspects of BW/CW defense. A selection of these is listed in the Bibliography. None, however, deals directly with problems of BW/CW defense at sea. The purpose of this chapter is to provide the information lacking or not readily available elsewhere, and to combine it into a practical and effective shipboard system. Particular attention is called to **"Disaster Control Ashore and Afloat"** NAVPERS 10899A, a Navy training manual in BW/CW defense operations. Where differences exist, this chapter will take precedence over the information of NAVPERS 10899A.

Part 2. Orientation in BW/CW at sea

9770.11

The active materials or "agents" of present-day biological warfare (BW) and chemical warfare (CW) include a variety of microbes[1] (BW agents) and poisons (CW agents). These have been selected for their ability to cause temporary incapacitotion, sickness, or death in personnel at sea or ashore. In bulk form, these agents are liquids, slurries of powders in water, or concentrated dry powders. In modern tactical use the agents are generally atomized in the air to give aerosols (microscopic airborne solid particles, fine sprays, or mists) vapors, or gases. For practical purposes, BW/CW agents in these forms are odorless, colorless, tasteless, and invisible. However, a concentrated spray or aerosol cloud may be temporarily visible adjacent to an exploded or spraying munition. In addition, most BW/CW agents produce no pain[2] or other sensation until physiological damage is well under way. These properties allow an attacker to gain and hold the military advantages of surprise and concealment to a degree that is unique. Consequently, BW/CW agents are powerful and versatile materials of war.

The CW agents and weapons of World Wars I and II did not pose a major threat to the U.S. Fleet. The CW agents of that period were less toxic than the present nerve agents and lacked lethality by skin penetration. In addition, the mobility and dispersal of Fleet units made their personnel poor targets for CW weapons compared with troop concentrations ashore. It was also reasoned during World War II that any CW attack on ships could be bettered by conventional attack with high-explosive bombs, shells, or torpedoes. Later, with the postwar development of nuclear weapons, it appeared that toxic warfare at sea was a dead issue.

Two factors have combined to modify these opinions. The first was international development, in the 1945-55 decade, of the large family of CW nerve agents. This group includes the "V" and "G" series of agents. Although these vary widely in physical properties, all are extremely toxic. The second factor was the advanced development of agents, weapons, and use-concepts of BW. Of particular interest to Naval forces is the possibility of contaminating the atmosphere over thousands of square miles of the earth's surface in a concealed attack by a single aircraft or submarine.

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[1]"Micro-organism", "pathogen", and "germ" are interchangeable with the word "microbe".

[2]Exceptions are the relatively harmless tear gases and riot agents which are intended to produce temporary but immediate and intense irritation of the eyes and respiratory system; the toxic agents CK and CX have similar immediate effects, which are incidental to their lethal purpose.

Although BW and CW agents are entirely different in their detailed effects on the human body and in the medical treatment required, and are also very different in their speed of action, the U.S. Navy has found it useful to consider BW and CW as a single system of toxic warfare for defensive purposes. Several good reasons exist for this policy. In the first place, the delivery weapons are frequently similar, if not interchangeable, for BW and CW agents. Secondly, the movement of both kinds of agents from munition to target is generally in aerosol or vapor form, carried and controlled by wind and weather. Thirdly, many items and procedures of physical defense, such as the protective mask and clothing, decontamination, washdown and collective protection, are identical in BW and CW. These practical similarities in the defensive aspects of BW and CW have led to a new Navy classification of BW and CW agents which cuts across traditional agent groupings. All BW or CW agents which require the individual to wear both the protective mask and protective clothing fall into the MC (Mask and Clothing) group. Other BW and CW agents, against which adequate protection is given by the mask alone, are in the MO (Mask Only) group.

It is desirable that all Naval personnel understand fully the reasons which have led to a single <u>defense</u> system for BW/CW at sea. It also is desirable that the differences in the <u>offensive</u> characteristics and uses of BW and CW agents be understood. Another striking difference is in the quantities of BW and CW agents required for a single lethal dose.

For example, a typical lethal BW microbe is a sphere about one micron (1/10,000 centimeter or 1/25,000 inch) in diameter, and 100 of them is an ample military dose when inhaled. A calculation shows that one cubic centimeter of a 50-50 slurry of microbes and water contains 10^{10}, or ten billion lethal doses. Turning to CW agents of the highly toxic nerve agent group, a lethal dose by inhalation is about half a milligram, and there are roughly 1800 lethal doses per cubic centimeter. The BW agent, in its munition, is then about 5 million times as deadly as the CW agent. If 95 percent of the microbes are killed by sunlight or by drying on their airborne route to the target,[3] the BW agent still has a 250,000 fold advantage in lethality at the target.

Calculations like the one just made, taken together with the incubation time of BW disease, show why BW agents appear to have the potential for producing delayed effects over very large areas as well as over smaller areas. CW agents, on the other hand, find their preferred use in producing casualties quickly over areas of a square mile or less, or on a single ship.

Differences in detectability also are important in understanding the offensive uses and effects of BW and CW. The present first-line detection device[4] for CW spray or aerosols has the capability for instant response. A CW attacker, therefore, must count on the probability that an alert and highly trained ship will: (a) begin post-attack countermeasures immediately, (b) carry them out effectively with minimum interference to other responsibilities, and (c) experience relatively few casualties.

BW detection devices, comparable with the CW items in speed and simplicity, are not available for shipboard use. Early indications of a BW attack may exist, but they will probably be indirect and inferential. Detection of any kind may be delayed until the appearance of disease symptoms arouses suspicion. An attacker, therefore, can assume that no prompt countermeasures will be taken as a direct result of the attack unless he himself reveals the attack by his actions. However, he must also recognize that there will be no reduction in the combat effectiveness of the target until the incubation period of the disease has elapsed.

BW, therefore, is a large-area, delayed-action weapon. The munitions can be carried in relative security to a line far upwind of the target force or area. From this line the aerosol moves with the prevailing wind on a collision course with the target. As soon as aerosol generation is completed, the tanks or floats can be jettisoned or sunk, leaving no trace of their presence.

The following is a brief summary of factors which make BW, and to a degree, CW, remarkably well adapted to use at sea.

1. BW is potentially capable of contamination coverages of the order of thousands of square miles, such as the area occupied by a naval task force.

2. Any side of a high-seas target can be reached in concealment for discharge of BW/CW agents into the atmosphere. To a degree this is also true of islands and coastal areas.

3. The submarine or floating spray-munitions are effective means of discharging BW/CW aerosols at no risk to personnel conducting an attack.

4. There is less waste of BW/CW agents by vertical diffusion in marine atmospheres than ashore. (As a rule, the atmosphere over the ocean is more stable than the atmosphere over land.)

Part 3. Basic factors in BW/CW at sea

9770.21. GENERAL EFFECTS ON PERSONNEL

Although the effects of BW/CW agents are purely antipersonnel,[5] they nevertheless vary over the entire range

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[3] It is at just this point that the operational unknowns of BW are concentrated. Complete information is not yet available on the extent to which airborne BW organisms can, in spite of the damaging effects of dehydration and sunlight over periods of many hours, remain alive and capable of infecting. Under ideal conditions, the death rate of airborne BW organisms between munitions and distant target may be less than 95 percent. More commonly, it can be higher. However, there is no doubt about the ability of lifeless particles of the BW-agent size to travel long distances while airborne.

[4] M6A1 Detector Paper, continuously observed.

[5] BW agents may include certain materials of war designed to weaken or destroy food crops and domestic animals. In a similar sense CW agents may include incendiary materials and screening smokes. Such materials are of secondary interest for the purpose of this chapter.

of the most deadly to the merely incapacitating diseases and poisons.

BW effects are those of comparatively rare human diseases (such as anthrax or plague), but even these can be modified by the use of new and more virulent or antibiotic-resistant strains of microbes, and by heavier doses than those common in natural infection.

The effects of CW agents cover an even wider range than the BW effects. The newer incapacitating agents (such as the riot-control agent CS, a strong eye and respiratory irritant) are more effective than the tear gases and vomiting gases of World Wars I and II. They also include agents which cause various kinds of temporary mental or personality upsets. Some of these can seriously affect a person's judgment, working accuracy, and general reliability, all while he is unaware of his deficiencies. Mustard gas (HD) continues to be an outstanding CW agent for producing disabilities* among both masked and unmasked personnel. The nerve agents (G- or V- series) attack by the same routes as mustard gas (through the eyes, respiratory system, or skin) to cause temporary incapacitation or rapid death. In addition, the nerve agents are effective in much smaller amounts than mustard.

In addition to the nerve agents and mustard, other powerful CW agents exist. They are mentioned in Appendix A and provision is made for their identification-detection in the detector kits. The probability of large scale use of such agents as phosgene, cyanogen chloride, phosgene oxime, nitrogen mustard, and the arsenicals is considered to be very small, however, because none of them has a lethality or incapacitating power against masked personnel comparable with the V, G, and HD agents. Nevertheless, it is recognized that the unexpected use of a less common agent would have tactical value against poorly trained personnel.

9770.22. THE TIME FACTOR IN BW/CW

The speed with which individual BW/CW agents act on personnel, as well as the time required for the victims' recovery, are related to the times, places, and situations in which BW/CW attacks are most likely to be made. The symptoms of BW diseases generally do not appear until days or weeks after exposure to the agents, and recovery—if recovery occurs—may require days or weeks more. This means the BW agents are not quick-acting tactical weapons, but are best used for delayed effects against convoys, advance bases, repair facilities, shipyards, presortie concentrations of ships, task groups at sea, and civilian populations. CW agents, on the other hand, can be selected for either immediate or delayed action, for brief or prolonged disability, or for temporary physical or mental incapacitation. In general, however, CW agents are best adapted for quick antipersonnel effects. CW agents can be mixed, as can BW agents, to obtain combinations of properties, and to complicate and confuse the defense. This was a common practice in World War I. For example, small amounts of a riot-control agent can be mixed with a lethal agent; the effects of the riot-control agent can delay masking, and so prolong inhalation of the lethal material.

9770.23. THE DELIVERY OF BW/CW AGENTS: THE ELEMENT OF SURPRISE

The methods and conditions suitable for delivering BW/CW agents to their targets are to a large extent influenced by the properties of the agents themselves. For example, BW agents are effective in remarkably small doses—about one ten-millionth of a milligram—but require at least several days for the disease to develop. Also because they normally invade the body by inhalation, the Mark V protective mask can give excellent protection to the wearer against BW microbes. These factors suggest attack procedures so designed and executed that they are undetected until the disease erupts in the target personnel. To promote concealment and surprise, as well as to aid in covering very large areas, BW attacks from long distances will be favored. However, under conditions particularly suitable for concealment, a close-in attack on one or a few ships, or on a shore installation, is practical and, to promote economy of agent or survival of the microbes, may be preferred.

Lethal CW agents, on the other hand, are effective only if milligram quantities are inhaled or deposited on the body. Their action is generally rapid and occurs in seconds to minutes if the agent is inhaled or received in the eyes. Skin penetration requires minutes to hours. For efficient deposition on the skin of personnel, very small or freefloating particles are not desirable (see Table 9770-2). On the other hand, a CW attack designed for inhalation only will employ a true vapor or a small-particle aerosol. To be sure of hitting or intercepting the target ship, it, like the attack with large droplets, must be made from relatively close in.

The preferred size for a particular aerosol depends on its intended function and on the conditions under which it is to be used. For example, BW aerosols must be capable of penetrating deep into the human respiratory system and depositing there, and should be capable of floating in air for many hours. Particles smaller than 0.5 micron are readily inhaled, but are also exhaled without extensive deposition in the lungs. Particles larger than 5 microns may fail to enter the respiratory system or may be filtered out in the nose. Therefore, the maximum allowable size for BW particles is five microns, and one to two microns is considered ideal. In contrast, windborne particles of CW aerosols must be capable of striking and adhering to men and their clothing, not moving around and past them as will a BW aerosol. Moreover, CW aerosol particles need not remain airborne for more than a few minutes at most. In fact, it is usually necessary that they drop onto a target rapidly to give little time for protective countermeasures to be taken after an airburst missile or spraying aircraft is observed.

Some common aerosols and their characteristic sizes are: tobacco smoke, 1/2 micron; fog and cloud, 2 to 70

*Of the total U.S. Army and Marine Corps battle casualties in World War I (272,000), 27 percent were caused by CW agents, mainly mustard. However, of the CW casualties, only two percent died, compared with 26 percent deaths among non-CW casualties. The average U.S. mustard casualty spent 60 days in a hospital.

microns; and mist, 70 to 200 microns. With drizzle, 200-500 microns, the airborne period is relatively short, and the rote of fall becomes noticeable; it is at the top of the size range of aerosols.

In summary, because BW agents produce their effects primarily by inhalation, (eating and drinking food and water which has been secretly contaminated is a less probable means of BW infection), BW tactics and munitions must emphasize factors which make for deep penetration of the lungs and little impaction on surfaces. The most important of such factors is a very small particle size—one to five microns. CW agents, on the other hand, are effective both by inhalation and through the skin. The latter route is favored especially against well-trained forces, since it is harder to protect the entire body than the respiratory system alone. CW tactics and munitions therefore will normally attempt to optimize factors making for impaction of liquid agent particles on the body; inhalation casualties can be regarded as incidental. The most important of the factors which facilitate impaction is a large particle size, probably of 100 microns and up.

9770.24. BC/CW WEAPONS

The weapons or munitions of BW/CW—the hardware of agent delivery—exist in unusual variety. This is a logical consequence of the variation in the biological and physical properties of the agents, and in their tactical applications.

The more conventional BW/CW munitions include bombs and bomblets, rockets, thermal aerosol generators (resembling smoke grenades, smoke pots or smoke floats) aircraft spray tanks, artillery and mortar shells, and other explosive or spraying devices. In the explosive munitions, part of the usual high-explosive charge is replaced by agent. When such a filling is used in proximity-fuzed projectiles, a BW/CW attack can be made accurately on large or small, stationary or moving targets regardless of wind or weather. The effectiveness of the attack, however, usually will be greater for low relative wind speeds on the target because of slower dispersal and dilution of the sprayed and/or vaporized agent by the wind. In a conventional-weapon attack the element of surprise is weakened, but it will still contribute to the effectiveness of the attack if the ship is unable to recognize quickly the presence of the BW/CW agent.

It is believed that BW/CW agents will be delivered, whenever possible, by special weapons particularly designed to exploit their special military advantages. These advantages are the ability to kill or incapacitate by means which are noiseless, odorless, invisible, and difficult or impossible to detect quickly, either by the human senses or by instruments. By appropriate special weapons, not only can initial surprise be gained through concealment of the attack itself, but also surprise may be maintained until the appearance of casualties in the exposed personnel. This unusual principle of warfare—initial and sustained surprise—can be carried out, for example, by large-scale BW contamination of the atmosphere upwind of naval forces or bases, or by concealed BW or CW contamination of supplies of food or water. The highly concentrated nature of packaged BW slurries or powders makes BW agents a "natural" for large-scale atmospheric contamination, using submarines, subsurface or floating aerosol generators, torpedoes, or spray from missiles or aircraft.

The use of insect "vectors" is also an efficient, though limited, means of making a BW attack. Hungry mosquitoes, for example, may "home in" on humans from a considerable distance and transmit a disease with which they have previously been infected. This technique is a military adaptation of the means by which malaria and other tropical diseases are commonly transmitted.

9770.25. WEATHER AND GEOGRAPHIC FACTORS

The preferred, or maximum-surprise, BW/CW attack, therefore, employs an aerosol which travels with the wind for a considerable distance from the point of release. Such an aerosol will necessarily be subject to horizontal and vertical air currents. It will be useful to recognize that, in such case, the wind is actually an extension or an arm of the primary munition, just as the wind carries a ragweed-pollen aerosol from the weed to the allergic victim.

This basic dependence of offensive BW/CW on the relative wind for delivery of airborne agents is both a strength and a weakness. That is, the wind can be used to distribute and deliver the airborne BW/CW agents from air, surface, or subsurface munitions upwind of the target ship or force. On the other hand, if the true wind is strong and gusty, if the direction of the relative wind at the target is unpredictable, or if a position upwind of the target is inaccessible, then an attack will be unfavorable as far as weather considerations are concerned.

In addition to the wind itself, two other weather factors are of major importance in the effectiveness of BW/CW attacks. These are precipitation and the vertical temperature gradient in the lower atmosphere. Heavy and extended rain or snow will gradually wash the air clean of all suspended matter, but short, light precipitation is of little help in cleaning the air.

Normally, the air temperature decreases with an increase in altitude, as any gas cools when it expands, and the rate of decrease is known as the temperature gradient. When the temperature decreases 5.5° F. per 1000 feet altitude in dry air or 2.8° F. per 1000 feet in saturated air, the gradient is neutral and a neutral stability condition prevails. This condition is also described as the adiabatic lapse rate. Neutral stability is promoted by overcast skies and a sea-surface temperature equal to the air temperature. A visible indication of the neutral gradient is the tendency for the funnel smoke plume, when some distance from a ship, to stream at constant altitude without rising or falling.

When the temperature gradient is larger than the figures given above, the air becomes unstable. A sea surface warmer than the air, the presence of a cold air mass, and bright sunlight all contribute to atmospheric instability. Visual indications of this condition are good visibility and a tendency for funnel smoke to rise continuously (see figure 9770-1).

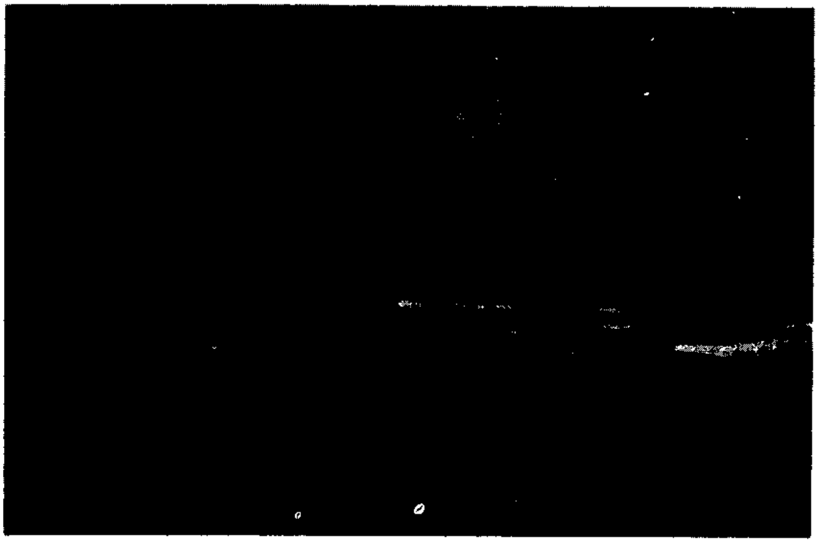

Figure 9770-1. Ship's smoke rising, an indication of a thermally unstable atmosphere.

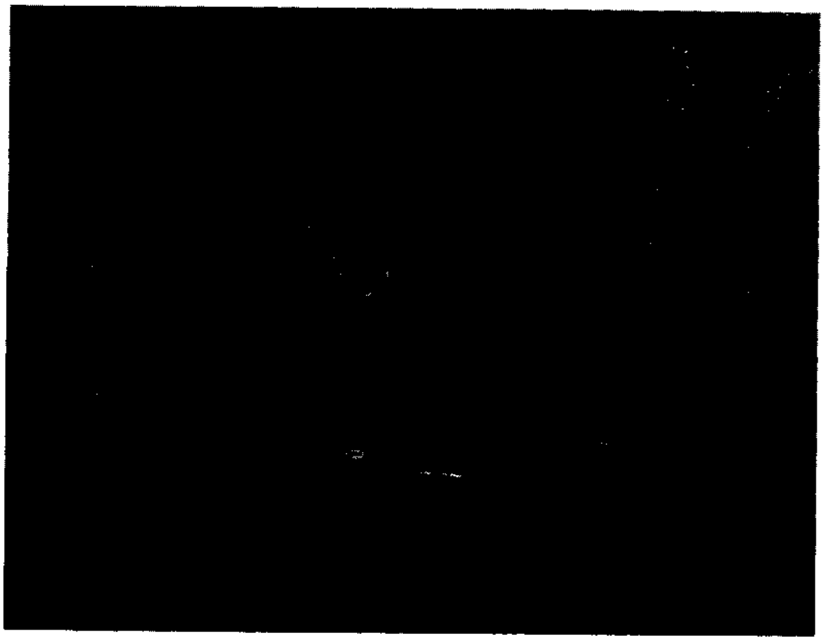

Figure 9770-2. Ship's smoke falling, an indication of a thermally stable atmosphere.

The atmosphere increases in stability as the temperature gradient decreases. In a temperature inversion (temperature increases with altitude) the atmosphere is extremely stable. It results from a sea surface which is cooler than the air. Mixing of the lower atmosphere in this condition is produced only by strong winds. A visible indication of a stable lower atmosphere is the tendency for funnel smoke to drift down to the sea surface with little vertical spread (see figure 9770-2).

A peculiar combination of temperature gradients occurs in certain areas at sea and ashore when the lower levels of the atmosphere undergo some mixing due to an unstable gradient or neutral-gradient-plus-wind condition, but are topped by an inversion "cap" or "lid". A visible clue to such an inversion is the rising of smoke or smog to a few hundred feet, then flattening out as if held down by an impenetrable ceiling.

The importance of atmospheric stability to BW/CW is evident when it is considered that the path followed by visible smoke represents closely the path which invisible airborne BW/CW agents would follow. With much vertical mixing of the air, such as results from thermal effects or strong winds, conditions are unfavorable (but not prohibitive) for BW/CW, because a large amount of agent is wasted by mixing into air layers above those occupied by the targets. Thus, abnormally large quantities of agent must be delivered and dispersed for a given task. On the other hand, in a stable temperature gradient with winds no more than moderate, or under an inversion cap, the use of BW/CW agents becomes much more efficient because more of the agent remains in the air layer occupied by the targets. When BW agents can be dispersed in a large and stable mass of moving air, very large areas of sea or land can be swept by the aerosol.

In addition to the effects of air movement and atmospheric stability on the use of biological and chemical warfare agents, there is the everpresent factor of direct temperature effects on the agents themselves. Although temperature affects the success or probability of BW and CW operations for different reasons, it is a major factor in both. In the case of BW, the facts are simple: cold greatly lengthens the life span of BW microbes, and in hot environments they live out their life spans more rapidly. Other things being equal, at low temperatures a given BW attack can be made with less agent, and a relatively large downwind coverage can be expected.

The connection between temperature and CW operations is less direct. However, the general effect of low temperature on CW is to lower the speed of evaporation of the liquid agents and to reduce the attainable concentrations of vapor. Thus, the airborne droplets of CW agents can travel with the wind longer before evaporating and, after falling or impacting on the ship, they will remain longer as a skin-contact hazard. Once CW liquids are deposited on ship surfaces, their speed of evaporation will depend on surface temperatures instead of air temperatures, and on wind speed. In general, therefore, lower temperatures favor CW attacks designed to reach the target with liquid particles, and higher temperatures favor CW vapor attacks. Further, warm weather can radically increase the effectiveness of liquid CW agents against topside personnel if it results in reduced body coverage by clothing.

Finally, there are weather factors which are important in BW operations only, because of the fact that BW agents are living organisms. These factors are relative humidity and sunlight. They are important because certain levels of either can render the atmosphere friendly or hostile to most BW organisms. Very low (20 to 25 percent or less), and very high (70 to 75 percent and above) relative humidities are favorable for long lifetimes of most airborne BW microbes. Intermediate relative humidities tend to promote a high death rate in BW organisms, but the use of a protective material may reduce such adverse effects.

The ultraviolet portion of direct sunlight is the most effective natural destroyer of all airborne microorganisms, including BW agents. Here, too, there has been some success in reducing the effectiveness of this natural enemy of BW by protecting the BW microbes with opaque materials, such as carbon black or ultraviolet-absorbing dyes. Nevertheless, it must be assumed that overcast days and, especially, the hours of darkness are the favorable periods for offensive BW operations. This means that a sunlight attack, if made, should reach the target within minutes, or at most within a hour or so, if excessive agent death is to be avoided. Conversely, when a BW attack is made at

Table 9770-1. Influence of some atmospheric conditions on BW/CW operations at sea.

Temperature Stability of the Lower Atmosphere and Frequently Associated Conditions	Wind Speeds (knots)		
	0-10	10-20	20 plus
Neutral Stability Air and sea surface temperatures are equal. Skies overcast.	Favorable	Indifferent	Unfavorable
Unstable Sea-surface temperature warmer than air, bright sunshine, cold air mass, good visibility, clouds aloft, gusty and variable winds.	Indifferent	Unfavorable	Very Unfavorable
Stable Sea-surface temperature colder than air, darkness, warm air mass, fog, high relative humidity, poor visibility.	Highly Favorable	Favorable	Unfavorable

dusk, at night, or during a heavy overcast, less loss of the agent takes place, and downwind effectiveness may continue for long distances, provided that there are no bright sunlight periods to which the microbes are exposed. It is interesting to note the unique adaptability of the arctic night and twilight to BW operations.

In summary, a full consideration of the influence of weather factors on BW/CW operations at sea is of particular importance to an efficient defense. Some of these factors and the approximate extent to which they favor or oppose BW and CW attack are given in Table 9770-1.

9770.26. THE DYNAMIC BEHAVIOR OF SMALL AIRBORNE PARTICLES; THEIR COLLISION WITH OBSTACLES

It has been pointed out that BW/CW agents most probably will be met in the form of very small airborne particles. The inhalation of such particles, as well as their deposition on the human body and on ship structures, follows certain laws which are fairly simple and understandable but not widely appreciated. Since an understanding of the effects of these laws will contribute to intelligent and efficient personnel protection in BW/CW, the general effects are outlined and a few numerical data given.

For particles to remain airborne for appreciable periods of time, their rates of fall in quiet air must be slow. The airborne period for slow-settling particles of a given size is greatly lengthened by vertical mixing or turbulence of the lower atmosphere. For example, although ragweed pollen particles settle in absolutely still air at a rate of three feet per minute, in accordance with their diameter of about 20 microns, ragweed allergy victims know that the pollen can be found at considerable distances from the growing weed, and at appreciable altitudes[7]. BW particles, which ideally are all less than two microns in diameter, show a still-air settling rate of 1/4 inch per minute or less. For practical purposes, their settling rate in moving air is zero. This is because moving air is naturally turbulent, and turbulence results in mixing. For particles having a very small settling rate in still air, the mixing effect of turbulent air neutralizes gravitational settling.

For air-suspended particles to be militarily effective against personnel, they must not only remain airborne long enough to reach the targets, but they must also inpact on the ship or personnel, or be inhaled. It is noteworthy that these two factors, inhalation of small particles and impaction of small particles on the body, are to some extent contradictory for a given particle size. For example, particles under five microns, which can remain airborne for very long periods, are readily inhalable but show negligible impaction on the smoothly clothed human body. On the other hand, the relatively large particles (about 75 microns and larger) which impact readily on the smoothly clothed human body can remain airborne in nonturbulent air for less than a minute, and such particles are not readily inhalable.

However, most of the practical methods for generating air suspensions of particles yield a considerable range of sizes in addition to the size desired for a particular BW/CW mission and agent. The largest particles may settle out close to the generator or point of origin, and as the particles travel downwind, the average size becomes smaller and the settling and impaction characteristics more uniform.

Table 9770-2 summarizes some characteristics of BW/CW and other aerosols. All of the characteristics shown are closely related to the tendency of the various sizes to settle or impact on various surfaces. Table 9770-3 shows the impaction efficiency of three sizes of airborne particles, moving at three different wind speeds, on cylindrical objects with diameters of 0.002, 0.1, 1.0, and 10 inches. These cylinder diameters are roughly typical of a human hair, a small wire, a stanchion or cable, and the human body considered as a ten-inch cylinder. The data of Table 3 on the impaction of small particles on the human body, which is considered as a smoothly clothed ten-inch cylinder, are not entirely realistic in that they do not take into account the added and often highly efficient collection capability of the fiber fuzz which projects from all woven fabrics, and of the fine hair which covers all of the body except palms and soles. It is not practical at present to calculate the collection efficiency of fine hairs and fibers which are attached to large cylinders, but their additional effect should be noted.[8]

[7]One source reports that pollens have been collected at heights of 4000 feet above ground level, as well as at sea level in the mid-Atlantic Ocean.

[8]Water droplets in fog or cloud, which have negligible tendency to settle or impinge on large slow-moving objects, are noticeably collected by spiderweb, by the nap of wool clothing, and by the hair of the eyebrows, etc. Spiderweb is, in fact, sometimes used as a collecting device for fine airborne particles. For the same reason, antenna wires, signal halliards, and the smaller sizes of manila and wire rope collect appreciably more water droplets (per square inch of surface) from fog and mist than do stacks, masts, and other large surfaces of the ship. The same principle is demonstrated in the icing of ship and aircraft surfaces.

Table 9770-2.

	Size (Microns)							
	0.1	1	5	20	60	100	400	1000
Typical Particles	← Tobacco Smoke →		← Fog →		← Mist →	← Drizzle →	← Rain →	
			← Pollen →					
Atmospheric Dust	← Permanent → Atmospheric Impurities		← Temporary Atmospheric → Impurities			← Heavy Industrial → Dust		
						← Nuclear Fallout → Reaching Surface Within 24 Hours		
Settling Speed in Still Air (fpm)	0.00007	0.007	0.15	2.4	22	60	500	800
Behavior in Respiratory System	Inhaled and Exhaled	Inhaled and Retained in Lungs	Inhaled and Retained in Nose			Not Inhaled		
Favorable BW Sizes (Inhalation Only)	←	→	→					
Favorable CW Sizes (For Inhalation)	←	→	→	→				
Favorable BW/CW Sizes (For Impaction on Body and Clothes at 10 kt)						←	→	→
Favorable BW/CW Sizes (For Impaction on Body and Clothes at 30 kt)					←	→	→	→

Table 9770-2. BW/CW and other aerosols: variation of aerosol particle size with aerosol types, properties and uses.

Table 9770.3 Approximate impaction efficiency of small particles on cylinders at different wind speeds.

Particle Diameter, d (microns)	Wind Speed, S (knots)	Cylinder Diameter, D. (inches)	Impaction Efficiency, E (percent)
5	1	0.002	15
		0.1	0
		1	0
		10	0
5	10	0.002	75
		0.1	0
		1	0
		10	0
5	30	0.002	100
		0.1	15
		1	0
		10	0
50	1	0.002	100
		0.1	50
		1	0
		10	0
50	10	0.002	100
		0.1	100
		1	50
		10	0
50	30	0.002	100
		0.1	100
		1	75
		10	15
250	1	0.002	100
		0.1	100
		1	75
		10	15
250	10	0.002	100
		0.1	100
		1	100
		10	75
250	30	0.002	100
		0.1	100
		1	100
		10	100

9770.27 PENETRATION OF AEROSOLS AND VAPORS INTO SHIPS; VENTILATION CONTROL

1. Principles and Basic Information.

The importance of the watertight integrity of ships is well-known to every Navy man. Combatant ships–and to lesser degrees, auxiliaries–are subdivided and enclosed with watertight decks, bulkheads, doors, hatches, and interior ventilation valves or closures[9] to prevent progressive flooding of the ship by water which has entered a battle-damaged compartment. Many compartments well above the normal waterline are also required to be watertight in order to provide reserve buoyancy. A less-known fact is that all Navy ships, with exception of submarines, are continuously ventilated with weather air to some degree, under all material conditions and degrees of closure presently available. Theory and practical tests show that there is no "gastight envelope" on any type of ship, with the exception of submerged submarines.

The normal ventilation rates, expressed as rates of change (or "R of C") for some typical spaces on a **Worcester** class cruiser are shown below:

Spaces	R of C (Minutes per Change)
Galley	0.5
Radio, radar, sonar, laundry	1
Washroom, head, shower	2
Messing, berthing	3-3.5
Magazine, shop, wardroom	4
Windlass	15

An average rate of change for spaces in which little heat is generated is three minutes per change. In air-conditioned spaces, the corresponding R of C is approximately 20 to 30 minutes per change, although air within the air-conditioned compartment is recirculated over cooling coils at a much higher rate.

In material condition Zebra, with X-ray, Yoke, and Circle William fittings closed, all nonessential fans and blowers are secured, and the ship is expected to be in a satisfactory condition of watertight integrity. However, it is not genuinely airtight. This is particularly true above the damage-control deck or armor deck, and it also applies to a lesser degree within "armored box." Even compartments which pass a "pressure test" are only shown by the test to have air leakage of less than a specified amount.[10] In fact, the pressure test recognizes and accepts the principle that air leaks are difficult to eliminate, and requires only that the leakage shall not exceed a certain figure which is adequate to prevent progressive serious flooding.

A typical standard pressure test requirement (chapter 9880) is that a compartment pressurized to 4 ounces per square inch shall not show a pressure drop of more than 2 ounces per square inch in ten minutes. This pressure drop corresponds to a leakage of 1 cfm for a 1200-cubic-foot compartment, or an R of C of 1200 minutes per change and demonstrates that compartments, including doors and hatches, can be constructed to very tight standards. In practice, however, tests on operating ships show overall leak rates far in excess of that suggested by pressure tests on new compartments.

What are the sources of leaks in a well "buttoned-up" ship? In the first place, spaces on or above the armor deck or damage-control deck may be served by ventilation intake and exhaust ducts which have no closures at any point in the system. Natural ventilation through these systems, during typical cruising conditions, is estimated to average about five percent of the powered ventilation rate. Secondly, there are structural leaks through defective welds, through aluminum-to-steel joints, through glands and stuff-

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[9]Naval Ships Technical Manual, Chapter 9380.

[10]Naval Ship Technical Manual, Chapters 9290 and 9880; General Specifications for the Ships of the U.S. Navy S29-8-d through g.

ing boxes, etc. Thirdly, there are the bypass leaks through doors, hatches, portholes and closures. These can be made very slight when gaskets and knife edges are in top condition and tightening is done correctly. However, where the mating surfaces are worn or warped, where rubber gaskets are cut, marred, hardened, or pointed, and where closing pressures are uneven, leaks can become surprisingly large. Even under conditions of excellent maintenance[11] and correct operation, the existing leaks are usually increased by the "working" of the ship in a seaway. Fourthly, very large air leaks can result from breaching the airtight and watertight integrity of the ship's Zebra material condition, or by unauthorized opening of doors, etc. The total effect of these various leaks is that all parts of a ship are ventilated to a greater or less degree, although this ventilation often is unintentional and unsuspected. In general, compartments remote from the weather have less natural ventilation than those close to the weather, but this is not a fixed rule.

The force that pushes air into the ship through the many unrecognized and difficult-to-detect leaks of various kinds is the relative wind. The ram pressure, or velocity pressure, against all parts of the ship facing the relative wind can be calculated by the formulas:

$$P\text{, inches of water} = \frac{(\text{relative wind speed, knots})^2}{1570}$$

$$P\text{, pounds per square foot} = \frac{(\text{relative wind speed, knots})^2}{300}$$

$$P\text{, pounds per square inch} = \frac{(\text{relative wind speed, knots})^2}{43400}$$

$$P\text{, ounces per square inch} = \frac{(\text{relative wind speed, knots})^2}{2700}$$

They yield the data of Table 9770-4. The ram air pressure can be considered as acting on all the windward surfaces of the ship. Its effect is increased by a smaller and negative pressure, or suction, also resulting from the wind, which acts on the leeward surfaces of the ship.

Table 9770-4. Velocity air pressure resulting from relative wind.

Relative Wind Speed (knots)	Ram, or Velocity, Air Pressure Inches of Water	Pounds per sq ft.	Pounds per sq in.	Ounces per sq in.
1	0.00064	0.0033	0.000023	0.00037
2	0.0025	0.013	0.000092	0.0015
5	0.016	0.083	0.00058	0.0092
10	0.064	0.33	0.0023	0.037
20	0.25	1.33	0.0092	0.15
30	0.57	2.98	0.021	0.33
40	1.02	5.26	0.036	0.58
50	1.60	8.30	0.058	0.92
56	2.00	10.4	0.072	1.16
60	2.30	12.0	0.083	1.33
80	4.08	21.2	0.15	2.36
100	6.38	33.2	0.23	3.68

The above discussion makes clear that a buttoned-up ship at sea, where it is constantly exposed to the ram pressure of the relative wind, will be ventilated continuously through air leaks of various kinds. The total effect of such air leaks on the ship's watertight integrity may be insignificant, but it poses a serious problem with regard to the ingress of BW/CW agents.

2. Buildup and Decay of Airborne BW/CW Contamination in a Ship Compartment

To help in appreciating the rate at which the air in a ship compartment is progressively contaminated by the intake of outside air carrying a BW/CW contaminant, some ventilation theory will be useful. The rate of increase, or buildup, of outside contamination in a ventilated compartment follows an exponential growth rule. The concentration of contaminant in the air increases very rapidly at first, and then more slowly as it approaches the concentration in the outside air.

[11]Naval Ships Technical Manual, Chapter 9160.

As soon as the ship passes out of the zone of BW/CW contaminated air, the concentration of contaminant in the compartment air begins to decrease or "decay." The rate of decay follows a mathematical law similar to that for the buildup: That is, it is fastest at first but gradually decreases as the contaminant concentration in the compartment approaches zero. This decay law is mathematically similar to that for radioactive decay.

The above rules are illustrated by the curves of figure 9770-3. The line OB shows the rate of growth, or buildup, of the contamination concentration in a compartment from the instant the ship enters the zone of contaminated air. After a single air change, the concentration inside the compartment is 0.63 or 63 percent of that topside; after three air changes it is 95 percent of the topside concentration; and after six air changes the interior concentration is 99.8 percent. The falling lines trace the interior concentration during the decay phase for each of five different topside exposures. Each decay curve begins at the point where the ship emerges from contaminated air, at which time only the topside concentration drops from fully contaminated air to zero, or fully clean air. For example, the curve OD shows the interior concentration rising, from zero to 0.5 of the topside figure, during 0.7 air change. At this point the ship steams into clean air, and the interior concentration gradually dies away or decays, rapidly at first, and then more slowly toward and beyond the point H, eventually dropping to zero. If the ship passes out of the contaminated zone after different numbers of air changes, the concentration buildup/decay sequences are illustrated by the typical curves OC/CG, OE/EI, and OF/FJ. For the design standard rate of ventilation, the number of air changes in any given time is found as follows: divide the time by the rate of change, R of C, taken from the ship ventilation plans.

Similarly, the curve BK of Figure 9770-3 illustrates the rate of decay of contaminant concentration, when the ship leaves the contamination zone and enters pure air, at any time after six or more air changes; i.e., when the compartment air is essentially 100 percent contaminated. To show the displacement of 100 percent contaminated air by clean air, the curve BK is drawn on a new scale, starting with zero. After a single air change the concentration drops to 37 percent; after three air changes, to five percent; and after six air changes, to about 0.2 percent.

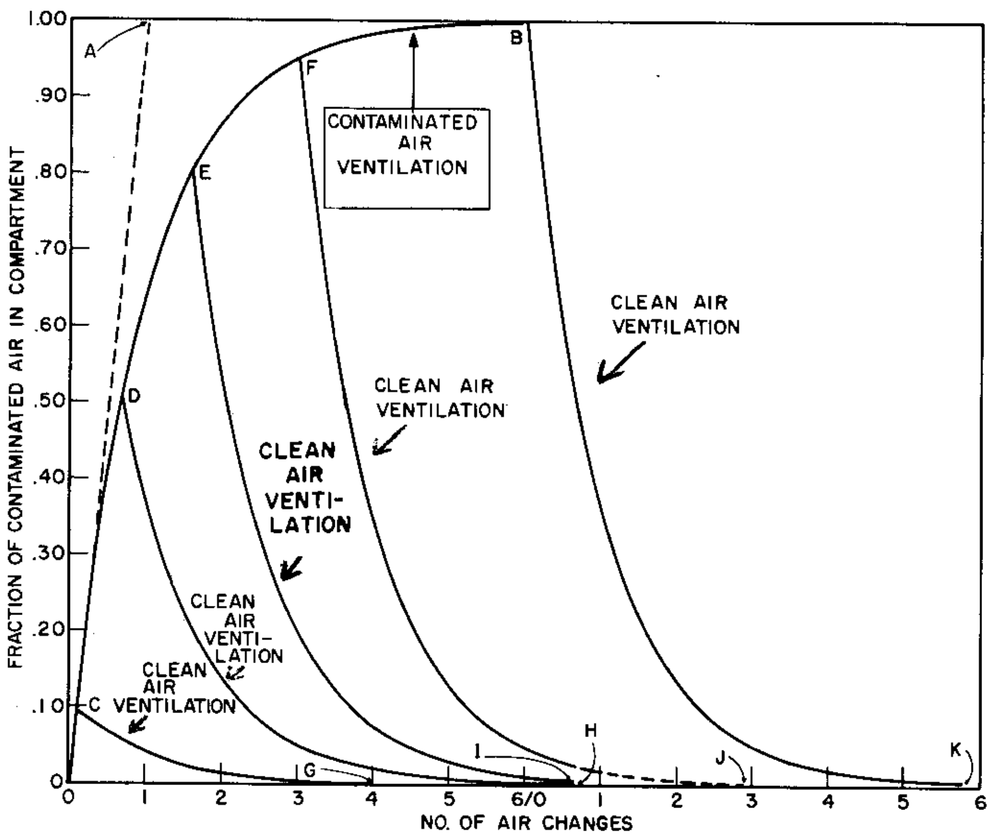

Figure 9770-3. Variations in the fraction of contaminated air in a ship compartment ventilated at a constant rate, first by contaminated air, then by clean air.

Only if the incoming air could displace that in the compartment like a piston, with no mixing, would all the compartment air be displaced in one air change. Under this unrealistic condition the contamination concentration would follow the straight dotted line OA.

Although figure 9770-3 shows that over 99 percent of the compartment air is displaced after six air changes, more complete displacement is desirable. Figure 9770-4, in a semilogarithmic plot, shows the effect of up to 11.5 air changes, a 99.999-percent displacement. This type of plot has the dual effect of presenting all the curves of figure 9770-4 on a single straight line, and of providing room for more data in a limited space.

It should be noted that all of the curves of figure 9770-3 and the processes they represent are of the "exponential" or "compound-interest" type. The rate of an exponential growth or decay is, at every instant, proportional to the size of the thing growing or decaying. The buildup curve OB of figure 9770-3 then actually represents the loss of clean air from the compartment. When the clean-air concentration is high, at the instant the ship enters contaminated air, the rate of change of concentration is at a maximum. When little clean air is left, after several air changes, the interior concentration changes very slowly.

3. **Ventilation Rates in a Closed-Down Ship.**

Very little is known of the exact ventilation rates of individual compartments in a buttoned-up ship at sea. However, it is reasonable to assume that a destroyer at sea, in a relative wind of 30 knots (a 20-knot speed plus a 10-knot head wind), will experience a total ventilation of several thousand cubic feet per minute through its occupied compartments under closed-down conditions and with all powered ventilation secured. Assuming a ventilation rate of 4000 cfm, and a ventilated volume of 200,000 cubic feet for a DD, a Rate of Change of 200,000/4,000, or 50 minutes per change, results. This is an approximate figure; faster rates would occur in some compartments, and slower ones in others. Somewhat smaller averages could be expected for larger ships, but these would also have even wider ranges in ventilation rates. Auxiliary types, because of lesser compartmentation and closure, are believed to have ventilation leak rates considerably higher than a DD.

It is instructive to consider the size of a single opening, equivalent to a given total air leak, when it is exposed to various relative wind speeds. Sample data[12] of this type following Table 9770-5. As a rule of thumb, the number of cubic feet of air per second leaking through a single open area of one square foot is numerically equal to the relative wind speed in knots.

4. **The Dosage Equivalence Rule**

For the purpose of improving BW/CW protection, the specific rate of ventilation leakage need not always be known. The fact that significant leaks do exist, and can be demonstrated, is enough. This is evident because it can be shown that men in any compartment which is ventilated at an unchanging rate **can receive the same BW/CW aerosol or vapor dosage as topside personnel,** regardless of the compartment ventilation rate. The explanation is that the dosage of the topside man results from exposure to a high concentration for a relatively short time, and that of the below-decks man comes from exposure to a lower concentration for a longer time.

This can also be seen from figure 9770-5, in which the vertical axis represents concentration and the horizontal axis indicates air changes or time. The topside dosage, or concentration x time (i.e., Ct), is given by the area of the rectangle OABD, which is seen to be 3.0. That is, at point 0, the ship enters the contaminated air, and the topside concentration rises instantaneously to the maximum value. At the time represented by three air changes, the ship leaves contaminated air and the topside concentration drops to zero. Inside the ship, the concentration rises gradually and only reaches C after three air changes. At this time the concentration begins to decrease. Corresponding to the topside case, the dosage is represented by an area, the sum of the area OCD (buildup phase dosage) and the area DCE (decay phase dosage). The buildup-phase area, or dosage, is found to be 2.05; the decay-phase dosage is 0.95. The total, as predicted, is 3.0.

Table 9770-5. Air flow into ship through openings vs. relative wind speed.

Relative Wind Speed (kt)	Air Flow Through Total Open Area of 1 sq ft (cfm)	Total Open Area per 1000 cfm Leak (sq ft)	Diameter of Single Round Opening per 1000 cfm Leak (in.)
1	61	16.0	55
2	120	8.2	39
5	305	3.3	25
10	610	1.6	17
20	1200	0.82	12
30	1800	0.55	10
40	2400	0.41	8.7
50	3000	0.33	7.8
60	3600	0.27	7.1
80	4900	0.21	6.1
100	6100	0.16	5.5

[12]These are all calculated from a standard orifice formula, using a discharge coefficient of 0.6.

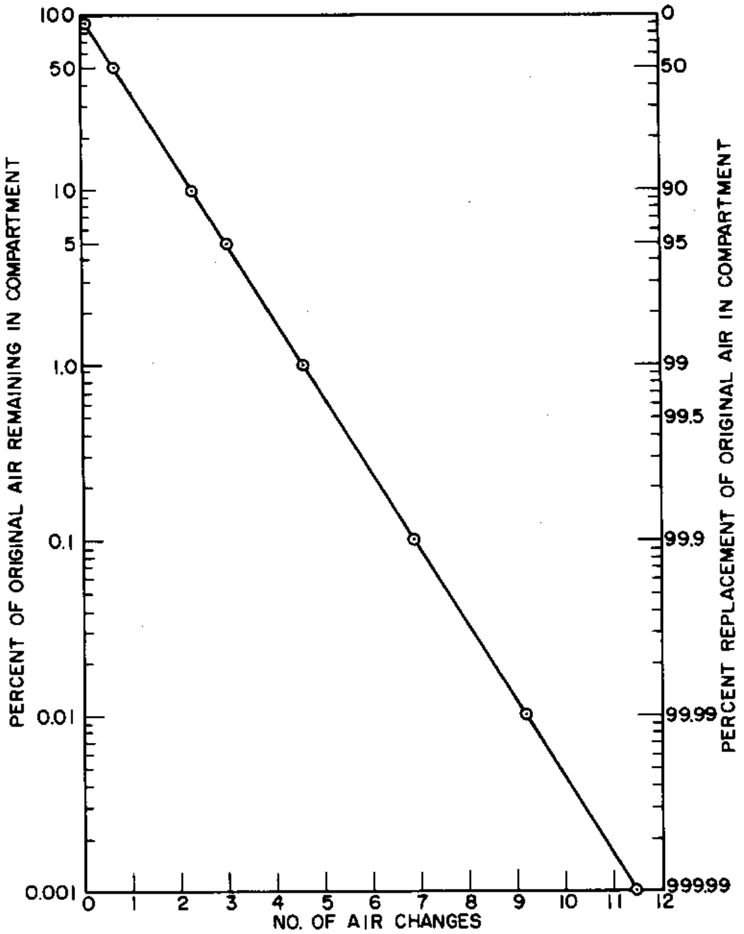

Figure 9770-4. Effect of air changes on retention and removal of original air in a compartment.

The correctness of the Dosage Equivalence Rule has been demonstrated on a Navy ship using a fog-oil aerosol to simulate a BW attack. However, if significant amounts of BW/CW agents are removed from the compartment air by means other than ventilation, the rule no longer applies exactly. Some nonventilation means of agent removal are: absorption of CW vapors in paint, clothing, blankets, and the impaction of BW/CW aerosols on the blowers and filters of recirculating air-conditioning systems. The exact degree to which these auxiliary agent-removal effects operate in many practical situations is at present unknown. It is clear, however, that the nonventilation effects will increase in importance as removal by ventilation becomes very slow and compartment exposures very long (i.e., for a tightly closed ship). At present, and until sufficient operating data are obtained, it is assumed that the Dosage Equivalence Rule is essentially correct under practical conditions.

5. **Reduction of Air Leaks In Ships**

The unfavorable effect of air leakage on a ship's BW/CW defense capability is evident. How then can the leakage be reduced to an acceptable minimum? Assuming that closure discipline is made 100 percent effective by thorough indoctrination and inspection, and that all of the ship's doors, hatches, stuffing boxes and other closures with their gaskets and packings have been carefully and expertly maintained or restored to their as-new condition, actual leakage rates should now be measured.

The standard pressure, or static, test for leakage is preferred for very tight compartments, although it must be applied only to compartments for which the test is specifically authorized. These compartments are listed in the ship's Schedule of Watertight Integrity Tests and Inspections, and they are equipped with air-testing fittings. Provided that the compartment pressurization for the test is only a few ounces above atmospheric pressure, the following formulas are used to calculate the leakage rate:

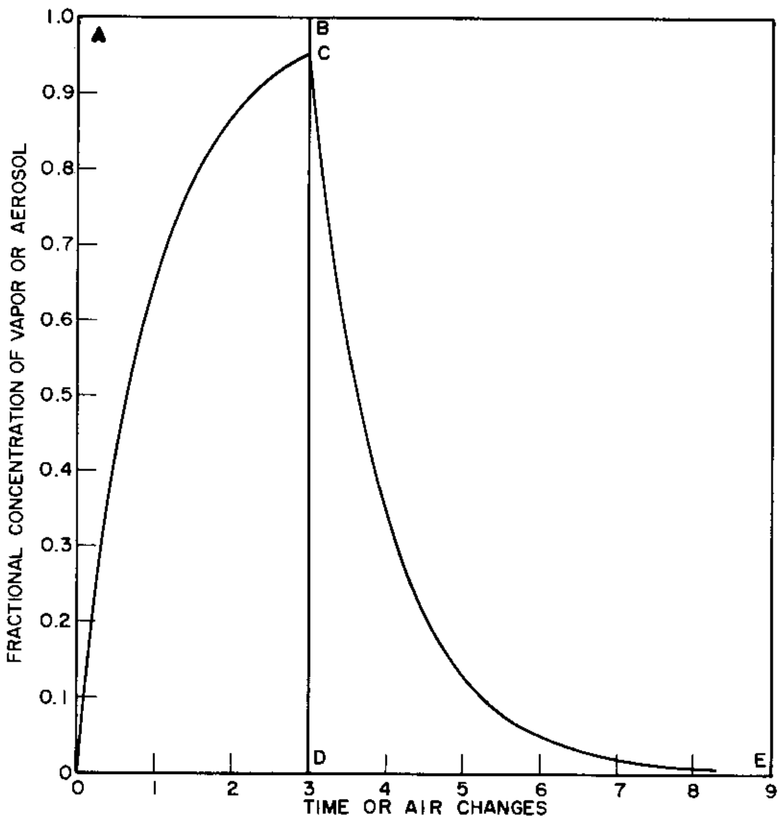

Figure 9770-5. Equivalence of interior and topside dosages.

$$\text{Compartment leakage, cfm} = \frac{\text{Compartment Volume, cu. ft}}{\text{Time for Pressure Drop, min}} \times \frac{\text{Pressure Drop, oz, per sq, in}}{240}$$

For compartments with high leakage rates, a dynamic test is required. This test is carried out by carefully closing, using normal procedures, all means of air supply or exhaust except one supply duct served by a standard axial-flow blower, which is used to conduct the pressure test on the compartments(s) served by the blower. The single test instrument required is an air-pressure gage which functions over a range of 0 to 5 inches of water (0 to 0.4 inches of mercury). This can be a glass or plastic U-tube, a slant gage, or an aneroid barometer with divisions of 0.02 inches of mercury. If a U-tube or slant gage is used, a rubber or plastic tube must be connected to one arm and led either to the outside atmosphere (preferred method) or to a bottle or a rigid and airtight metal container of about one quart capacity (second-choice method). Now, the supply blower is turned on and the rise in air pressure in the compartment noted. The higher the pressure reached, the tighter the compartment.

Reference to a set of Navy Standard vaneaxial[13] fan characteristic curves (figure 9770-6), and use of the curve for the particular blower used will indicate the air flow which is maintaining the observed pressure rise in the compartment(s). This flow is also the leakage flow out of the space being tested. For example, in a particular situation a Type A1 fan raises the compartment pressure to 2.5 inches. The A1 fan curve shows the fan to be delivering 1150 cfm. If the pressure rise had been only 1.5 inches, the fan curve shows the flow to be 1390 cfm. Similarly, a pressure of 4.0 inches from an A10 fan indicates a flow of 9000 cfm, in and out of the section of the ship supplied by the fan. The air flows observed can be converted directly to Rates of Change, in minutes per air change, by dividing them into the measured volume of the space under test. In case the pressure rises beyond the highest point of the fan curve, one of two steps can be taken: (a) the fan can be used to supply a larger section of the ship, thus adding more leaks, or (b) a standard leak can be used to bleed off a known flow of air and reduce the pressure to the range covered by the fan curve. The standard leak must be a smooth, round, sharp-edged hole in a thin plate which can be bolted tightly over a porthole, the exhaust duct opening, etc.

Figure 9770-7 is a nomograph which will assist both in predicting the size of the standard-leak orifice required and in giving the flow through the orifice at the pressure reached. The flow through the orifice is subtracted from the total flow indicated by the fan curve; the difference is the true leakage flow out of the compartment(s). It may be desirable to prepare an orifice plate having a number of holes of different sizes. The hole having the desired area or diameter can be selected, and the other holes closed with tapered softwood plugs.

If, as will often be the case, the Rate of Change shows an undesirably high leakage, a leak search should be made. A number of methods of leak detection are discussed in this manual, [14] and others will suggest themselves to an alert crew. Most leaks in pressurized compartments can be heard directly or through a tube or hose used to connect the leakage area with the ear. Leaks can also be detected visually by the bubbles produced when the leakage area is painted with soap and water on the low-pressure side. Means of correcting leaks will vary with the nature of the leak. For example, where ventilation-duct closures are not supplied, snug-fitting painted-canvas boots will be useful. Leaks at welds are better corrected by applying a flexible sealing compound on the high-pressure side than by rewelding.

As leaks are reduced in size and number, smaller blowers and/or larger test spaces will be required in order to remain on the blower curves. Caution is required in operating blowers for extended periods at flows much below normal; overheating may result. However, a minute will ordinarily suffice for accurate observation of a pressure rise; the blower can then be shut off or the compartment opened until the next test.

It should be noted that although the pressures produced by ventilation fans are comparatively low, the total force which can be exerted on a large area may be unexpectedly large. For example, a fan pressure of 5 inches of water is equivalent to 25 lb. per sq. ft.; this will result in a force of 300 lb. on a door having an area of 12 sq. ft.

It is recommended that tests occasionally be duplicated with another blower as a check for accuracy. An exhaust blower will be as satisfactory as a supply blower, except that pressure reductions will be observed instead of pressure rises.

While the above test procedure will not always give leak rates precisely equal to those due to wind pressure, since wind-induced leaks may be different for different wind directions, the method is adequate. The fact that it may over-indicate the ship's leak rate will be roughly compensated by the increase in the leak rate caused by the flexing or "working" of the ship in a seaway. In fact, it is recommended that the leak test occasionally be conducted, as a matter of experience, with the ship both moored and underway. In the latter situation, the relative wind should not exceed ten knots, in order to avoid the complicating effects of wind-induced leaks on the test.

To aid in evaluating the test results, the following formula may be used. This will enable the results of all tests to be compared at the reference pressure of one inch

[13]It is assumed here that the blower fan involved is of the vaneaxial type. Identical procedures apply for Navy standard centrifugal blowers, using the appropriate characteristic curves.

[14]Naval Ships Technical Manual, Chapter 9880. See also General Specification for Ships of the U.S. Navy S29-B-d.

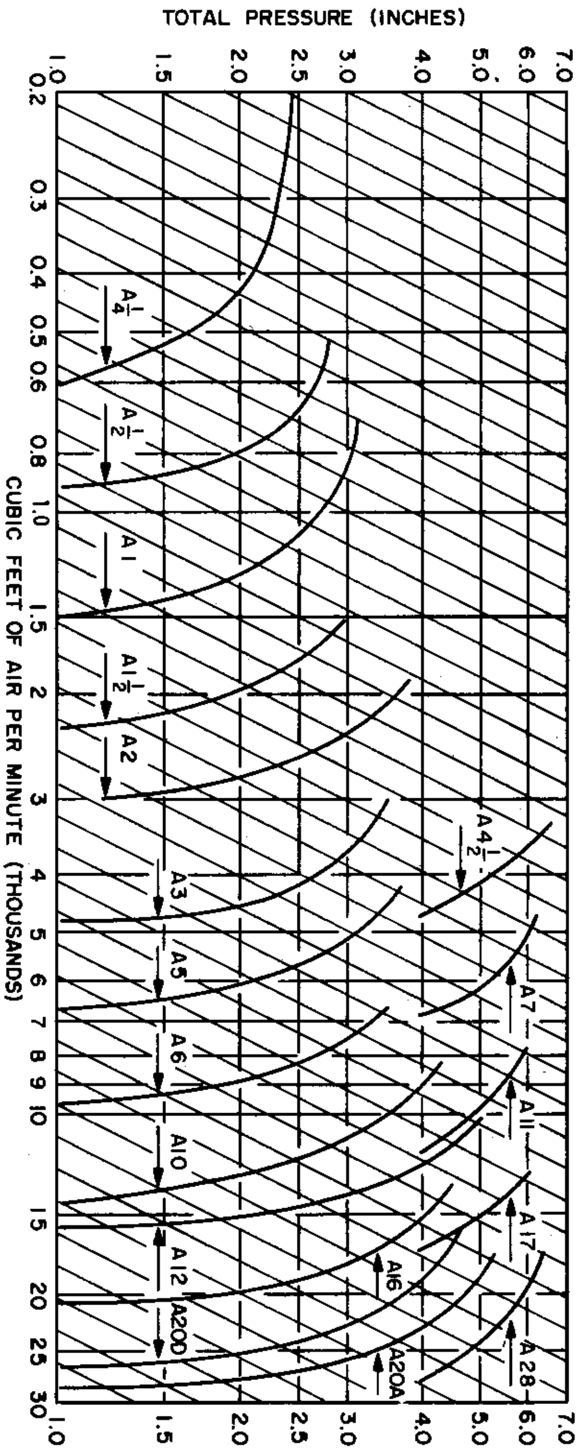

Figure 9770-6. Navy standard vaneaxial fans, selector chart. The letter-number combinations appearing on the graph (A1, A2, etc.) are fan sizes.

of water; i.e., the pressure due to a relative wind of 40 knots.

$L_1 = Lp\,(1/P)^2$

Where L_1 = leakage in cfm at one-inch pressure
Lp = leakage in cfm at actual pressure differential P
P = inches of water

Some noncombatant ships may be unable to follow the leak measurement procedures given above. Topside tightness can be improved, however, by attention to three principles: (1) many air leaks in or out of ships occurs at doors, hatches, ventilation openings, etc.; (2) If it is feasible to pressurize a compartment through the ventilation system, leaks can be located by the ear test or the bubble test; (3) Whether detected or located, or not, air leakage can be reduced by careful maintenance and corrective measures applied at the point of probable leakage.

6. **Summary of Ventilation Control in BW/CW**

1. The most favorable ventilation control in a BW/CW situation is ventilation at the lowest practical rate while in the contaminated zone (interior concentration buildup phase), followed by the highest practical rate in clean air (interior concentration decay phase). If the ship is in the contaminated zone for six or more air changes, the compartment dosage will approach the topside dosage, but cannot exceed it.
NAVSHIPS 250-000, Chapter 9770

2. The least favorable ventilation management is ventilation at a high rate while in the contaminated zone, followed by a low rate as the ship enters clean air. Under these conditions, the compartment dosage may reach several times the topside dosage.

3. Situations 1 and 2 are considered possible but difficult to achieve in practice because they presume: (a) exact knowledge of the time of entering and leaving the contaminated zone, or (b) the chance increase or decrease of ventilation rate just when the ship leaves the contaminated zone.

4. A more probable situation is that the ship transits a contaminated zone with no knowledge of the presence of a contaminant. Assuming an unchanging ventilation rate, compartment dosages will be approximately equal to topside dosages.

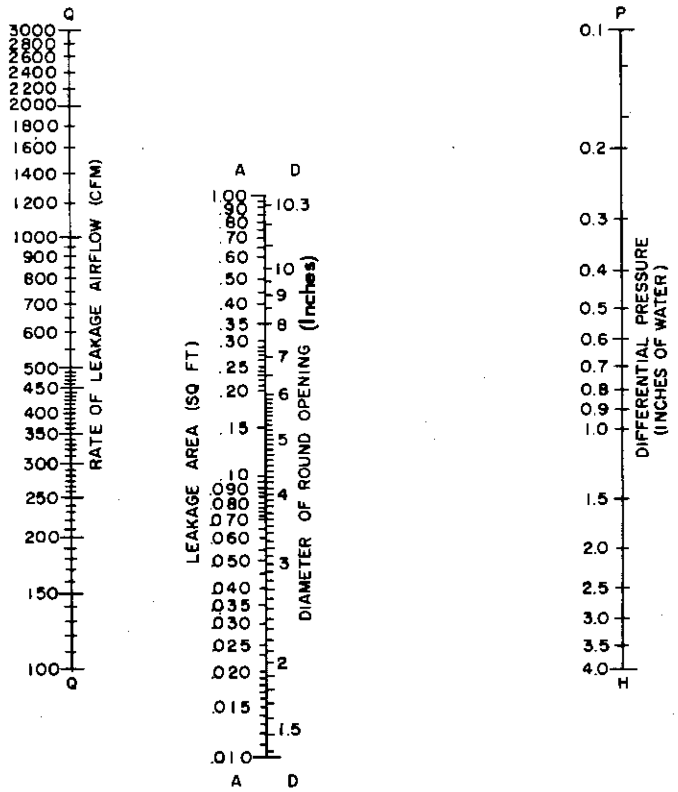

Figure 9770-7. Nomograph for determining leakage area and diameter of round opening corresponding to a given differential pressure and leakage airflow. Connect the desired points on lines Q and P with a straightedge. It will cross line D at the required diameter and area.

5. It is believed that the most probable situation in which a ship will be exposed to BW/CW-contaminated air is that thorough indoctrination, full intelligence data, and alert observation will, even in the case of BW, result in some clues as to the existence of contaminated zones. These clues, considered together with the other elements of the tactical situation, can be applied to best advantage by minimizing ventilation rates during the period of suspected exposure to contaminated air, and subsequently maximizing ventilation rates for a period of 6 to 12 air changes in clean air.

6. Part of the doctrine referred to above, in the absence of more exact and specific information, will be related to the effect of sunlight on airborne microbes. That is, in areas of possible or probable BW exposure, ventilation should be maintained at a minimum during the hours of late afternoon, dusk, darkness, and for an hour or two after sunrise, since this period is favorable to long lifetimes of airborne microbes. Similarly, if ventilation rates must be increased at some time during the 24 hours, it is believed that the safest period, from the BW point of view, is from midmorning to midafternoon.

SECTION II. BW/CW COUNTERMEASURES AT SEA

Part 1. Introduction

9770.41.

The efficiency of BW/CW countermeasures depends on the promptness with which they are started. In fact, the period between indications of impending BW/CW attack and serious—perhaps lethal—exposure of topside personnel may be too short to allow any protective actions to be started. Since the period after an attack in which useful self aid or first aid can be started also is very short, the advantages of preattack protection of topside personnel are obvious. To prevent advance protection from seriously limiting personnel performance, adequate indoctrination and regular, realistic drills or exercises are needed. The U.S. Army has found that "green" personnel are at first considerably handicapped in combat operations while wearing protective clothing and masks. As personnel gain experience in performing combat duties while wearing protective clothing and masks, the handicaps are reduced.

Measures which protect the ship structure itself from contamination also are easier, simpler, and quicker than decontamination after an attack. Ship-protective actions are of two kinds: use of the washdown system, which protects the exterior surfaces with a moving film or shield of water, and use of the system of closures, regular and jury-rigged, which can minimize penetration of aerosols and gases into the ship. In these actions, as in those which are directly personnel-protective, promptness of execution is the major factor in effectiveness. Specifically, drops and sprays of CW agents cannot lodge on or contaminate a ship which is pre-wet or covered with the washdown shield; they are flushed harmlessly into the sea. In contrast, when deposited on dry surfaces of the ship, the same oily drops or sprays of CW agents are only partially removed by washdown; much of the remainder soaks into the paint and is removed only gradually by evaporation. The same principle of prompt action governs the use of ship-closure devices. If the ship is not already closed down tightly when a BW/CW attack arrives, the advantages of tight closure during or after an attack are unpredictable. Postattack closure for an extended period may even increase the severity of exposures or dosages for below-decks personnel.

It is important to recognize that the washdown shield is the flowing film of water on ship surfaces. Where the film is lacking there is no shield. While the washdown spray is in the air it has little or no shielding effect against aerosols or spray.

Part 2. The shipboard BW/CW defense system

9770-51.

We define "system" to be a planned organization of people, devices, machines, etc., each designed or trained to perform a particular job, working together in an orderly and efficient way to perform a major task. The BW/CW defense of a ship or group of ships is such a system. It will function most smoothly and effectively when every officer and enlisted man understands not only his individual duties but also the makeup and operation of the system as a whole.

Figure 9770-8 shows the organization and main functions of the shipboard BW/CW defense system. The order from top to bottom is also the normal order in which the parts of the system will act. For example, self aid usually will not be carried out until the need for it is shown by some means of identification-detection. The means of detection, however, need not be a kit or automatic alarm. Instead, symptoms known to result only from nerve-agent attack are a means of identification-detection. As a further example, individual and collective protection actions should precede positive warning-detection. The general responsibilities for the various actions are outlined in the right-hand margin, but the BW/CW Defense Bill and other standing orders should be consulted for exact and detailed assignment of duties.

It is a useful "paper" exercise for responsible personnel to expand each box of figure 9770-8 into its own sequence of actions and responsibilities. This is, however, preliminary to and not a replacement for the carrying out of complete and specific drills and exercises with all possible realism.

Part 3. Equipment, Facilities, and Supplies for BW/CW Defense at Sea

9770-61.

The principal shipboard items provided for NBC protection aboard ship are listed below. Medical supplies are not included. All clothing, footwear, and handwear items are under the cognizance of the Bureau of Supplies and Accounts.

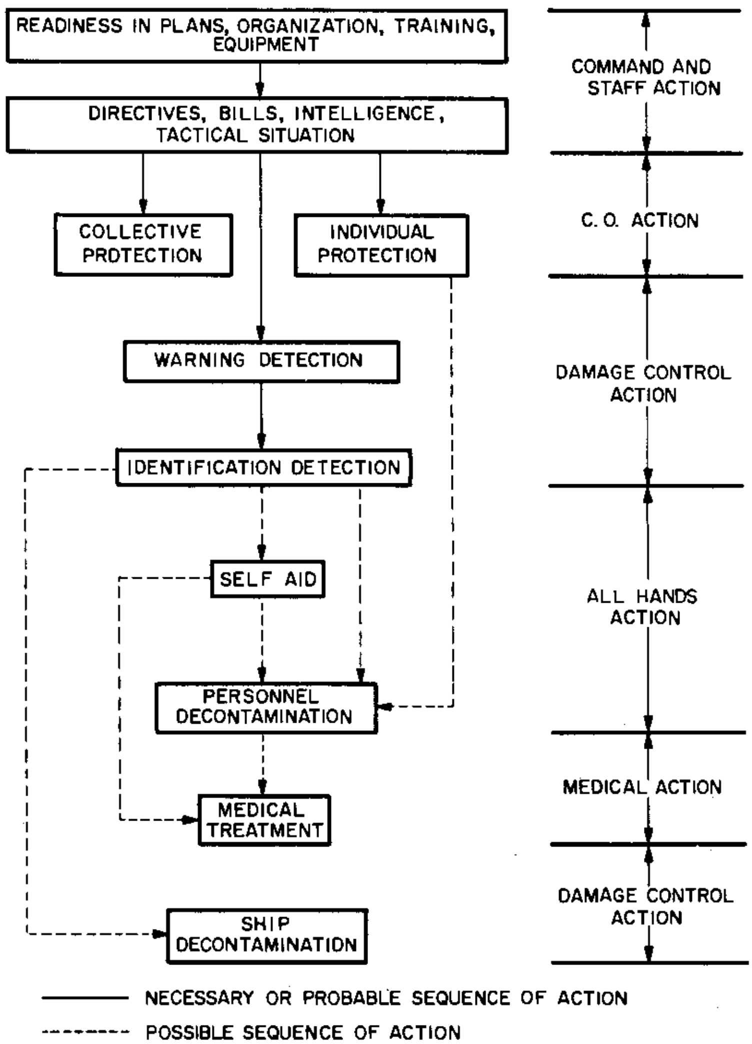

Figure 9770-8.—The shipboard BW/CW defense system[11]

[11]Adapted from "Battle Control" NWIP 50-1.

Protective mask (gas mask) ND Mk V

Wet weather clothing, regular issue, parka and overalls (See Manual of the Bureau of supplies and Accounts, chapter 8, Part A).

Protective clothing, special, impregnated, jumper (parka) and trousers, with impregnated socks and gloves (see the Manual of the Bureau of Supplies and Accounts, Chapter 8, part B)

Rubber gloves and overshoes (see the above Manual, Chapter 8, part B)

Impregnite-in-clothing test kits (see the above Manual, Chapter 8, part B)

Chemical agent identification kits (detector kits M15A2, M18A2

Liquid CW agent detector paper M6, M6A1 (marked "Vesicant Detector Paper")

Liquid CW agent detector paper M8 (morked "Paper, Chemicol Agent Detector, 3-way")

Calcium hypochlorite, high test (70 percent)

Decontaminating Compound (a detergent) MIL-C-7907 Aer

Washdown system and firehoses (see **NAVSHIPS Technical Manual**, Chapter 9900)

Personnel decontamination stations (see **NAVSHIPS Technical Manual**, Chapter 9900)

Additional items adaptable to BW/CW defense aboard ship are: Detergents, grease-emulsifying solvents, water-emulsion cleaners, etc.

Allowances of equipment and supplies for representative ship types are given in Appendix B.

Part 4. Principles and Procedures for BW/CW Defense at Sea

9770.71.

This section discusses the background and practical application of the following items and procedures:

- Protective mask
- Impregnated clothing
- Wet-weather clothing
- Interior decontamination
- Topside decontamination
- Decontamination of clothing, masks, food, and water
- Personnel decontamination
- Detection
- Self aid and first aid

A number of procedures for use of shipboard BW/CW defense facilities, equipment and supplies are presented in NAVPERS 10899A. Additional dicussion and explanation are provided here only where considered necessary.

"A stitch in time saves nine" is an excellent motto for all shipboard personnel to apply to BW/CW defense. Although advance planning, practice, and protection may be difficult and do require personnel time at all levels of responsibility, in a period of active BW/CW they will pay unique dividends in missions accomplished and in personnel survival. Post-attack procedures of personnel and material decontamination and rehabilitation are always difficult and seldom completely satisfactory. These factors should be recognized as underlying the BW/CW countermeasure procedures recommended in this chapter.

9770.72. PROTECTIVE MASK

The ND Mk V mask is a modem, efficient, and comfortable mask which, when properly fitted and properly worn, provides excellent protection to the face, eyes, and respiratory system against all BW/CW agents. Its major components are illustrated in figure 9770-9. After it has been worn routinely for entire watches while normal shipboard duties are performed, it should have only a minor effect on the efficiency of most personnel. The mask does not provide protection against some common gases such as carbon monoxide, carbon dioxide, and ammonia. It also does not protect against atmospheres deficient in oxygen. For these gases, the Oxygen Breathing Apparatus or airline mask is required.

The Mk V mask is supplied to ships in numbers equal to 105 percent of the wartime complement. Ten percent of the ship's allowance has been designated for training use by the Chief of Naval Operations. The remainder should be stowed in cool-to-warm, but not hot, conditions until a command decision is taken to issue masks to all hands. Stowage of unissued masks in their original cartons is necessary to prevent distortion and damage. Since the facepiece is made in only one size to fit all personnel, careful attention to fitting of the head-harness straps is required in order to ensure maximum protection and comfort.

Correct fit and adjustment of the Mk V mask is particularly important when masks have been issued to all hands for indefinite retention. The mask should be tested by wearing in a tear-gas chamber, if feasible. A leakproof fit cannot be expected unless the wearer is smoothshaven. In addition, the mask should be worn for at least one-half hour to make sure that it has not been fitted so tightly as to cause headache or leave red marks on the face. This is a fitting period only. Repeated wearing drills of four hours or more are required for maximum familiarization and personnel efficiency. After all the foregoing tests have been made, and it has been ascertained that strap adjustments are correct, the loose ends of the three top-head-harness straps must be threaded through the buckles between the body and sliding member, figure 9770-10. The excess length of these straps should be cut off, leaving about one-half inch protruding beyond the buckle. These straps will now be permanently adjusted to the individual. Only the two bottom straps are loosened and tightened each time the mask is removed and replaced (figures 9770-11 and 9770-12). Both mask and carrier should be securely marked or tagged with the name of the person to whom it has been fitted.

It has been noted that the protective mask outlet valve sometimes sticks closed due to sweat drying on it. If this occurs, the valve may be loosened by forceful exhalation of air, or by massaging the valve through the outlet valve cover or with the outlet valve cover partially removed (figure 9770-13).

Fogging of the eyepiece is minimized by application of the antidim which is packed in the mask carrier. The antidim should be applied to the inside of the eyepiece after each wearing period.

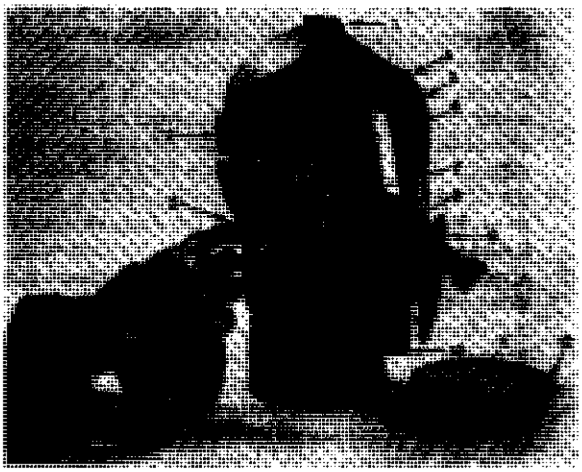

Figure 9770-9. Protective mask ND Mk V, showing major components. 1. Top strap and buckle, 2. Side strap and buckle, 3. Bottom strap and buckle, 4. Facepiece, 5. Hood stop, 6. Eye-piece, 7. Air deflector, 8. Diaphragm assembly, 9. Canister holder, 10. Outlet valve cover, 11. Canister, and 12. Canister apron.

Figure 9770-10. Fitting the mask; securing the top strap for permanent fit.

Figure 9770-11. Removing mask. First step: release bottom straps.

Figure 9770-12. Removing mask. Second step: pull m forward to clear chin.

The following procedure is used for mounting the canisters on new masks after removing them form the original "coffee can" containers:

1. Roll rubber apron of each canister completely over the outer edge of the canister (figure 9770-9).

2. Position each canister snugly against its canister holder (saucer-shaped metal plates permanently attached to cheeks of facepiece) so that the holder contacts the perforated plate of the canister at all points on its circumference.

3. Roll the rubber apron of each canister back over the canister holder (figure 9770-14).

Canisters are removed from the facepiece by rolling approximately one third of the rubber apron over the outer edge of the canister (figure 9770-14) and then sliding the canister off the holder (fig. 9770-15). The aprons sbould then be unrolled to the relaxed position.

No repair kit for the Mk V mask is supplied to ships. Where adequate stowage and good care are the rule, it is believed that the need for repairs or replacement will be negligible. Replacement canisters are not supplied to ships in time of peace.

9770.73. IMPREGNATED CLOTHING

Impregnated clothing is supplied to ships in quantities sufficient to outfit 25 percent or more of ships' complements. An outfit comprises impregnated socks and gloves, trousers with attached suspenders, and jumper (parka) with attached hood. It is illustrated in figure 9770-16. The color is an olive green. All items have been treated with a CW agent-neutralizing chemical, CC2, plus a viscous binder, chlorinated paraffin. The presence of these two chemicals results in a faint odor of chlorine, and a slightly greasy or clammy feel. In cool-to-warm dry stowage, and in the absence of sunlight or daylight, the impregnation treatment is believed to remain effective for five to ten years or more. A test kit is provided (see below).

This clothing is **not** to be worn for general-purpose coveralls, or for **any** other purpose than NBC training or NBC defense operations. The effectiveness of the impregnite is reduced by contact with oil, grease, moisture, or dirt, or by exposure to sunlight. The clothing therefore should be stored in a clean, dark, thoroughly dry location, and in the original packages as far as possible. The instruction to replace the clothing within 6 months of the 4th anniversary of the impregnation date has been found too conservative, and is now disregarded.

The impregnated clothing alone is effective against CW agent vapor or very fine aerosols. However, large aerosol particles or droplets can partially penetrate the fabric when carried by a strong wind. In addition, it is not possible to impregnate the clothing with enough CC2 to neutralize agent drops of sizes which can soak through the fabric. Accordingly, impregnated clothing is not worn topside without the additional protection given by wet-weather clothing worn as the outside garment. The combination designated XZ clothing (see below) provides excellent protection when all closures are tightly secured. The impregnated clothing neutralizes vapors and aerosols which may penetrate the wet-weather clothing, and the latter protects the CC2 clothing from drops or gross quantities of CW agents. After the clothing is worn in drills or actual operations, it should be thoroughly dried in warm current of air (moisture is normally the principal factor in deterioration of the CC2 impregnite). Laundering should be as infrequent as possible, although several light-duty launderings are possible before the CC2 is degraded to the minimal level. See chapters 9350.2, 9350.3, and 9350.4, **Naval Ships Technical Manual,** or the **ships serviceman Laundry Handbook** (NAVPERS 10291A), for laundering instructions. This laundering is not a decontamination operation. The clothing is self-decontaminating, within limits, and should normally not require the laundry-decontamination treatment, which is described under clothing decontamination. Decontamination is avoided, unless made necessary by proven CW contamination, because it degrades CC2 more than does the normal light-duty laundering.

In the Navy system for classifying BW/CW protective clothing, impregnated clothing is designated Class Z. The same garments in the unimpregnated condition are class Y.

The Impregnite-in-Clothing Test Kit, M2, is a simple and valuable indicator of the activity of the CC2 in impregnated clothing. It is recommended that samples of all of the ship's protective clothing be tested in a batch annually by experienced personnel. Ten percent of the garments in any single storage location will serve as an adequate sample. This production-scale testing, if conducted throughout by the same personnel will promote consistency. Retesting of the earliest-tested garments at the end of the program will constitute a useful check. The results of the annual tests should be retained.

9770.74 WET-WEATHER CLOTHING

Wet-weather clothing often is described as impermeable or rubberized clothing and designated Class X. Its value results from the fact that the standard impregnated clothing can be partially penetrated by all but the smallest droplets of liquid agents, especially in high relative winds. Moreover the impregnated clothing is not equally efficient in neutralizing all liquid CW agents. Wet-weather clothing, on the other hand, if the closures at the neck, wrists, ankles, and protective mask are well adjusted or taped, is for a limited time resistant to **all** liquid CW agents. Gradual penetration of the synthetic-rubber layer of the wet-weather clothing fabric is dealt with in two ways: first, by impregnated clothing worn underneath, and second, by frequent and thorough flushing of the rain clothing surface with sea-water washdown or an equivalent, such as jury-rigged topside sea-water showers, or by swabbing with liquid hypochlorite.

The removal of any type of BW/CW contaminated clothing must be done with extreme care to avoid any body contact with the outer surface of the clothing.

Rubber overshoes are furnished for use with impregnated clothing, and in the same quantity. Rubber gloves are supplied in smaller numbers (see Appendix B).

Figure 9770-13. Correcting sticking outlet valve, with cover partially removed.

Fig. 9770-15. Removing canister; sliding canister off holder.

Fig. 9770-14. Removing canister; roll back apron.

Figure 9770-16. Impregnated clothing minus mask, gloves, and rubber footwear.

In warm weather impermeable BW/CW protective clothing, such as wet-weather clothing, can be tolerated for limited periods only. Recent information from the Naval Medical Research Institute gives approximate tolerance times for experienced personnel wearing Class XZ clothing (impermeable worn over impregnated clothing) under certain environmental conditions. The clothing included rubber gloves and footwear, and the Mk-V protective mask. In the NMRI tests, wind speed was constant at 0.25 knots, the relative humidity was practically constant at 58 to 63 percent, and the test personnel were not exposed to direct sunlight. Two levels of physical activity were used: standing only, and moderate activity. In the latter, test personnel stepped up two six-inch steps ten times per minute for ten minutes; they were then allowed to stand at rest for ten minutes, after which the 20-minute cycle was repeated. In some cases, personnel were sprayed with 3 gpm of water at 80° F. for various fractions of a 20-minute cycle; five minutes spraying out of 20 is designated 5'/20'. The data are shown in Table 9770-6.

It is recommended, on the basis of the tests thus far conducted, that a sea-water spray be used on watchstanders in Class X or Class XZ clothing when the air temperature is above 70° F. As the temperature rises, more spraying is required, and, at 95° F. and 60 percent relative humidity, spraying should be continuous. Normal wind speeds and low relative humidities will tend to lengthen the tolerance times; direct sunlight and high humidities tend to shorten the tolerance times. Delaying the start of spraying is inadvisable. Once rapid deterioration of performance has begun, it is unlikely that the situation can be reversed by water-spray cooling. Instead, removal from the suit and treatment as a heat casualty is strongly advised.

It is important to recognize that the wearer is cooled both by water evaporation and by direct contact with the spray or stream, and that cooling by evaporation increases at higher wind speeds.

Table 9770-6. Approximate tolerance times of Naval personnel for BW/CW protective clothing at various air temperatures (Wind 0.25 kt, relative humidity 58-63 percent).

Class of Clothing*	Physical Activity	Air Temp. (°F)	Water Spray	Tolerance Time (Hours)
Z	Standing	85	None	3 to 4
Z	Exercising	75	None	2.25 to 4
XZ	Standing	85	None	2.25 to 4
XZ	Standing	95	None	1.5 to 2
XZ	Standing	95	3'/20'	4
XZ	Standing	95	5'/20'	4
XZ	Exercising	70	None	4
XZ	Exercising	75	None	2 to 3.25
XZ	Exercising	95	10'/20'	2
XZ	Exercising	95	15'/20'	1.75 to 4
XZ	Exercising	95	20'/20'	2.25 to 4

*Class Z clothing: standard impregnated. Class XZ clothing: impermeable clothing over standard impregnated.

The spraying can take a variety of forms. For a large number of personnel, use of sections of the wash-down system at low pressure is suitable. For fewer personnel, it may be preferable to rig topside sea-water showers, using both vertical and horizontal shower heads, or to use fog nozzles.

Sweat is normally accumulated inside an impermeable suit. Underclothing, gloves, socks, and shoes become saturated. Sweating can be reduced and tolerance times lenghtened by reducing the exercise rate, using water-spray cooling, and reducing exposure to the sun.

9770.75 INTERIOR DECONTAMINATION

In practice, decontamination is any process which eliminates or substantially reduces the hazards of contaminated surfaces or objects. Decontamination, therefore, includes the **physical removal** of an agent by washdown or hosing; the **chemical destruction** or **neutralization** of an agent; and the mixture of the effects of heat, wind, sun, and water, called **weathering.**

Two levels of decontamination are recognized. **Operationally-Complete** decontamination is a degree and extent of decontamination which is sufficient to allow completion of the ship's assigned mission without undue hazards to personnel. This is not a fixed level of decontamination, but depends on the ship's operating schedule and the urgency of the assigned mission. Decontamination at sea or by ship's personnel will normally be the operationally-complete type.

Chemically-Complete decontamination is a degree of decontamination such that the appropriate chemical test fails to give a positive response for residual agent. Decontamination at Naval shipyards, advanced bases, or by shore-based personnel, will normally be of the chemically-complete type.

Although complete decontamination of a ship's weather surfaces seldom is necessary, or even possible, interior spaces and ductwork may be a different matter. When the exterior of the ship has been partly cleansed by washdown and firehosing, and sensitive areas further treated by detergent and hypochlorite scrubbing, the remainder of the exterior surfaces generally can be left to the evaporating and hydrolyzing effects of wind and weather on CW agents, and to the lethal action of sunlight on BW agents. Inside the ship, contamination cannot as readily be tolerated, and it is far less subject to the natural decontamination that acts on the ship's exterior. On the favorable side, the ship's interior also is less prone to BW/CW contamination. This does not contradict the earlier discussion of the penetration of BW/CW aerosols into ships via ventilation systems and leaks. Aerosols, particularly those in the very small particle sizes characteristic of BW agents, can and will penetrate into the ship through every existing opening. However, the same factors which allow easy entrance into the ship of BW aerosols also allow easy discharge from the ship; deposition within the ship is only partial. CW aerosols, on the other hand, generally are designed to impact on personnel and ship surfaces. Their relatively large size and inertia will seldom allow penetration of cracks and crevices, and will ensure a considerable degree of centrifugal removal by ventilation fans of the CW particles which start to enter ventilation systems. A similar rule applies to nuclear-fallout particles. It is seen that most BW/CW aerosols will either be too small to deposit completely inside a ship or too large to enter. There will be some deposition inside, however, although there is insufficient experience to assess the hazard with accuracy. For this reason, and to deal with gross contamination from leaking munitions, interior decontamination is provided for.

Where BW interior contamination is suspected or known to exist, a decision must be made whether to: (a) take no action other than to equip all personnel in the affected area with masks and protective clothing (that is, wait for organisms to die), or (b) attempt thorough decontamination by steaming, liquid-decontaminant swabbing, or spraying, or vapor-phase treatment. The first choice is slow and hazardous, since it is known that movement and activity of any kind in a compartment may serve to restore a portion of surface-deposited microbes to the airborne state. The second choice is the more effective and less hazardous to personnel, but requires considerable manpower for swabbing and for the other decontamination procedures, and does put the compartment and its equipment out of service for a period of hours. It also, in the case of steam, requires rigging a steam line and providing special drainage and ventilation. However, this choice is thorough, and circumstances may require its use.

The principles and procedures for BW steam decontamination will be discussed below as a dual purpose BW/CW countermeasure because of the basic similarity in the two operations. Although there are extra steps, materials, and hazards in CW decontamination by steam, as it is applied to BW agents, steam decontamination can be regarded simply as an autoclaving procedure, done at atmospheric pressure.

Certain liquid decontaminants are highly effective against BW agents. The problems in the use of these materials are not in the effectiveness of the liquids themselves, but rather in reaching all contaminated surfaces with the liquid, and then in obtaining intimate contact between the organisms and the liquid. These incidental but important parts of the decontamination process usually are carried out best by applying the liquid decontaminant to all surfaces with a coarse-spray device or swab until they are completely wetted. All dirty, greasy or water-repellent surfaces are then rubbed or scrubbed with swabs or brushes to bring the organisms into suspension in the liquid, which is left on the surfaces as long as possible, but for not less than the periods prescribed below. Operating personnel are equipped with masks for protection from both the BW agent and the decontaminant. Normal use of the compartment may continue if necessary.

Of the several decontaminants which have been proved effective against BW agents, the only one generally available on Navy ships is calcium hypochlorite (Stock No. 6810-255-0471 for the six-ounce bottle, 6810-242-4770 for the 3-3/4-pound can or plastic jug). Solutions of calcium hypochlorite are more effective if 0.5 percent detergent or wetting agent is added. The preferred detergent for use in hypochlorite solution is Decontaminating Compound (Stock No. 6850-664-2008). Laundry detergents (not soaps) are also generally suitable for use in hypochlorite solutions.

The disinfectants, germicides, and fungicides intended for general light-duty disinfection or cold sterilization of surgical instruments are regarded as inferior to hypochlorite for BW decontamination.

The one-percent hypochlorite decontamination solution for heavy-duty use in magazines and on grossly contaminated surfaces is prepared by dissolving calcium hypochlorite in fresh water in the proportion of a six-ounce plastic bottle to 3 1/2 gallons of water, then dissolving three ounces of decontaminating compound in 1/2 gallon of water, and mixing to make four gallons of decontamination solution. This solution is well-scrubbed on and then left on the contaminated surfaces for 20 or 30 minutes. Calcium hypochlorite does not dissolve rapidly, and considerable stirring is required. Three ounces of decontaminating compound is measured as 1/3 of a six-ounce calcium hypochlorite bottle. The standard decontamination solution of 0.3 percent hypochlorite is used for typical light contamination, and on clothing, etc. It contains two ounces of calcium hypochlorite (1/3 of a six-ounce bottle), plus three ounces (also 1/3 of a six-ounce bottle) of decontaminating compound, dissolved separately as above, then mixed to make a total of four gallons of solution (the apparent error of two ounces of calcium hypochlorite and three ounces of decontaminating compound each occupying 1/3 of a six-ounce bottle results from the different density of the two materials), When decontamination is complete, all decontamination solutions should be wiped or hosed off.

It should be noted that calcium hypochlorite is a true universal decontaminant for BW and CW agents on men and materials. It is also compact, inexpensive, stable in storage, and safe to use. It is a powerful oxidizing agent and the solid should always be stored in the original plastic containers. If the solid is heated in contact with oxidizable material such as paper, wood, cloth, or oil, ignition may occur. It is always dissolved in water for decontamination purposes.

BW decontamination by bactericidal vapors or gases, sometimes called vapor-phase decontamination, is not currently recommended for use on Navy ships at sea. It is discussed under Industrial Decontamination.

Steaming is effective for both BW and CW decontamination of ship interiors. The principle of operation is first to displace all air from the contaminated compartment[16] with steam. This allows the compartment surfaces to be heated rapidly and efficiently to the maximum temperature of approximately 212° F. Higher temperatures are not attained because, under the conditions of steam flow and condensation, the steam rapidly loses superheat. Since air is over

[16]The principles and procedures given for steam decontamination are to be understood as also generally applicable to ductwork and ventilation systems.

[17]The accuracy of the 212° F. mark on the thermometer can be checked simply by immersing the bulb and an inch or two of stem into rapidly boiling fresh water in the galley. Do not allow the thermometer bulb to touch the surfaces of the water container.

60 percent heavier than steam, it is effectively displaced from the compartment by admitting and discharging steam from points close to the deck. Complete displacement of air is signalled by a reading of 211° - 212° F. on an accurate[17] thermometer which is held in the steam exhaust from the compartment.

When compartment surfaces reach 212° F., BW organisms are killed in 15 minutes or less. In the case of CW contamination, four different mechanisms operate: (a) the evaporation of the agent which has soaked into the paint is accelerated; (b) hydrolysis and other types of chemical neutralization of the agent are accelerated; (c) some of the agent vapor is discharged from the compartment unchanged, mixed with the exhaust steam; (d) some of the liquid agent may remain on the deck, under or mixed with the pool of condensate. Item (c) results in some hazard to personnel, and item (d) is the reason for the additional use of chemicals for deck decontamination.

Before starting actual steaming, all visible and accessible deposits of liquid CW agent are absorbed in suitable material and the absorbent carefully jettisoned. The entire deck now is treated with a decontamination material, scattered by hand. The material is selected from: (a) heavy-duty cleaning compound of the solvent-emulsion or water-emulsion type; (b) alkali, such as soda ash, sodium metasilicate steam-cleaning compound, or alkaline paint-stripper; and/or (c) calcium hypochlorite.* For a deck area of 200 sq. ft., a gallon of cleaning compound, five pounds of alkali, and/or two pounds of calcium hypochlorite are recommended. Alkaline materials are generally undesirable, however, for use on aluminum decks, in compartments with aluminum bulkheads, or in aluminum ductwork. Alkaline dishwashing compounds are an exception to this rule if they contain a silicate to inhibit attack on aluminum.

Based on the principles cited, the following procedures are used. Steam is taken from a 100 to 150 psi line, led to the contaminated compartment through a steam hose, and admitted through a hole cut in the compartment bulkhead a few inches above the deck. The hole is preferably near a corner and, where the deck slopes appreciably, at the upper end of the deck. Steam is exhausted from the compartment through another hole, 6 to 12 inches above the deck, cut for the purpose, and located as far as possible from the first hole; i.e., near the opposite corner, or in the opposite bulkhead. Ideally, both steam condensate and exhaust steam would be carried through a steel pipe, over the side, and to a point close to the water line. Since this is seldom feasible, the condensate can be retained in the compartment for later disposal, and the steam exhausted directly, or through a pipe or hose, to the atmosphere. This involves a severe CW hazard to personnel downwind from the discharge point, in that the exhaust steam may be heavily loaded with agent vapor. Suitable precautions should, therefore, be taken. The adjacent atmosphere can be checked for agent vapor with a detector kit, but the test will be invalidated if the air sample is taken in or close to the plume of exhaust steam.

The steam supply hose, and discharge pipe or hose, if any, should be calked into their respective openings with oakum or rags to minimize leakage. After deenergizing all electrical and electronic equipment and lighting circuits, steam is admitted rapidly until the temperature of the vapor at the discharge point reaches at least 210° F.; 211° or 212° F. is preferable. At this time the steam flow is reduced to an amount just sufficient to maintain the exit temperature, and the treatment continued for 30 minutes. The steam is now shut off, and the compartment ventilated at a high rate until all visible moisture has evaporated. It can usually be entered in 20 to 30 minutes, but kit tests for the CW agents(s) involved should always be made prior to reoccupying the compartment.

The deck of a compartment usually is the slowest and most difficult area to decontaminate; this is the reason for spreading a chemical decontaminant on the deck. Not only is liquid agent apt to accumulate there, but the deck is the last surface to be heated to steam temperature. Therefore, the accumulated steam condensate must be suspected of carrying or covering undestroyed agent until the contrary is proved. Since a test for contamination cannot readily be made until the condensate is removed, bailing and other condensate-removal procedures should use great care to avoid unnecessary hazard to personnel.

To promote drying of equipment, insulation, etc., the compartment is kept as hot as possible and ventilation maintained for the length of time required for drying. Since the high temperature also will increase the vapor concentration of any residual CW agent, this is an opportune time to make kit tests of the compartment air. Deck areas should be checked in particular.

During the drying period, all electronic equipment ventilation blowers should be kept operating if practical. Auxiliary or portable ventilation blowers can also be used to advantage in recirculating hot air over and through electronic and other equipment. These drying procedures are prescribed in order to minimize damage to electronic and electrical devices, but very little experience exists on which to predict specific drying times or possible electronic component failures. The water-displacing and drying methods of this manual[19] should be considered for use in this application. After several hours of hot-air drying, electrical and electronic equipment may be reenergized cautiously. If thoroughly dry, little or no trouble should occur.

A special case of BW/CW decontamination, that will arise after every CW aerosol or spray attack in which any ventilation blowers are operating, is that of the blowers themselves (see chapter 9900.33). Blower vanes, and in particular the surrounding housings, can be expected to be heavily contaminated. This material must be dealt with because of its re-evaporation or blow-off hazard to the compartments served. Use the same procedures as for

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*Calcium hypochlorite is the most effective CW agent neutralizer available aboard ship, but it is also the most corrosive. This corrosiveness is increased at high temperatures. Therefore, hypochlorite should not be used in conjunction with steam where the compartment contains delicate or critical electronic or electrical equipment.

[19]Naval Ships Technical Manual, Chapter 9190, Section X.

Industrial Decontamination, and apply postdecontamination tests in the case of CW agents. Avoid the careless use of corrosive materials where blower housings are of aluminum.

BW/CW decontamination of continuously ventilated machinery spaces is believed **not** to be a severe problem, except on hull surfaces which are cooled by the sea or by fuel or water in tanks. Contamination of bilge areas can also present serious difficulties in decontamination. The characteristic high temperatures and high ventilation rates will combine to evaporate or destroy agents deposited on hot surfaces. Deposition will itself be reduced by rapid air movement through the spaces. It should be noted, however, that the direct hazard to personnel is high, particularly for CW. The high temperatures increase not only the agent vapor pressure and skin sensitivity to the vapor, but also increase the hardship of wearing protective clothing and masks. The present solution is, in case of likely BW exposure, to require continuous wearing of the mask, as for topside personnel. For anticipated CW exposure, the impregnated CW protective clothing (not wet weather clothing) will also be required. **Frequent changing of machinery-space watchstanders will be a necessity under these conditions.**

In all BW/CW decontamination aboard ship, consideration must be given to possible interference with the essential functions and operational responsibilities of the ship. Protective masks, impregnated clothing, and/or impermeable clothing (wet-weather clothing) are available and will protect personnel for extended periods even in the presence of high concentrations of CW vapor or BW aerosols. Personnel should be able to avoid direct contact with liquid CW deposits if their presence and location are identified and marked. Therefore, it is believed feasible for well-trained personnel to carry out essential functions and duties in spite of the presence of CW contamination. Some casualties may result, however, and relief will be required at intervals more frequent than usual because of the abnormal heat load on the heavily clothed personnel.

If the decision is made to continue essential functions in contaminated compartments, it is recommended that decontamination be carried out concurrently, or at the earliest practical time. The only procedure adaptable to all BW/CW decontamination under these conditions is handswabbing with one percent hypochlorite plus detergent. Decontamination of all BW and CW agents will be effected on all surfaces which can be reached. Subsequent evolution of CW vapor from paint should be checked by use of the detector kits.

Exceptionally heavy BW/CW contamination may occur from leaking spray tanks, bombs, etc. in magazines or elsewhere. The decontamination procedure is straightforward: (a) liquid agents are absorbed in any available absorbent material and jettisoned; (b) the contaminated area is scrubbed with five percent hypochlorite solution plus detergent; (c) after flushing the decontaminant away, air and surfaces are monitored for residual contamination. If residual contamination is heavy enough to be objectionable, reapply the decontaminant and leave in place for an extended period.

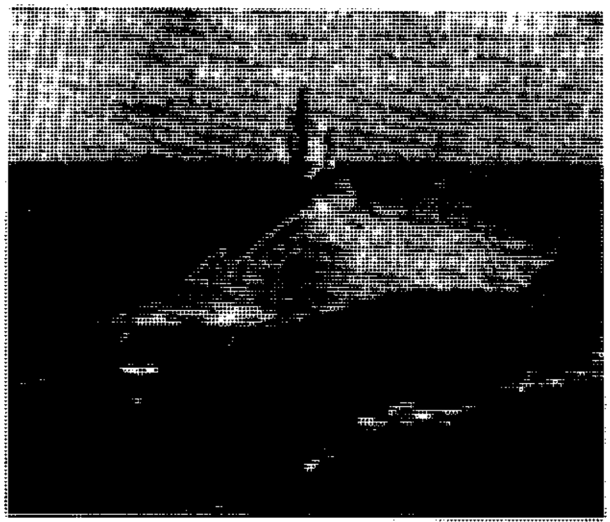

Figure 9770-17. Ship washdown system in operation.

9770.76 TOPSIDE DECONTAMINATION

The washdown system is an item of major importance in the ship's NBC defense system figure 9770-17. A general discussion is given in chapters 9900.121 and 9900.131. Although the washdown system has application in both protection from, and decontamination of BW/CW agents, in the past it has been more familiar in the latter use, and therefore will be discussed fully at this point.

In all NBC warfare situations, the effectiveness of the washdown system as a protective or preventive (preattack) device is greater than for decontamination (postattack). Spray or drops of BW/CW agents which strike a ship already covered with a flowing water film are normally washed overboard. However, in areas where the runoff water flows very slowly or collects in pools, some of the agent may adhere to the ship and, in the case of CW agents, be absorbed by paint. Hosing is useful in keeping such areas free of agent; note can be taken to their locations during washdown drills, and suitable instructions can be included in BW/CW (and nuclear) damage-control bills. When the tactical situation permits, steaming on a zig-zag course helps to clear the ship of pools of water as the ship heels, and, in addition, improves the distribution of the washdown spray by varying the direction of the relative wind (see chapter 9900.133).

BW/CW agent particles which impact on dry surfaces of the ship are not easily or completely removed by postattack washdown. Prompt use of the washdown system after CW attack can remove more agent than if the treatment is delayed, however. Without prewetting use of the washdown, general firehosing will be needed as an additional countermeasure. The following areas will be the most heavily contaminated by airborne agents, and therefore should be the areas most thoroughly firehosed. CW agents: (1) all decks and horizontal surfaces, (2) vertical surfaces facing the relative wind. BW agents: (1) all small-diameter cylinders such as lines, halliards, ropes, and handles; (2) all surfaces close to edges, corners, and protruding fittings.

The washdown system plus firehosing is the only countermeasure available for general, or overall, decontamination of the entire ship's exterior surfaces. Every effort should be made, therefore, to use it to maximum advantage.

Ships having built-in or "permanent" washdown installations have adequate general maintenance and operating instructions in the Ship Information Book Piping Section. Experience has shown that defective joints in plastic piping are common in the interim installations. Since testing of washdown systems has been infrequent, in practice the defects may be unknown to the ship. A single open joint can render a major section of the washdown system inoperative, and full-pressure testing should, therefore, be regular and thorough. The natural aversion to coverage of the ship with salt-water spray need not prevent washdown testing, since this can be done at dockside with fresh water. A more realistic and satisfactory test, however, is to use the washdown system when underway. Frequent testing also will afford opportunity for practice in partial-pressure adjustment of the various branches of the system to achieve personnel wetdown (for cooling) and ship-surface wetdown without the high volume flow necessary for removal of contamination. Other means of testing the washdown system are available. Although these fall short of full-scale testing, they have the advantage of minimizing salt-water wetting of the ship. One such procedure is to cover each nozzle with a canvas bag or hood. Operating the system under these conditions allows an estimate of adequacy of water flow, inspection of the plastic pipe and fittings for watertightness, and indication of the general condition of the firemains and pumps. Pressure tightness alone can be checked by replacing the spray nozzles with pipe plugs. Experience suggests that washdown piping leaks will be more frequent and more serious than coverage deficiency, assuming that installation instructions have been followed.

Ships operating in areas where marine growth is extensive may find that frequent, even daily, operation of the firepumps and mains up to the washdown jumper connections is necessary to keep the mains and strainers free of obstructions.

Leaks in the PVC (polyvinyl chloride) plastic piping of the washdown system may be due to poor cementing of joints at installation, to failure to provide for thermal expansion and contraction (which is about five times as great as with steel pipe), to insufficient supports,[20] to overheating as by aircraft jet blast, or to mishandling and abuse (such as use for steps). Solutions to these problems include recementing, provision of additional supports or protective shields, relocation, or replacement of vulnerable sections by metal piping or hose jumpers. Replacement plastic parts may be available with difficulty; every effort should be made to maintain, preserve, and utilize the original material. The replacement components are currently requisitioned from NSC, Mechanicsburg, Pa., and are listed in NAVSHIPS 250-548-2 with addendum of Dec. 5, 1958.

Assembly of portable components of washdown systems is discussed in chapter 9900.132. Firehosing is a valuable addition to washdown for more thorough removal of residues of NBC contamination. Recent studies have shown that the hose stream is most effective when projected well in advance of the nozzle so that there is little or no splash or rebound of the hose stream from the surface being decontaminated. In addition, a flat, 30-degree, fan-shaped stream is especially effective for treating large areas. This type of stream requires special nozzles which can be fabricated from flattened tubing by the ship's force. It is emphasized that rebound of contaminant-bearing water can be a serious hazard to decontamination personnel or to any one downwind of the hosing operation.

Even when used to maximum efficiency, the washdown system may not be capable of providing satisfactory decontamination in some areas or situations. Examples are: gross contamination of part of the ship without washdown prewetting, contamination of particularly hazardous or sensitive areas such as ordnance items which have to be handled or struck below, flaghoists, searchlight stations, the bridge area, deck areas of heavy foot traffic, and aircraft exterior surfaces routinely touched by flying or servicing personnel. All of these examples require additional or special decontamination. Therefore, it is normally more practical to expend extra effort in thorough decontamination of a limited area than to require full protection for all personnel who are required to work in the area.

The contamination to be dealt with, particularly if washdown and hosing have been used, will probably be invisible. In the case of CW, it is a continuous or intermittent thin film of oily material or deposit of droplets on all surfaces, plus agent which has penetrated into the paint. In view of the very small quantities of CW nerve agents capable of producing toxic effects, contact of the bare skin with such CW-contaminated surfaces must be avoided. Personnel working close to the contamination must be masked unless kit tests have proven the absence of a vapor hazard.

Agent deposits remaining after washdown and firehosing are of two types: **absorbed** and **surface. CW agents absorbed in paint, etc., are relatively harmless, and can usually be left to the decontaminating action of evaporation and the various chemical effects of the environment. BW agents are not absorbed. The invisible or near-invisible surface deposits of CW and BW agents left after washdown and firehosing will also evaporate or be destroyed by environmental effects, but the vapor and contact hazards require active treatment of critical areas. Critical areas are those likely to be touched or walked on, and those emitting hazardous amounts of vapor. Decontamination of topside surface deposits of CW or BW agents is done by use of the same 0.3 percent hypochlorite, 0.5 percent detergent solution that is required for interior decontamination (9770.75).** If the NBC decontamination compound (6850-664-2008) is not available, laundry detergents or compounds are acceptable for use with calcium hypochlorite in the standard decontamination solution.

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[20]PVC piping must be supported not only to hold its weight, and prevent carrying away by high seas or explosive blast, but also to prevent the characteristic slow sag or creep. When this is allowed to occur, severe stretching forces may be applied to the cemented joints.

If calcium hypochlorite is not available, chemical decontamination of BW/CW surface deposits cannot be accomplished. The deposits can, however, be **removed** (physical decontamination) to a considerable extent by the use of detergent solutions alone. In addition to the NBC decontamination compound, a variety of detergents or cleaning compounds is available in the Fleet, including laundry and dishwashing compounds, and the solvent-emulsion or water-emulsion cleaners (see Glossary). Items 2, 3, 7, 10, and 14 in the Bibliography are useful in describing the applications of Navy detergents and cleaners. NAVSHIPS 250-342-1 and NAVWEPS 07-1-503 provide guidance in selection of cleaning materials compatible with the surfaces to be cleaned: paint, rubber, aircraft, etc. Instead, BW/CW decontamination will be treated as primarily a CW problem. This approach is taken because the characteristics of BW aerosols are such as to minimize exterior surface contamination of the ship; in addition, methods and materials satisfactory for CW decontamination may be expected also to work well against BW agents. The decontamination detergent shown in BW/CW allowance lists is intended primarily for NW decontamination. It is believed that the cleaning compounds or detergents which are dilutable with mineral spirits or kerosene are preferable for CW decontamination. These materials are often described as solvent-emulsion cleaners. Examples are P-C-00576b Type 1 (light duty), Type 2 (heavy duty), see NAVWEPS 07-1-503; MIL-C-20207C (heavy duty), see NAVSHIPS 250-342-1; MIL-D-16791 Type 1 (light duty), Type 2 (heavy duty), see NAVSHIPS 250-342-1; MIL-C-7122 Type 1, "gunk" (heavy duty) see NAVAER 01-1A-508. The Bibliography gives full titles of these and other documents mentioned here by number only. NAVWEPS 07-1-503, a large wall chart, contains detailed and up-to-date information on the ingredients and uses of 31 light and heavy duty cleaning materials.

When the fire hazards connected with the solvent emulsion cleaners forbid their use, water-emulsion cleaners of a medium-or heavy-duty type are acceptable. More soaking time and/or brushing probably will be required to obtain a given degree of decontamination than in the case with the solvent-emulsion cleaners. Examples are MIL-C-22543A and MIL-C-22550; both are described in NAVWEPS 07-1-503.

The most numerous class of cleaning compounds and detergents is the solid material or concentrated liquid in which no flammable solvent at all is used. The fire hazard is therefore nil. These are basically light-duty materials, but, if alkalis are added, they enter the heavy-duty group. Examples are: the NBC decontamination detergent MIL-C-18687 Types 1 and 2 (see NAVWEPS 07-1-503); and MIL-D-16791 Type 1 (see NAVSHIPS 250-342-1). These materials also require scrubbing or other agitation to accomplish complete mixing with, and removal of, surface BW/CW deposits.

Compatibility of the selected cleaning compound with rubber, plastics, and paint should be checked in the appropriate manual or chart before use.

A wide variety of other soaps, cleaning compounds, compounds, etc. In the absence of the standard items, any of these is useful.

In the BW/CW decontamination of airplanes, helicopters, missiles, and any other items which may be relatively sensitive to corrosion or penetration by water, or attack by strong alkalis, only light-duty or medium-duty cleaners should be used. Cleaners containing **any** solid material also should be avoided as tending to promote corrosion. For the same reason no high-velocity hose streams or jets of water should be used on or close to joints, hinges, slots, or other openings in aircraft. Unless directed otherwise by responsible authority, cleaning solutions should be applied in a coarse, gentle spray, or mopped and scrubbed on. Subsequent flushing at or near openings in the aircraft skin should also be done with gentle streams of water. These procedures have the dual advantage of avoiding the scattering or atomizing of the BW/CW contaminants, and of keeping the cleaning materials from penetrating the skin of the aircraft, missile, or other equipment.

In BW/CW decontamination with washdown or detergents, whether it be of the exterior of the ship itself or of aircraft or ordnance equipment, it should be recognized that the contaminants often are merely **removed** rather than chemically neutralized or killed (unless hypochlorite is used at the same time). Therefore, the possibility exists that the removed agents, or agent-contaminated water, may drain or flow in such a way that undersirable quantities remain on the ship. Decontamination operations should be planned and conducted so that none of the agent reaches heavy-traffic points or other sensitive areas, and so that a maximum amount of the agent and wash water flows into the sea.

Personnel protection measures during decontamination operations are straightforward but important. Personnel directly involved in the operations must be masked and clothed in 100-percent impermeable (rubberized) garments, with all closures fully sealed. Other personnel necessarily downwind of the operation should be masked and, if necessary, wearing impregnated protective clothing. Finally, care should be taken to minimize the spraying or splashing of contaminated liquid which can act as sources of secondary aerosols.

No decontaminated surface should be assumed to be completely free of CW hazard until suitable kit tests are negative. Traces of agent often will remain, trapped in crevices or absorbed in paint. The degree of decontamination of large topside surfaces, previously exposed to washdown, can be increased somewhat by treatment with the standard hypochlorite/detergent solution. The extra effort may not be justified, however, and if the "safe times" indicated by detection kits are acceptable, final decontamination can be left to weathering. This is a normal situation.

Calcium hypochlorite is the most powerful shipboard decontaminant for CW and BW agents, either topside or below decks. It was originally supplied in small quantities for preparing liquid bleach in the ship's laundry. Additional stocks are now required for BW/CW decontamination (see Appendix B for allowances). The new plastic containers the caps are tightly closed and taped. Calcium hypochlorite normally is used at only one concentration (0.3 percent) in the standard BW/CW decon solution, and is always used with the NBC decon compound, or detergent, at 0.5 percent.

In all decon work, a minimum of decon solution should be used. Solution runoff is both useless and wasteful. As much agitation, rubbing and scrubbing should be done as is feasible. This step is desirable to mix thoroughly the BW/CW agent with hypochlorite. As in all other chemical reactions the materials cannot react or combine until they are brought into the most intimate, or molecular, contact. Most shipboard surfaces can be decontaminated safely with calcium hypochlorite plus detergent. Hypochlorite should not be used on aircraft, ordnance material, navigation instruments, etc., because of the possibility of corrosion damage to exterior surfaces or concealed parts.

The Naval Ordnance Systems Command is primarily responsible for the instructions on the decontamination of BW/CW magazines, leakers, spills, and contaminated cargo holds. However, as a matter of general information, it is desirable that the basic principles of such specialized decontamination jobs be outlined here. These are: (1) prevent spread of liquid agent; (2) absorb liquid agent in rags or other material; (3) remove and discard contaminated absorbent; (4) thoroughly flush contaminated surfaces with a stream of water, avoiding further spread of agent by splash or spray; (5) treat contaminated surfaces with standard hypochlorite/detergent solution, scrubbing where feasible; (6) test surfaces and atmosphere for agent; (7) if necessary, retreat with decontamination solution for operationally-complete decontamination. Previously clean surfaces will be relatively easy to decontaminate, but oily, greasy or dirty surfaces will be more difficult. In such cases, heated solutions of strong detergents, degreasing agents or emulsion cleaners, with 0.3 percent of calcium hypochlorite added should be recirculated over the contaminated surface or area, if feasible. If recirculation cannot be accomplished readily, hot solutions of solvent-emulsion cleaner or water-emulsion cleaners, with 0.3 percent hypochlorite, should be applied with as much agitation as is feasible, allowed to stand for 30-60 minutes, flushed with water, and the cycle repeated as necessary. Enclosed areas which have been heavily contaminated should be ventilated after decontamination at as high a rate as is practicable to accelerate evaporation of residual agent.

In summary, it is helpful to recognize that CW agents are in fact oils which vary in degree of solubility in water (HD almost nil, other agents somewhat more), and which penetrate into paintwork. All washdown, hosing, or detergent-scrubbing decontamination methods are based on these agent properties, but they must also take into account one additional fact; the agents are violently toxic; one-tenth of a drop in the eye or one-half a drop left on the skin may be a lethal dose.

9770.77. DECONTAMINATION OF CLOTHING, PROTECTIVE MASKS, FOOD, AND WATER

The currently approved method of BW/CW decontamination of all woven clothing items requires a standard "wool-wash" (NAVPERS 10291) to which is added 0.2 percent (2000 ppm) available chlorine in the first suds. To obtain this concentration, one-fifth the normal volume of water is added in the form of the usual one-percent liquid bleach (NAVPERS 10291, p. 28), or calcium hypochlorite, in the amount of one-quarter ounce per gallon of water in the washer, is dissolved in a bucket and then added to the load.

The procedure for decontaminating wet-weather (rubberized) clothing follows; except in cases of heavy contamination, it is believed that it will prove adequate. The procedure is to wipe off, using a cloth moistened with one percent hypochlorite solution, all visible agent. The garments are then dipped in one percent hypochlorite, rolled up wet, allowed to stand for one to 24 hours, rinsed in fresh water, and dried. The initial need for decontamination, and the effectiveness of any decontamination method selected, can be determined as recommended for gas masks: place one or more garments in a tightly covered metal container in a warm location for four hours, then apply a detector kit test to the air between the garments.

Two alternative procedures are recommended for the CW decontamination of the Mk V protective mask. The first is also satisfactory for BW decontamination, but an immersion period of 15 minutes is considered adequate.

1. Wipe all surfaces of canisters with a cloth moistened with one percent calcium hypochlorite, wipe with a cloth wet with fresh water (do not allow any liquid to enter either opening of canisters), wipe completely dry, and set aside for reassembly on facepiece. Dip complete facepieces, with head harnesses, in one percent calcium hypochlorite, leave wet or immersed for one to 24 hours (for the shorter exposures, use warm hypochlorite solution), rinse thoroughly in warm fresh water, dry completely in a warm to hot current of air (as in machinery spaces), test for agent residues. Any cloudy condition of the eyepiece will gradually disappear as dissolved water evaporates. Test facepieces for CW agent by placing one or more in a tightly closed metal container and leaving in a warm area (100° to 140° F.) for four hours. Then sample the air in the container, using the maximum number of bulb compressions allowed by the detector kit instructions. Wearers of decontaminated masks should be watched by medical personnel for eye irritation.

2. As a supplementary treatment to the above methods, if one is required, masks can be aired in a current of warm to hot air (100° to 140° F.), as in machinery spaces, for two days to one week. Masks should be supported so as to minimize stretch or distortion, and not allowed to come in contact with oil or grease.

The BW/CW decontamination of food and water is described in instructions from the Bureau of Supplies and Accounts (Instruction 3300.6). There is little reason to expect direct BW/CW contamination of food (except vegetables stored topside) or water. Covert (sabotage) contamination of food or water is recognized as difficult but highly profitable for an enemy. If such contamination is suspected or definitely indicated, the foods subsequently served may require special selection and/or extra-thorough cooking, and drinking water may require super-chlorination. Other appropriate countermeasures cannot be forecast, but will be determined by medical and command personnel.

9770.78. PERSONNEL DECONTAMINATION

Personnel decontamination stations are used both for BW/CW and for nuclear-fallout decontamination (see chapter 9900.124). The method of operation for all three types of contamination is essentially the same; all details are calculated to give the most thorough removal of the oily CW agent, the dry BW agent, or nuclear fallout contaminants that is possible by a soap and water treatment. The process is described elsewhere, but certain points are to be emphasized. In the first place, the process is one of removal of contaminants which are inherently extremely difficult to remove. As with decontamination of materials, use of much water is of little value; what counts is thorough and vigorous detergent-and-water scrubbing and rubbing, with emphasis on the parts of the body most likely to be contaminated, and on skin cracks and crevices (as around fingernails) and hairy areas. The use of moderate quantities of one percent hypochlorite solution (laundry bleach) together with detergent is expected to give better results than the use of soap alone. The liquid bleach can be picked up in the cupped hands from containers provided in the decontamination station, and rubbed onto all parts of the body while waiting for use of a shower. Slight but harmless irritation may be expected on delicate areas; the liquid should **not** be allowed in the eyes.

With BW contamination, rapidity of removal is of little importance other than to make way for other men and to return to duty. With NW contamination, speed is more important but not crucial.

With CW contamination, if contamination is actually or probably present on the body, speed is of maximum importance. Only the parts of the body most likely to be contaminated should be given detailed attention at first; thoroughness coupled with speed is paramount. Then consideration must be given to other men waiting for decontamination; all waiting must be minimized by efficient use of facilities. It is highly desirable that personnel decontamination facilities should be able to take care simultaneously of at least half the exposed topside personnel. Personnel **waiting** to enter the decontamination station should be provided with buckets of hypochlorite/detergent solution, cellulose sponges, and topside showers. These items provide for a preliminary decontamination of clothing and for personnel cooling. Topside showers can be improvised using firehose and fog nozzles. For efficient operation of a decontamination station, it is desirable that personnel be given help in removal of clothing. Body contact with contamination on the outside of clothing is minimized by removing the outer garment first, then footwear, gloves, socks, and underwear, in that order. The protective mask is removed last, just before showering.

9770.79. DETECTION

Liquid Chemical Agent Detector Paper M6 or M6A1[21] (figure 9770-18) is an exceptionally versatile material and today is the Navy's first-line item for detection of liquid CW agents. (It is generally marked "Liquid Vesicant Detector Paper.") If in place at suitable points on the ship, it is continually ready for instantaneous response to droplets of all known liquid CW agents. It is usually serviceable for a matter of weeks, and its response can be checked at any time by application of a drop of methyl salicylate (oil of wintergreen), a medical store item, which gives the same red color as do the liquid CW agents. The M6 paper does not provide **advance**, or warning, detection; it only shows that liquid CW agent is already on the ship and on its topside crew.

It is important to note that M6 paper responds identically (by a green-to-red color change) to **all** liquid CW agents. That is, its response is exactly that required to indicate the MC class of CW agents. The value of M6 (or M6A1) paper as a universal detector of liquid CW agents is obvious when it is recognized that all the liquid, or MC, agents require the same initial personnel-protective and ship-protective actions. Identification of the particular agent or agents present is necessary and is to be given a high priority, but the required initial actions by command and by individuals are to be taken at once, before specific agent identification is made by one of the kits or other devices. Droplets of the MC agents all result in detector-paper spots having a diameter four to five times that of the droplets themselves. This "magnification" aids in the detection process, but close and careful inspection is nevertheless required to observe the spots resulting from droplets of 100 to 200 microns (0.004 to 0.008 inch) or less. Based on the previous discussion of small-particle impaction, it will be recognized that the M6 paper will be a more efficient and sensitive detector of smaller particles if it is curved around a pipe, stanchion, or other cylindrical object which is not more than an inch or so in diameter. In the form of a vertical cylinder the detector paper also is effective for a wide range of relative wind directions, and is less exposed to the deteriorating effect of sunlight. During periods of probable CW attack, the detector paper should be under observation at continuously manned watch stations which are fully exposed to the weather and located as far forward (or windward) in the ship as is practical. At night, the paper cylinder must be capable of periodic removal to a lighted area for examination.

The shelf life of detector paper is 10 to 20 years at 70° F. At temperatures between 125° F. and 150°F. the paper may change color slightly and lose sensitivity over a period of months. However, useful sensitivity is retained after six months at 165° F. Stored paper should not be discarded unless a spot test with oil of wintergreen shows development of the red color to be markedly slower or weaker than on fresh paper. Outdoor weathering also results in deterioration, and this is accelerated by high temperature and intense sunlight. Three weeks is an average topside lifetime for M6 detector paper. Exposed paper can be tested for sensitivity in the same way as stored paper.

Of the various fuels and other liquids present in large quantities on Navy ships, only Cellulube 220 hydraulic elevator fluid gives a response on M6 paper that in any way resembles that of liquid CW agents. As can be easily demonstrated, however, the Cellulube 220 response is

[21] M6 and M6A1 papers differ only in size. Sheets of the former are 5 x 5 in.; the latter are 2-1/2 x 3-1/2 in.

comparatively slow and pale. Dilute acids, alkalis, and hypochlorite produce no color change.

Chemical agent detector paper M8 (figure 9770-18) is a new material, and distinctly different from M6 paper. M8 paper also is described as 3-way or differential detector paper. At present it is furnished only as a component of the detector kits. It can be mounted at the same location as the M6 paper, or reserved for follow-up tests after the M6 paper gives a positive response. The M8 detector paper responds differently to the three major types of liquid CW agents. The color with mustard is red; with G agent, yellow; and with V agents, greenish-black. Variation in color occurs with agent mixtures. M8 paper is valuable in rapidly identifying a liquid agent by type after M6 paper has shown that a liquid agent is present. Although an effort should be made as soon as possible to confirm the M8 test with the regular kit tests, agents of very low volatility may not furnish enough vapor for a positive kit test.

The M6 paper is expected to remain the primary detector for liquid CW agents on shipboard for the following reasons: 1. Since the color change of the M6 paper is the same for all liquid CW agents or any combination of them, the observer is not required to decide whether a spot on the paper is red, yellow, greenish-black, or none of them. He can therefore sound the alarm more quickly and surely. 2. The M6 paper will give the correct red response to any liquid CW agent mixture, whereas M8 paper will give uncertain or indefinite colors with some mixtures, and may indicate some mixtures as single agents only. 3. The M6 paper is less apt to give a false alarm. On M8 paper a spot of soot or black oil may resemble the greenish-black V agent test.

Two CW agent detector kits are available to most Navy ships. The M15A2 is shown in figure 9770.20 and the M18A2 in figure 9770.20. Similar views of the M18A2 kit and its refill kit are shown in figures 9770-22, 9770-23, and 9770-24. The M15A1 kit provides tests for the following agents or agent types: nerve agents (the enzyme ticket test), G agents (a separate test), H agents, CK, and CX. The M18A1 kit provides the above tests and, in addition, tests for arsenicals (L and ED), AC and CG.

Many ships still have the M15 and M18 kits rather than the newer A1 models. The A1 kits are a radical improvement over the earlier models in that they contain the enzyme ticket test. This is a very sensitive test for all nerve agents, including V agents. The M15 and M18 kits cannot test for V agents.

The detection kits, in contrast to the detector papers, are to detect the presence of CW agents in the vapor state, and to identify particular types of agents. They give no advance warning of approaching gases or aerosols. Their purpose, once a CW attack is known to have occurred, is to identify the agent or agents for guidance of the Medical Department, and to tell when protective masks may be removed with safety. The kits may also be used to locate the contaminated and uncontaminated areas of the ship, and to check the completeness of decontamination. Since the kits are designed to take air samples only, auxiliary means must be used to test for contamination of material or surfaces. Clothing, gas masks, and similar items to be tested can be placed in a tightly covered metal container for an hour, and the air close to the material then tested. The container serves to confine and retain the agent that evaporates; in the open most agents evaporate so slowly that the vapor is carried away before enough accumulates to provide a sure test. Similar confinement of the air in contact with a section of deck or bulkhead can be accomplished by covering the section with a small shallow can. After a few minutes a hole is punched in the container to permit the insertion of the end of a detector tube or detector ticket, and the air sample taken. A visible liquid film can be identified for the specific agent present by wiping with a small piece of absorbent cotton, cloth, or paper, then holding the cloth or paper in contact with the detector tube or ticket while an air sample is drawn through it. Such a film can, of course, be given the tests for liquid CW agents by pressing against it a piece of M8 or M6 paper, or both. M6 paper never should be wiped or rubbed on a surface. The abrasion alone can produce red marks which might be regarded as a positive test.

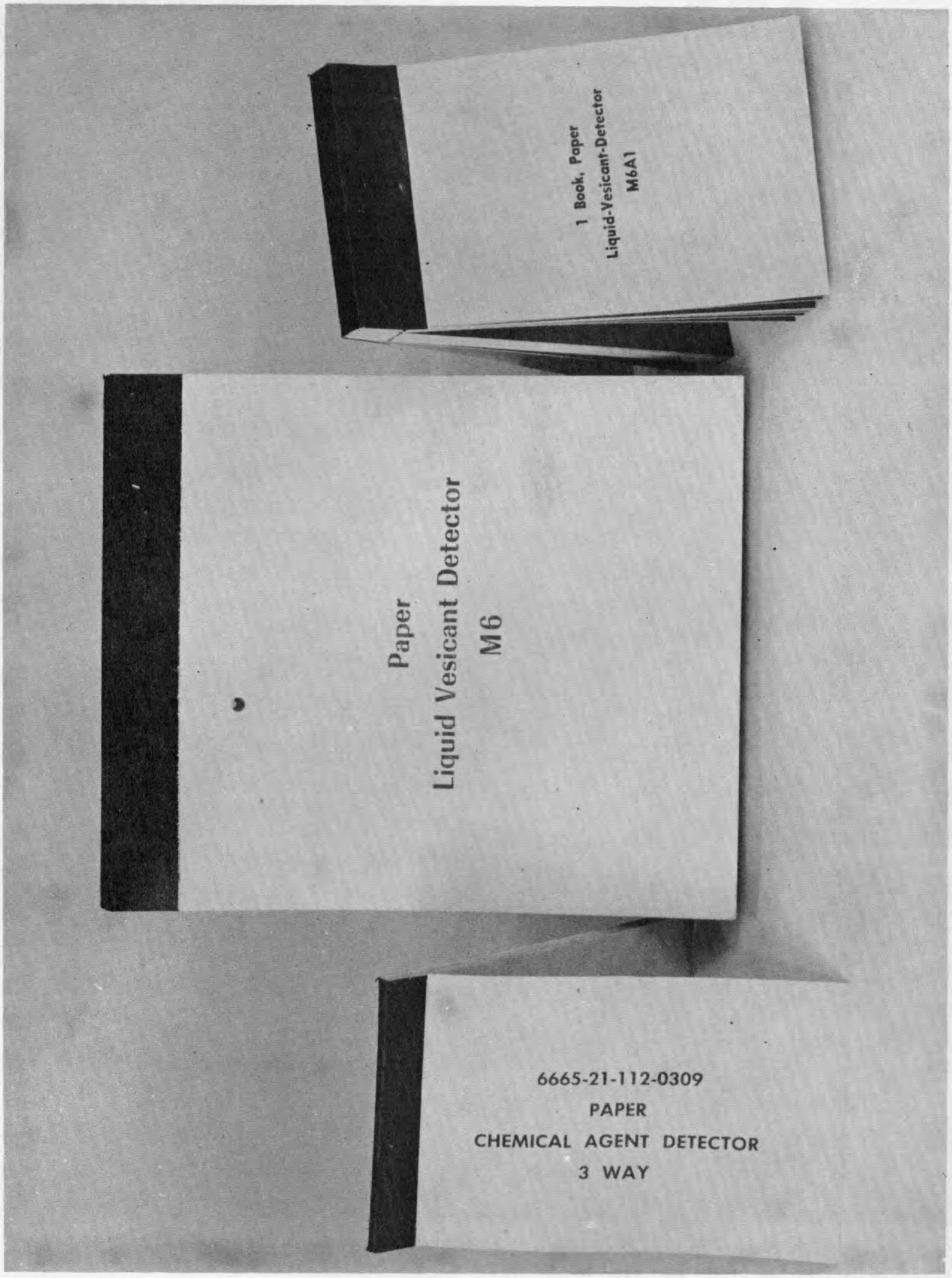

Figure 9770-18. Chemical agent detector papers.

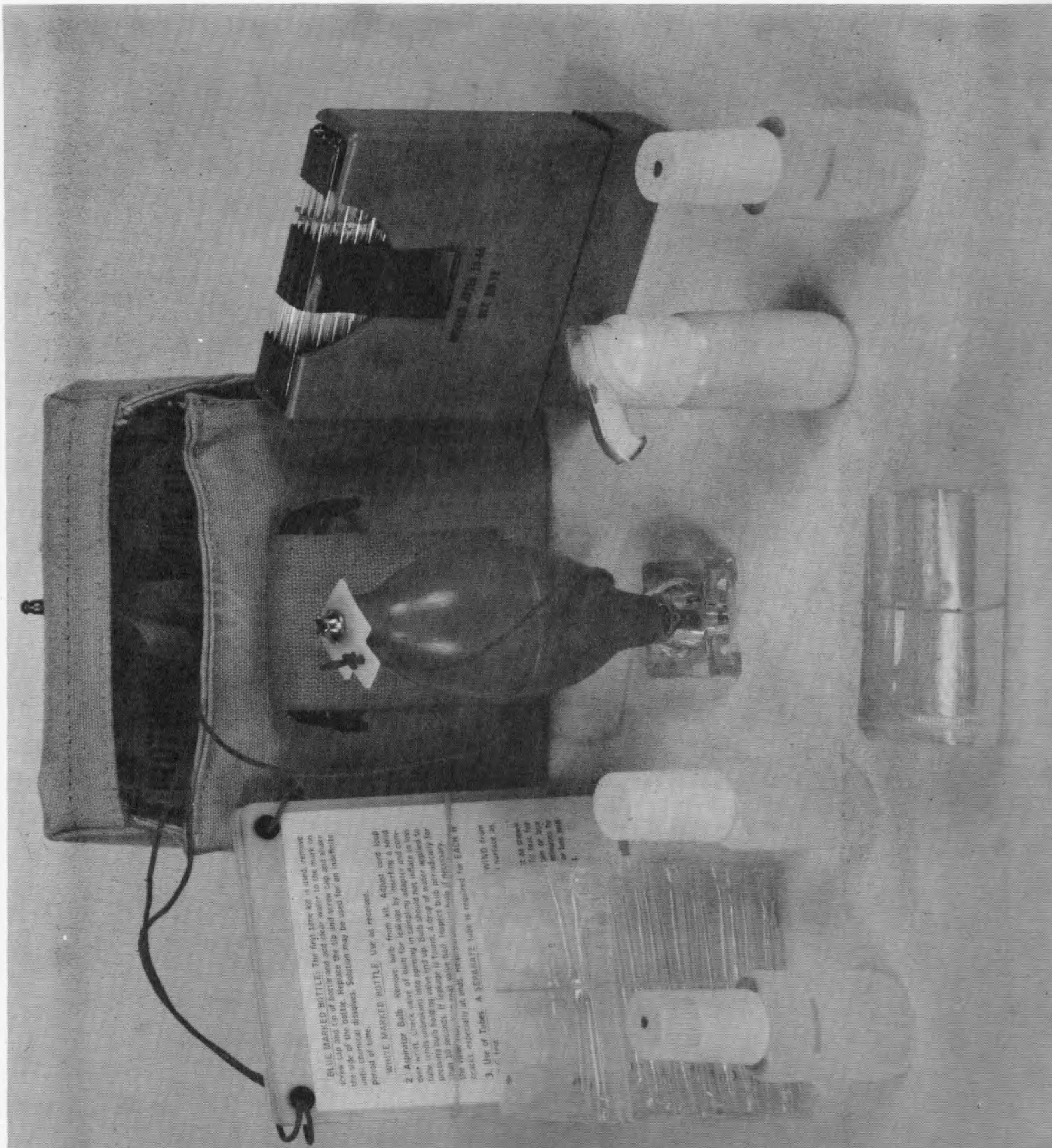

Figure 9770-19. Open view of M15A2 CW agent detector kit.

Figure 9770-20. Open view of M18A2 CW agent detector kit.

Detector kits will give more rapid, direct, and reliable results if one or more well-protected men perform the sampling, and if the other steps required in using the kit are taken by personnel inside the ship in good light and under conditions favorable for handling the various kit components. The latter men obviously must wear protective gloves when handling detector tubes, tickets, or other components which may be contaminated.

It is now recommended that all detector kits, except those regularly used in training, be stored under refrigeration–the coldest available. This will greatly prolong the storage life of the kits, reduce the expense of periodic replacement, and improve combat readiness. Kits placed in cold storage should be conspicuously marked for easy recognition. Securely-fastened tags should bear the normal kit expiration date; the date placed in cold storage; the dates of removal from and replacement in cold storage, if any; and the ship's name, cold storage compartment, and temperature, Following are estimates of the storage life of M15A2 and M18A2 kits.

Table

Effect of Cold Storage on Life of Detector Kits

Storage Temperature, Degrees F	Storage Life Improvement Factor	Kit Storage Life, Years
70	1	3
40	2.9	9
33	3.7	11
15	7.6	23
0	14	42

Valuable extensions of the storage life of detector kits are also given even though a considerable time has elapsed between the date of manufacture and the date placed in cold storage. Typical details are given in Table

Table

Total Lifetime of Detector Kits Stored at Normal Temperature Then Placed in Cold Storage, Years

Cold Storage Temperature,	Time Elapsed from Date of Manufacture Placed in Cold Storage, Years				
Degrees F	0	1/2	1	2	3
40	9	8	7	4	3
33	11	10	8	5	3
15	23	19	15	7	3
0	42	35	28	14	3

9770.80. SELF AID AND FIRST AID

Although it is not the function of this chapter to provide medical information or instruction, it is desirable that every opportunity should be taken to familiarize personnel with the essentials of the medical or medical-related aspects of BW/CW defense. These essentials are:

1. Self-aid removal of CW agent droplets from eyes by thorough flushing with a gentle stream from any available source of water, fresh or salt. Flush each eye alternately for a few seconds, for a total of two minutes, holding lids away from eyeball with clean thumb and forefinger. Speed is of utmost importance.

2. Self-aid use of M5 ointment to remove a few drops of CW agent, from a relatively small area of the skin, after first flushing the skin area with water, and blotting dry. Follow instructions on the M5A1 Protective Ointment Kit (flat, olive-brown can), which is packed in the Mk V protective mask carrier. The M5 ointment is the **large** tube, wrapped in gauze. This kit also contains the atropine injector (syrette). Extensive contamination of the body with liquid CW agent is best removed by an extremely thorough soap-and-water shower, with use of hypochlorite solution, in a decontamination station. Protective ointment M5 is not to be used in or close to the eyes, as it is extremely irritating to these tissues.

3. Self-aid, or buddy-aid, use of the atropine syrette to inject one dose of atropine in leg, thigh, or meaty part of shoulder or arm, **when use of this item is indicated,** should conform to Bureau of Medicine and Surgery policy. At present this states that the individual injects one syrette of atropine, his buddies inject the next two syrettes, and over three syrettes are injected under medical supervision. If medical supervision is unavailable, the officer or petty officer in charge may authorize the administration. Syrettes should be given at ten-minute intervals as needed. Initial PAM (see Glossary) may also be given by other than medical personnel.

4. Buddy-aid use of mouth-to-mouth artificial respiration on personnel who have severe difficulty in breathing or who have collapsed, due to nerve agent exposure. All shipboard personnel should be drilled in this highly effective treatment, which can also save lives of personnel who have lost consciousness due to drowning, electrical shock, or smoke suffocation. Details of the treatment, while simple, must be followed correctly. There need be no fear of inhaling nerve-agent vapors from the mouth of a victim, but appropriate precautions should be taken if the victim's face is contaminated. In a toxic atmosphere, the patient and buddy must wear masks, and the back-pressure arm-lift method used for respiration.

5. Use of hypochlorite solution by self or buddies, to decontaminate the mask, clothing or body parts while waiting to enter decontamination stations. Equipment or skin believed to be contaminated should be well sponged and rubbed with the solution; to keep hypochlorite out of the canister, the mask should be rubbed with a **moist** (not saturated) sponge only. The solution may be left on the clothing, but the skin should be flushed free of hypochlorite using showers outside the decontamination station. Special care should be taken to keep hypochlorite out of the eyes.

SECTION III. INDUSTRIAL BW/CW DECONTAMINATION

Part 1. Introduction

9770.91.

Industrial decontamination implies BW/CW countermeasures which are beyond the ship's own ability to perform. Normally, it will be conducted at or near a shipyard, advanced base, or other Navy industrial facility.

Although industrial BW/CW decontamination introduces no new principles, it does involve three factors not found in decontamination at sea. These are: 1. The ability to suspend all normal activity and withdraw all personnel from any or all sections of the ship; 2. the availability of kinds and quantities of materials and facilities not present aboard ship; and 3. the presence of BW/CW contamination in areas or quantities not typical of enemy action. For these reasons, industrial decontamination will often differ from decontamination at sea in the details of its application of basic principles, and in the scale of its operations.

Industrial BW/CW decontamination will normally aim at chemically-complete decontamination rather than the operationally-complete decontamination which is characteristic of BW/CW countermeasures at sea. However, owing to the effect of time and weather, chemically-complete topside decontamination will be relatively easy to accomplish at an industrial facility. The ease with which below decks industrial decontamination can be carried to a chemically-complete stage will depend on the extent to which the ship's force has isolated the contamination and physically removed surface contamination.

Part 2. Plans and Preparations

9770.101.

The first step in the industrial decontamination of a ship is to make a careful estimate of the situation with regard to the following factors. As far as practical the estimates should be made prior to arrival of the ship at the assigned berth or mooring. The ship's force can perform a preliminary CW evaluation, but is not equipped to evaluate BW contamination. Therefore the ship should be isolated until the BW evaluation can be performed, and the ship's CW report checked.

1. The agents or classes of agents present.
2. The extent of the contaminated areas of the ship.
3. The presence within such areas of sensitive equipment, such as communications or ordnance material.
4. The degree of contamination, such as pools of liquid, thin films of liquid, or contaminated paint or grease with no liquid agent visible.
5. Accessibility of the contaminated sections and routes by which they can be reached.
6. Special problems in personnel movement, including transfer of personnel to and from the personnel dressing and decontamination site.
7. Feasibility of normal or jury-rigged ventilation.
8. Availability of steam, fresh water, and electric power.
9. Availability of butyl-rubber protective clothing, and means for its decontamination daily.
10. Air temperatures to be expected below decks, topside, and in transit of rubber-suited personnel.
11. Feasibility of cooling rubber-suited personnel by cool-air blast, evaporative cooling using an absorbent overgarment, or periodic drenching with cool water.
12. Length of work periods, and number of work periods per day, which can be expected of rubber-suited personnel.
13. The availability of clean and tight barges or tanks for holding contaminated water.
14. Facilities for personnel dressing and undressing and for personnel decontamination.
15. Medical facilities which are equipped and trained to handle cases of exposure to the agent(s) being decontaminated.
16. Bacteriological laboratory facilities for taking and evaluating surface and air samples for BW contamination.

Decisions and plans are then made as to the decontamination procedures to be used, the supplies and facilities required, the number of personnel needed, personnel training and possible dry runs, personnel deployment for operations, monitoring and safety procedures, and approximate scheduling of all phases of the operation.

The contaminated ship should be located at an isolated point, though not necessarily a remote one. A location at which the prevailing wind is toward unoccupied areas is highly desirable. Steam and electric power from the ship's own system, from the shore, or from a service craft will be a normal requirement. There need be no unreasoning fear of the hazard of CW vapors or BW aerosols to nearby ships or areas, inasmuch as this will not be materially increased by controlled decontamination processes. Moreover, the hazard should decrease rapidly as the work progresses. In any case, the operations plan will include frequent monitoring of the atmosphere in appropriate sections of the ship and in nearby areas downwind.

The evaluation of aerosol or surface samples for BW organisms normally requires 24 hours or longer. Therefore, in crucial phases of BW decontamination, it may be necessary to defer subsequent shipboard operations until laboratory evaluation reports have been received.

Part 3. Operations

9770.111.

As previously emphasized, the CW decontamination process in general will recognize that the liquid CW agents are extremely toxic oily subtances which readily penetrate paint, greasy or porous materials. BW industrial decontamination operations will recognize that BW agents are best decontaminated in place, with special precautions taken to avoid the setting up of secondary aerosols of the microbes.

The specific decontamination processes and procedures selected will depend on the nature and quantity of BW/CW agents present, on their location on the ship, and on the materials and facilities available. Two examples will be given, together with suggested actions.

9770.112. CW DECONTAMINATION

A ship has received extensive topside contamination with CW agent(s) believed to be a VX-mustard mixture. Ventilation intakes and fans are extensively contaminated, cool surfaces in machinery spaces are moderately contaminated, and there is very light contamination of a number of compartments throughout the ship, including the hot areas of machinery spaces. A very thorough chemically-complete, decontamination job is required in order that repair of battle damage and modernization of major facilities can go forward at maximum speed without the necessity of protective masks or clothing for shipyard workers.

It is assumed that the operationally-complete decontamination of the ship, previously carried out at sea, has included all-over topside use of washdown and firehosing, plus application of standard decontamination solution to personnel-traffic and personnel-contact areas. In addition, weathering will have improved the effectiveness of the operationally-complete decontamination.

A major remaining problem may be retention of BW/CW agents in greasy or oily surfaces. This can best be dealt with by a degreasing operation. It is therefore recommended that the first decontamination step topside, after the initial survey (9770.101), be the all-over spray application of a light-duty or medium-duty solvent emulsion cleaner, cut with diesel oil in proportion as for light-duty cleaning. This diluent will minimize the fire hazard and will remain on surfaces without evaporating for an extended period, thus promoting extraction of CW agent from paint, etc. The emulsion cleaner should be one that can be applied to all topside fittings or equipment without causing significant deterioration other than through removal of oil or grease film. The cleaner should also be one that will not cause any substantial degradation or deterioration of paint or rubber. In areas known to be greasy or oily or heavily contaminated with CW agents, the cleaner should be applied with sufficient rubbing or force to dissolve fully the oily material. After 24 hours or longer, the entire topside should be very thoroughly hosed down with fresh water, or salt water followed by fresh water, until all traces of the emulsion cleaner are washed over the side. In an industrial operation, it is very unlikely that this topside wash water will contain sufficient agent to result in detectable contamination of the adjacent body of water. Retention of this water in tanks or barges for further decontamination and disposal may be necessary in certain areas, however. The ship should now be essentially oil and grease-free topside.

Since ventilation fans and contiguous ductwork are relatively small in area, and are also difficult to reach for repeated decontamination treatment, it is recommended that they be decontaminated with the standard hypochlorite-detergent decontamination solution, as for decontamination at sea. The entire contaminated area should be vigorously scrubbed or swabbed with the mixture. Approximately four hours after the scrubbing is completed, the hypochlorite should be removed completely by wiping or hosing. Any hypochlorite remaining will be an active source of corrosion. The amount of liquid applied should be kept to a minimum to prevent it running to inaccessible sections of ductwork. The location and degree of contamination may require removal of ductwork for separate treatment.

A resurvey now can be made to detect residual topside contamination, with extra attention given to the following points and areas: those likely to have been heavily contaminated, those difficult to reach with decontaminant, and those likely to retain contaminants tenaciously. In the third group of areas are corners and crevices, enclosed or concealed sections of machinery and fixtures, porous or still-greasy surfaces, and many painted surfaces.

Painted surfaces still giving a positive test can be treated with a paint stripper to remove agent and paint together. Strongly alkaline types are preferred for nonsensitive surfaces such as decks and bulkheads, because the alkali assists in destroying the agent. However, for surfaces sensitive to alkali, such as aluminum, an organic-solvent stripper must be used. In either case, the subsequent water flush to remove paint and agent residues must be run into a holding tank or barge for subsequent treatment as required. Treatment should involve: 1. holding until alkaline hydrolysis is complete, or 2. the addition of dissolved hypochlorite, in the amount of one-half pound of calcium hypochlorite per 100 gallons of water, to accelerate destruction of CW agents, together with a means of recirculation or other adequate mixing.

A similar process is suggested for painted surfaces below decks. However, two special factors may now apply: sensitive communications and other equipment may be present, and large amounts of oil and grease will in all probability be present in machinery spaces and bilges. The sensitive equipment, whether below decks or topside, should be treated by the simplest procedure that will effectively decontaminate. The solvent-emulsion treatment may have to be repeated with greater emphasis on reaching concealed ports, and on agitation, scrubbing, or other mechanical action. Prolonged ventilation with air as hot as the equipment will tolerate may be tried.

If these treatments are inadequate, the procedures of this manual[22] for reconditioning flooded equipment should be used, without, however, applying sea water at any time. It is not believed that an ultrasonic treatment[23] will normally be required. The contaminated machinery spaces and fittings are probably best given one or two all-over treatments of a heavy-duty solvent emulsion cleaner cut with diesel oil. Scrubbing and additional applications of emulsion cleaner may be required on exceptionally greasy surfaces. After all surfaces are thoroughly flushed with fresh water, which is drained to the bilges, two further steps can go on concurrently. When dry, the treated surfaces can be tested for agent, with positive-test areas further treated with alkaline paint stripper; and the bilge water-oil mixture, with the addition of emulsifying agent, can be continuously recirculated by pumping to dissolve or take into suspension all agent-contaminated oil and grease.

The bilge treatment[23] is similar to that used for cleaning fuel-oil tanks, etc.; an ample supply of alkaline heavy-duty emulsion cleaner is used, and steam heating is carried on carefully to avoid producing excessive amounts of agent vapor. If the vapor concentration remains low, the bilge water and emulsified oil is heated by steam, with recircu-

[22] Naval Ships Technical Manual, chapter 9190.

[23] Bureau of Ships, Journal, July, 1959, Page 24.

lating pumping, until all oil and grease is believed to be in suspension. The addition of small amounts of previously dissolved calcium hypochlorite is recommended to promote decontamination of the bilge water in place. One-half pound of hypochlorite per 100 gallons of water should be sufficient. This is a 0.05-percent solution. The bilges now can be pumped and flushed until clean, and the water retained and treated as necessary in the same holding tank or barge mentioned previously. If consistently positive tests for agent still are obtainable on bilge surfaces, the above treatment is repeated with a longer period of recirculation and with both the recirculation and steam heating optimized in the contaminated zone.

It is believed that the above typical and generalized procedures can be applied, with adjustment for special conditions, to most problems of industrial CW decontamination of ships.

It will be recognized that, even though approved procedures for decontamination and monitoring have been followed, contamination may persist in inaccessible areas, for example, underneath machinery foundations or behind thermal insulation. Therefore, thorough and resourceful monitoring should be conducted preceding, and in conjunction with, subsequent overhaul or repair operations. Careful check should be made of areas underneath or behind machinery and fixtures which have been removed. Spot treatment of any surface contamination found can be performed by scrubbing with a strong hypochlorite/detergent mixture, and alkaline paint remover used as required.

No general statement can be made on the practicability of decontaminating highly absorbent material such as lines, hose, tarpaulins, etc. However, it may be found economically feasible to soak such materials in a tank of one percent solution of an alkali, such as soda ash, containing 0.1 percent hypochlorite.

In connection with normal industrial operations on a previously decontaminated ship, the necessity of protection for workers should be carefully weighed. The wide use of protective goggles and butyl-rubber gloves may be deemed advisable. The need for wearing gas masks in topside areas is unlikely, but a below-decks requirements for masks may arise.

It should be noted that the use of steam-cleaning procedures, using high-pressure steam guns, has not been recommended. Although highly efficient for removing grease and heavy oils, an aerosol and vapor hazard could result from the use of such procedures on CW-contaminated material. However, it is visualized that steam-gun cleaning may occasionally be required for complex and heavy mechanisms, such as gun mounts. If steam cleaning is used, there should be full understanding of, and provision for, the hazards involved, particularly to downwind areas.

Protection of personnel conducting any industrial decontamination procedures should be thorough and complete, using special butyl-rubber suits throughout. Facilities for change of clothing, personnel decontamination, and medical supervision will be required also (see chapter 9900). Although all of the steps listed are calculated to minimize vapor concentrations, if these appear to be high, air-line masks for industrial decontamination workers may be preferable to the standard Mk V mask (the hose line itself must be carefully guarded for contamination, which might soak through and contaminate the breathing air). No man should work in below-decks contamination without a safety observer, equally well protected, nearby. Responsible and expert supervision must be exercised in all phases of the operation. This supervision includes the frequent, careful, and judicious use of detection apparatus to ensure personnel safety and adequacy of decontamination.

9770.113. BW DECONTAMINATION

If the ship under treatment is known to be BW-contaminated, a survey of the location, extent, and degree of the agent deposits is indicated, as for CW contamination. This will require the services of an experienced bacteriological laboratory, which will also supply information on the identity of the BW agent, and therefore of its susceptibility to standard decontamination procedures. However, only the most resistant spore-forming organisms can be expected to survive topside weather conditions until the ship's arrival at an industrial facility. In case such are detected, an all-over topside treatment with standard hypochlorite-detergent solution will be required. Scrubbing accessible areas with the solution is highly desirable. All solutions must be flowed on to minimize secondary aerosols. The final removal of detergent and hypochlorite may be with fire hose. Interior decontamination, however, is the most likely problem, with the locations and degree of contamination resembling those cited above for CW agents. Although BW agents may be expected to adhere to painted surfaces, they do **not** penetrate or diffuse into these materials as do all liquid CW agents.

Large-scale industrial decontamination of a ship's interior normally will use one of the proven vapor-phase decontaminants, such as formaldehyde, ethylene oxide, carboxide, ethylene oxide/Freon, or beta-propio-lactone (BPL). All are relatively noncorrosive, although an end-product of the beta-propiolactone treatment is a very dilute solution of propionic acid. This acid is comparable in corrosiveness to vinegar. Formaldehyde (formalin) is perhaps the simplest and most readily available. It is easily vaporized with steam, which also supplies the heat and high humidity required. Excessive persistence of the formaldehyde odor can be countered with a light post-treatment with ammonia vapor.

No vapor-phase decontaminant is regarded as an all-purpose BW decontaminant. Formaldehyde requires relative humidities above 70 percent and temperatures above 70°F. Ethylene oxide excels in penetrating power, and is effective at low relative humidities but is slower than formaldehyde, and is inflammable unless diluted with carbon dioxide (Carboxide) or Freon. BPL is the most potent BW decontaminant, and will work at cool temperatures, but requires relative humidities of at least 70 percent, and at present must be stored under refrigeration. BPL is a vesicant, and rubber or leather, which has been exposed briefly to BPL vapor, can produce severe reactions when worn in close or confined contact with the skin. Although BPL is of proven effectiveness in decontaminating the interiors of large structures contaminated with resistant spores, its use at present requires specially-trained or professional personnel.

To ensure that the vapor-phase decontaminant reaches all contaminated sections of ventilation systems, access plates must all be removed. Direct injection of steam–formaldehyde or other decontaminant into weather ends of the ducts and into fan housings may be advisable.

It cannot be stated at present that a 24-hour treatment with one of the vapor-phase decontaminants will kill all organisms on greasy surfaces or in bilge water. Therefore, the post-decontamination survey will check these points in particular. A solvent-emulsion treatment may be required prior to a second vapor-phase decontaminant application to assure removal of the grease and oil which may protect organisms from the decontaminant vapor.

APPENDIX B

Bureau of Ships Master Allowance List Summary of BW/CW Defense Clothing and Equipment for Representative Ship Types

	AD	AGE	AO	APA	APD	ATA/ATF	CA/CAG	CLG	CVA41	CVA59	CVS	DD/DE	DLG	LST	MSF	MSO
Protective Mask, Mk V 4240-268-9732	105% of Wartime Complement →															
Impregnated Clothing Outfits 8415-261-6667, -6668	25%	*30%	25%	*30%	*30%	30%	of Complement →									
Rubber Overshoes, Pr. 8430-144-1651	25%	*30%	25%	*30%	*30%	30%	of Complement →									
Rubber Gloves, Pr. 8415-753-6551	54	45	63	54	18	18	72	63	216	387	198	27	27	27	18	18
Detergent, Decon., Lbs. 6850-664-2008	200	150	200	300	100	50	250	200	700	1300	650	100	150	100	50	50
Detector Kit, M15A2 6665-903-4766	4	4	4	4	4	2	10	10	20	20	16	6	6	4	4	2
Detector Kit, M18A2 6665-893-4767	2	4	2	2	2	2	4	4	6	8	4	2	2	2	0	0
Detector Paper, M6A1, Book 6665-285-6175	8	8	8	8	8	4	16	16	16	16	16	8	8	8	4	4
Test Kit, Impregnated Clothing 6630-368-6147	2	5	2	5	1	1	5	5	8	9	6	1	1	2	1	1
Knee Boots, Rubber, Pr. 8430-147-1019	36	30	42	36	12	12	48	42	144	258	132	18	24	18	12	12

*Plus additional outfits, if needed, to outfit boat crews.

(A listing of BW/CW medical defense items can be obtained from Code 7214, Bureau of Medicine and Surgery, Navy Department)

APPENDIX C

Glossary

ABC	Atomic, biological, and chemical; applied to warfare; an obsolete term which has been replaced by NBC. Also a collective term for America, Britain, and Canada in reference to BW/CW items jointly standardized.
Adiabatic lapse rate	A condition of temperature balance between all levels of the atmosphere such thot there is no tendency for vertical air currents; in dry air it is a decrease of 5.5° F. per 1000 feet of altitude.
Aerosol	A suspension of fine liquid or solid particles in air, the particles being small enough to remain suspended for a significant period of time.
Agent	An active toxic material, or other primary functional material, of biological and chemical warfare; in addition to antipersonnel agents, it broadly includes smokes, incendiaries, anticrop and antianimal materials.
Air change	An air volume equal to a compartment volume; passage of this volume of air through a compartment; a misleading term in that, with good mixing, only 63 percent of the air originally in a compartment is removed by one air change.
Atropine	A drug capable of partly reversing some of the effects of nerve agents.
Biological warfare agent	Any micro-organism militarily useful in causing disease in man, plants, or animals; also biological agent or BWA.
BPL	Beta propiolactone, a chemical useful in vapor-phase decontamination of BW agents.
Buddy aid	On-the-spot and immediate assistance given by any available person to a crew member contaminated or affected by CW agents; includes injection of atropine, assistance in personal decontamination, and artificial respiration.
BW	Biological warfare, the intentional employment of a biological agent in military operations.
Calcium Hypochlorite	A chemical, $Ca(OCl)_2$; the standard chemical decontaminant for BW and CW on shipboard.
CBN	Chemical, biological, and radiological; applied to warfare or agents.
CC2	A chemical containing active chlorine; the impregnite or active materiol in impregnated CW protective clothing.
Chemically complete Decontamination	A relatively thorough degree of decontamination such that the appropriate chemical test fails to give a positive test for residual contamination. Comparable to industrial decontomination.
Chlorinated paraffin	An inert, extremely viscous liquid used in Class Z protective clothing to absorb CW vapors and retain CC2 powder.
CK	Symbol for the CW agent cyanogen chloride.
Class X	Navy BW/CW protective clothing which is impermeable to air and resistant to liquid CW agents; rubberized clothing; standard wet-weather clothing.
Class Y	Navy BW/CW unimpregnated protective clothing which is permeable to air and CW vapors, but is designed for complete body coverage; temporarily or partially excludes BW and liquid CW agents.
Class Z	Class Y clothing which is treated with CC2 and chlorinated paraffin to neutralize CW agents.
Collective protection	Group protection against BW and CW; provided by the ship structure and by exclusion of contamination.
Contamination	BW/CW agents alone or mixed with air, water, dust, dirt, or other material which thereby becomes a BW/CW hazard requiring exclusion, decontamination, or removal.
CS	A riot-control or tear agent; used in aerosol form; not considered o CW agent.
CX	Phosgene oxime, a quick-acting and intensely irritating CW agent.

Chemical warfare agent — Any nonliving substance militarily useful in producing death or incapacitation through biochemical action; also chemical agent or CWA.

Concentration — Quantity of material in a unit volume; for airborne CW agents is given as milligrams per cubic meter or the numerically-equivalent micrograms per liter; for airborne BW agents is given as organisms per liter; for for liquid solutions, such as hypochlorite, is given as percent by weight, or in other units. One percent concentration in water is one ounce in 3 quarts (6 lbs.) or six ounces in 18 quarts (36 lbs.).

Ct — The concentration of an airborne BW/CW agent, multiplied by the length of exposure in minutes; dosage; exposure.

Decay — Decrease in concentration of BW or CW agents in the air or on surfaces; due to ventilation displacement of air, death of airborne organisms, or evaporation of CW agents from surfaces; often follows an exponential course, initially fast but becoming progressively slower.

Decontamination — In a broad sense, any process which reduces or eliminates the effect of BW/CW agent at a particular point; in this sense it includes not only chemical neutralization, destruction, or sterilization, but also simple removal by washdown or evaporation. In a limited sense it refers only to actual detoxification of CW agents or sterilization of BW agents.

Detection — A process by which the approach or presence of BW/CW agents is made known. See also warning-detection and identification-detection.

Detergent — A soap-like cleaning and emulsifying substance. In a broad sense it includes soaps, but commonly refers only to modern synthetic, non-soap detergents or surfactants which are usable in either fresh water or sea water.

Disinfection — A process which renders BW agents or bacteria incapable of producing infection; an inexact term which may imply something less than complete sterilization.

Dosage equivalence rule — The rule that the BW/CW dosage in an enclosed but non-airtight space, which is exposed to a contaminated outside atmosphere is the same as in the outside atmosphere; a limiting or ideal rule which is approached more or less closely in practical situations.

Dynamic test — A test for compartment tightness which continuously supplies air at constant rate; when a steady pressure is reached in the compartment the leak rate is equal to the rate of air supply; measurement of the supply volume and the compartment pressure defines the compartment tightness.

Enzyme — A protein which controls or accelerates a chemical reaction in a biological system; An indefinitely large number of enzymes exist; the cholinesterase enzyme in the detector ticket causes a color-producing reaction except in the presence of a CW nerve agent; the nerve agent, which is an anti-cholinesterase, or anti-enzyme, compound, reacts with the enzyme and thus prevents the color-forming reaction.

Exponential — A rate of increase or decrease in which the rate is at all times proportional to the size of the quantity which is increasing or decreasing; many natural processes occur at exponential rates.

First Aid — In the BW/CW defense system, first aid is the first help given by medical personnel; because of the quick action of some CW agents and of the possibly large number of casualties, the first steps in helping casualties or contaminated personnel must be self-aid or buddy-aid.

Gas Mask — The standard military masks for BW/CW protection are gas masks; they are not intended for protection against oxygen deficiency; the term "protective mask" is preferred.

G agent — A highly toxic phosphorus compound with anticholinesterase action; GB, GD, and GA are the common members of the group.

Germ — A nontechnical term for a disease-producing microorganism.

HD — Mustard gas; the only common member of the sulfur mustard group.

Hydrolysis — The splitting of a chemical compound by reaction with water; a major decontamination reaction; often accelerated by acid or alkaline solutions, and by the presence of hypochlorite.

Hypochlorite — Designates any of the class of hypochlorite compounds; in the shipboard BW/CW defense system, it refers to calcium hypochlorite or its solution in water.

Identification-Detection — A CW identification process which identifies the agent or type of agent present; the process is started **after** a CW agent is known or suspected to be present; the process uses the M15A2/M18A2 detector kits and/or M8 detector paper.

Impaction — Collision of an aerosol particle or spray droplet with an obstacle, followed by adherence to the obstacle.

Incapacitating Agent — A BW or CW agent which renders a person unfit for military duty without permanent injury. Riot or tear agents (CS or CN) incapacitate for a few minutes, agents which produce disorientation and confusion (BZ) incapacitate for a few hours, and blister agents (HD) incapacitate for a few days or weeks; duration of effects varies with dosage.

Individual Protection — The process or means of protecting an individual in BW/CW; includes protective mask, clothing, and clothing accessories; contrasted with collective protection.

Industrial Decontamination — Decontamination at a Naval industrial facility to render a ship safe for workmen. Comparable to chemically complete decontamination.

Inversion — An inversion of the normal temperature gradient in the atmosphere so that temperature **increases** with height; contributes to a highly stable atmosphere; normally begins at sea or ground level, but may begin at any elevation; it then is an inversion cap which blocks vertical air and aerosol movement through the cap.

MC agent — A CW agent requiring both protective mask and clothing for individual protection; includes all liquid CW agents, all of which give a red color with the M6 detector paper.

Microbe — The word formed from "micro" (small) and "bios" (life); a microorganism, generally disease producing; a pathogen.

Micron — 0.001 millimeter, 1/25000 of an inch; a human hair is of the order of 30 or 40 microns in diameter.

Microorganism — A very small living thing, not necessarily disease-producing; a microbe.

MO agent — A mask-only agent; a BW/CW agent not requiring protective clothing for adequate individual protection; includes most BW agents and true CW gases.

M5 ointment — A very viscous, olive-drab colored ointment containing an active-chlorine compound similar to CC2; useful in decontaminating liquid CW agents on the skin when hypchlorite solutions are not available.

M6 Detector Paper — The primary shipboard detector for liquid CW agents: an olive-drab paint vehicle contains a red dye which is extractable by liquid CW agents; essentially unaffected by other shipboard liquids; same response to all liquid CW agents or their mixtures.

M6A1 Detector Paper — Identical with M6 paper except for size.

M8 Detector Paper — A differential or 3-way detector paper which responds differently to V, G, and H agents; variable colors produced by agent mixtures; effective for use with kits in identification-detection, or with M6 paper in warning-detection.

M15A2 Detector Kit — A CW detector kit providing tests responsive to nerve agents, G agents, H agents, CK and CX.

M18A2 Detector Kit	A CW detector kit providing same tests as M15A1, plus tests for arsenicals (L and ED), CG and AC.
NBC	An abbreviation for nuclear, biological and chemical
NBCW	NBC warfare.
Neutral Gradient	A succession of air temperatures from sea level upward such that there is no tendency for the air at any level to rise or fall; equivalent to Adiabatic Lapse Rate (which see).
Neutral Stability	The stability, against vertical air movement, of an atmosphere in which a neutral temperature gradient exists.
Operationally complete Decontamination	A degree or extent of decontamination sufficiently thorough to allow completion of the ship's assigned task without undue hazards to personnel.
PAM	A drug which, if administered before exposure to a nerve agent, increases the effectiveness of atropine.
Physical Defense	The use of physical, mechanical, or chemical means, devices or processes of decontamination, detection, and personnel protection in BW/CW; includes all types of protection and defense except medical ones.
Pathogen	A disease-producing microorganism; microbe.
Pressure Test	A standard Navy test for tightness in which authorized compartments are pressurized to a specified value, and the time measured for the pressure to drop to a lower value.
Protective Mask	A military gas mask; the standard shipboard protective mask is the Mk V; it is designed for protection against all known BW/CW agents.
Radiological Warfare	Warfare conducted by, and with the primary objective of, the deliberate and widespread distribution of highly radioactive materials; not to be confused with nuclear warfare, which distributes radioactive materials as fallout, but only incidentally to nuclear explosions.
R of C	Rate of change of air in a ship's compartment; usually expressed in minutes per change; see Air Change.
Self Aid	Personal decontamination and administration of drugs by the person affected.
Semilogarithmic	A plot or graph in which one axis is ruled on a logarithmic scale.
Slurry	A thick, soupy suspension of a solid in a liquid.
Solvent Emulsion Cleaner	A cleaning mixture concentrate of solvents and detergents which is diluted with a solvent for use; water-rinsible.
Stable	Steady, not easily disturbed; applied to an atmosphere in which the temperature decrease with altitude is equal to, or less than, a neutral gradient.
Static Pressure Test	See Pressure Test.
Syrette	A semiautomatic device for atropine injections.
Test Kit M2	A kit for testing the CC2 content of Navy Class-Z impregnated clothing.
Ticket	A specialized item used in the enzyme test for nerve agents; consists of an enzyme-impregnated disc of paper in a plastic holder; found in the M15A1 and M18A2 detector kits.
Turbulence	Mixing of a gas or liquid by random movements or eddies; applied to mixing of the atmosphere due to wind or thermal instability.
Unstable	Unsteady; easily disturbed; applied to an atmosphere in which the temperature decrease with altitude is greater than a neutral gradient; i.e., a super-adiabatic lapse rate prevails.
Vapor Phase Decontamination	BW decontamination in which the decontaminant is vaporized, by heat or spraying, and moves as a vapor to all compartment surfaces; common vapor phase decontaminants are BPL or formalin (formaldehyde).
Vector	An insect which transmits microbes to man.

Vesicant	A blister-producing chemical, such as HD; incorrectly used in describing M6 paper because it was assumed at one time that M6 paper would respond only to blister agents.
Warning-Detection	A CW identification process which identifies the agent or type of agent present; the process occurs **simultaneously** with the arrival of the agent on the ship; M6 and M8 papers are the detectors used. Early-warning or advance-warning detectors do not yet exist for shipboard use.
Washdown	The process or system by which the weather surfaces of a ship can be continuously sprayed with sea water through piping and spray heads connected to the ship's fire mains; used pre-attack for NBC protection, post-attack for NBC decontamination, and at low pressure for personnel cooling.
Water-Emulsion Cleaner	Cleaning mixture concentrate of solvents and detergents which is diluted with water for use; water-reusable.
Wet Weather Clothing	Standard Navy garments designed for complete protection from rain and spray; adapted for NBC protection; is cooled and protected from contamination by frequent sea-water spray; Class X clothing.

APPENDIX D – BIBLIOGRAPHY

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15 January 1967
Date of Transmittal

REVISION
TO
VOLUME THREE
OF
NAVAL SHIPS TECHNICAL MANUAL

Revised pages:

Chapter 9640, page 7

Chapter 9940 (Sec. I), page 17

NAVAL SHIPS TECHNICAL MANUAL
formerly
Bureau of Ships Technical Manual

NAVSHIPS 0901-000-0034