Chapter 17

CHEMICAL DEFENSE EQUIPMENT

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INTRODUCTION

A number of countries around the world have the capability to use chemical weapons, and terrorist groups around the world display great interest in these weapons and the willingness to use them. Within the past 2 decades, incidents of chemical weapons use in armed conflict, most notably during the Iran-Iraq War, have been well documented. The most recent threat of such use was during the Persian Gulf War, when US forces were possibly exposed to both chemical and biological agents.[1] However, the threat is no longer restricted to the battlefield. Recent events such as the September 11, 2001, terrorist attack on the World Trade Center in New York City and the Pentagon in Washington, DC, and subsequent national threat warnings, have raised fears of a future terrorist incident involving chemical agents. An essential part of preparedness to ensure continued operations in a chemical environment, whether in armed conflict or during a terrorist attack, is adequate equipment. Such equipment must encompass detection and warning, personal protection, decontamination, and treatment. Only an integrated approach to these aspects of protection can ensure an effective response in a chemical warfare environment with a minimum degradation in human performance.[1,2]

The primary item of protection is the personal respirator, designed to protect individuals against volatile agents and aerosols. The respirator must be carefully fitted to ensure minimal leakage, and individuals must be well trained in donning masks (a maximum time of ≤ 9 sec is desirable). In addition to the respiratory hazard, many chemical agents are dermally active, requiring that a proper overgarment, usually containing an activated charcoal layer to adsorb chemical agent, be donned, along with protective gloves and footwear. The complete ensemble can seriously degrade individual performance; a 50% reduction in mission-related task performance has routinely been measured in tests. In addition to physical performance degradation, psychological problems in some individuals wearing the complete ensemble, owing to its claustrophobic effects, have been reported.[3] This subject is discussed separately in the attachment at the end of this chapter.

The rapid "detection and warning" of chemical agent use is critical to force protection.[4,5] Usually, the chemical agent will be delivered via an aerial or missile attack, or in an upwind release causing a cloud of agent to pass over a troop concentration. Because the effects of agents can sometimes occur in less than a minute, timely detection is required to permit all potentially exposed forces to adopt an adequate posture. Detection equipment is also used to confirm agent hazard reduction, which facilitates reducing the mission-oriented protective posture (MOPP) level and removal of protection equipment—the "all clear" signal.

Decontamination of equipment, facilities, and personnel is also required after an attack if effective military operations are to be maintained. Some of this decontamination burden can be mitigated by the use of effective collective protection equipment, which can allow continuing operations, such as communications and medical care, within protected facilities.

This chapter is not intended as an all-encompassing overview of chemical defense equipment; rather, it will describe the items and operations of greatest interest to the medical community. The following sections address in detail each of the protection areas described above. Current equipment items are featured, and items in development that are designed to overcome the deficiencies of current equipment are briefly described. Sufficient technical data are included to allow healthcare professionals to become familiar with the equipment's operation, components, and the limitations. Several sources that provide additional detail are available, including the written references and expert consultants to this chapter. Possibly of more value to the healthcare professional are chemical, biological, radiological, and nuclear (CBRN) officers who are an integral part of each combat element and can provide detailed advice as well as hands-on assistance.

One criterion for the selection of protective equipment items is suitability for joint service use; differences between the missions of air and ground crews must be accommodated. As new and better chemical defense equipment is developed and made available to the forces, several principles must be followed for an optimal outcome:

- Intelligence must continually identify new agents that may be used against combat forces and ensure that the defense equipment meets the new threats.
- A viable, active training program must be maintained.
- Medical input into operations while participants are wearing protective equipment is vital to maintenance of a combat operation. Planned rest periods consonant with work loads and MOPP gear will allow continuing operations even in a contaminated environment.

INDIVIDUAL PROTECTIVE EQUIPMENT

Agents of chemical warfare can exist in three physical forms: gas, liquid, and aerosol (ie, a suspension in air of liquid or solid particles). These agents can gain entry into the body through two broad anatomical routes: (1) the mucosa of the oral and respiratory tracts and (2) the skin. Protection against chemical agents includes use of the gas mask, which protects the oral and nasal passages (as well as the eyes), while the skin is protected by the overgarment. An integrated approach to total individual protection, with respiratory protection as the primary goal, combined with an overgarment, gloves, and footwear, all properly fitted and used correctly, can provide excellent protection against chemical agents of all known types.[1]

Respiratory Protection

The general principles of respiratory protection are documented in four primary source documents:

1. "Chemical Warfare Respiratory Protection: Where We Were and Where We Are Going," an unpublished report prepared in 1918 for the US Army Chemical Research, Development, and Engineering Center[6];
2. *Jane's NBC Protection Equipment* (the most recent edition available), particularly the chapter titled "Choice of Materials for Use With NBC Protection Equipment"[7];
3. *Basic Personal Equipment*, volume 5 in the *NIAG Prefeasibility Study on a Soldier Modernisation Program*, published by the North Atlantic Treaty Organization (NATO) in 1994[8]; and
4. *Worldwide NBC Mask Handbook*, published in 1992.[9]

The fundamental question of protective mask design, first addressed in World War I, is whether the mask should completely isolate the soldier from the poisonous environment or simply remove the specific threat substance from the ambient air before it can reach the respiratory mucosa. The first approach requires that a self-contained oxygen supply be provided. Because of logistical constraints (eg, weight, size, expense), this approach is not used by the typical service member except for specialty applications in which the entire body must be enclosed.

The more common practice has been to follow the second approach: to prevent the agent from reaching the respiratory mucosa by chemically destroying it, removing it in a nonspecific manner by physically adsorbing it, or both. Destruction by chemical reaction was adopted in some of the earliest protective equipment such as the "hypo helmet" of 1915 (chlorine was removed by reaction with sodium thiosulfate) and the British and German masks of 1916 (phosgene was removed by reaction with hexamethyltetramine).[6] More commonly, the removal of the agent was brought about by its physical adsorption onto activated charcoal. (Charcoal, because of its mode of formation, has an extraordinarily large surface area, approximately 300–2,000 m^2/g, with a correspondingly large number of binding sites.[10]) Impregnation of charcoal with substances such as copper oxide, which reacts chemically with certain threat agents, further increases protection.[6]

The effectiveness of modern masks is based on both physical adsorption and chemical inactivation of the threat agent. For example, in the older M17 series protective mask, the adsorbent, known as ASC Whetlerite charcoal, is charcoal impregnated with copper oxide and salts of silver and hexavalent chromium (Figure 17-1). The Centers for Disease Control and Prevention and the National Institute for Occupation Safety and Health have identified hexavalent chromium as a potential human carcinogen.[11] Subsequently, newer protective masks in the M40 series began using an ASZ impregnated charcoal, which substitutes zinc for the chromium. A filter layer to remove particles and aerosols greater than *3* μm in diameter is also a component of all currently produced protective masks.

The location of the filters and adsorbent in relation to the respiratory tract was also addressed by mask designers in World War I. In the standard British mask (the small box respirator of 1916), the filter and adsorbent were housed in a separate container worn around the soldier's trunk and connected to the mask by a hose. In contrast, the standard German mask, introduced in late 1915, was directly attached to a small canister containing the filter and adsorbent. The canister arrangement was lighter and required less effort to breathe, but these advantages were gained at the expense of smaller protective capacity and a degree of clumsiness with head movement.[1] The canister (Figure 17-2) is attached directly to the mask in the majority of modern protective masks.

Several other essential features of modern protective mask design also originated during World War I, for example, designing the inside of the mask so that inhaled air is first deflected over the lenses (which prevents exhaled air, saturated with water vapor, from fogging the lenses) and the use of separate one-way inlet and outlet valves (to minimize the work of breath-

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b

Fig. 17-1. (a) The M17A2 chemical-biological field mask. **(b)** M13A2 filter elements are located inside the right and left cheek in the M17 series and can only fit inside in the appropriate opening in the facepiece.
Photographs: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

ing). World War I mask designers also recognized the need for masked soldiers to speak with each other but failed to solve the problem. After the war, the US Navy introduced the first useful communication solution: a moveable diaphragm held in place by perforated metal plates in the front of the mask. This device ultimately became the "voicemitter" found in today's protective masks.[6]

An important part of mask design is the composition of the elastic material used to cover the face (the "faceblank"). The first World War I masks were made of rubberized cloth or leather. Subsequent masks used natural rubber; recently, sophisticated synthetic polymers using silicone, butyl, and perfluorocarbon rubbers have been used.[6] Silicone rubber has the advantage of making a tight fit or seal between the mask and skin possible, with a correspondingly decreased leakage potential (a factor thought to be responsible for about 5% of mask failures).[12] Unfortunately, silicone rubber offers rather low resistance to the penetration of common chemical agents. Perfluorocarbon rubber is very impermeable but is expensive and tears easily. Butyl rubber, providing both good protection and good seal, has become the material of choice.[7]

Fig. 17-2. The C2A1 canister is used with the M40 series protective mask. After entering through the orifice on the left side, ambient air passes first through the pleated white filter (where aerosols are removed), then through the layer of ASZ charcoal, then through a second filter (to remove charcoal dust), finally exiting the canister through the orifice on the right side.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

The faceblank in current standard US military masks consists of two separate layers: an inner layer made of silicone rubber for maximum seal and an outer layer made of butyl rubber for maximum protection (Figure 17-3).[1] However, recent advancements in technology have resulted in the construction of a faceblank with elastic material composed of a mixture of butyl and silicone rubber, thus eliminating the need for an outer layer of butyl rubber. The joint service general purpose mask (JSGPM), the latest generation of protective mask to be issued to the US military, is built on a butyl/silicone rubber faceblank. This mask will be discussed later in the chapter.

The sophisticated design of modern protective masks is most evident in the recognition of the dictates of respiratory physiology: specifically, the importance of dead space. The greater the space between the back of the mask and the face of the wearer in relation to the tidal volume, the smaller the proportion of inhaled air that will reach the alveoli. To minimize dead-space ventilation, modern protective masks have a nose cup— the equivalent of a second mask—fitted separately from the mask proper and inserted between the main mask and the wearer's midface (Figure 17-4). The smaller volume encompassed by the nose cup, rather than the total volume enclosed by the entire mask, is responsible for most of the dead space added by the mask. Furthermore, the nose cup provides an extra seal against entry of threat agents.[6]

Fig. 17-3. The M40A1 protective mask facepiece has two skins. The inner skin is composed of silicone rubber, and the outer skin is composed of butyl rubber. This arrangement maximizes both mask-to-skin seal and chemical agent impermeability.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

The work of breathing added by the mask is an important factor; it determines not only soldiers' acceptance of a given mask, but more importantly, the degree that a soldier's exercise tolerance is degraded. Because the pressure gradient required to move a given mass of air is flow-rate dependent, a specific flow rate must be specified to make a quantitative comparison between the work of respiration needed for different masks. For example, at a flow rate of 85 L/min, a pressure gradient of about 8 cm H_2O is observed in World War II–vintage masks. At the same flow rate, the gradient for the M17 series is 4.5 cm H_2O, and for the M40 series it is 5 cm H_2O.[6] By way of contrast, breathing at a rate of 85 L/min without a mask requires a pressure gradient of 1.5 cm H_2O.[13] Some mask wearers perceive the 3-fold increase in the work of breathing as "shortness of breath."[1]

The developmental objectives in personal respiratory protection equipment generally encompass factors such as personal comfort, breathing resistance, mask weight, and the ability to provide protection from new chemical warfare agents and toxic industrial material (TIM). Current equipment was designed to meet a number of these objectives, but much remains to be done to protect adequately against TIM and toxic industrial chemicals (TICs), to incorporate the use of more chemically resistant materials, to utilize advanced manufacturing methods, and to incorporate scratch-resistant lenses. All of these items must be integrated into a new, reliable, less cumbersome, and less degrading system.[1]

The equipment described below is generally suitable for use by all services, although oceanic environments may require that other construction materials be developed for the US Navy and Marine Corps. The masks protect against all known chemical and biological agents, whether in droplet, aerosol, or vapor form. However, a protective mask is only as good as its fit. In the past, the degree of fit was assessed by field-expedient qualitative indices (eg, the degree to which the mask collapsed with its inlet valve obstructed). Modern technology incorporated into the M41 protection assessment test system (PATS) and the joint service mask leakage tester allows the degree of fit to be quantified.[14,15]

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Fig. 17-4. (a) Modern protective masks have a nose cup with a single large hole in the center through which exhaled air is expelled on its way to the exit valve in the main mask. Inhaled air, which has passed through the canister, passes up and around the side of the nose cup, preventing fogging of the mask's lenses, after which it passes through the valve on its way to the user's respiratory tract. **(b)** Location of the nose cup of the M40A1 mask.
Photographs: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

M41 Protection Assessment Test System

The protective masks issued to members of the US armed forces protect the individual's face, eyes, and respiratory tract from field concentrations of chemical and biological agents, toxins, and radioactive fallout particles. Several critical steps must be taken to ensure that an assigned mask will function properly in a toxic chemical environment:

- select the correct mask size,
- properly fit the selected mask,
- validate the mask protection,
- train the user in the proper wear and use of the mask, and
- perform preventive maintenance checks on the mask as required.

The M41 PATS, designed to validate the protection afforded by the M40, M45, MCU-2/P series and JSPGM masks, is a miniature, continuous flow, condensation nuclei counter. PATS samples particles from ambient air and compares them with particles in the air contained inside the wearer's mask. The resulting numerical values are then used to determine the protection factor of the mask. To pass the test, a mask must to provide a protection factor of at least 1,667 for the Army, Navy, and Air Force, and at least 2,000 for the Marine Corps.[14,15]

PATS ensures that the mask is the proper size for the individual wearer and that the mask system has no critical leaks caused by missing or defective parts or improper maintenance.[1] PATS is compatible with masks that have a NATO drink tube quick disconnect. Two PATS, located at the headquarters company, are fielded for each battalion-sized unit. One PATS is fielded for each separate company-sized unit. PATS is used by the Army, Navy, Air Force, Marine Corps, US surety sites, and foreign military sales clients.[14,15]

Joint Service Mask Leakage Tester

The joint service mask leakage tester (JSMLT) is a portable device capable of determining serviceability and proper fit, and identifying defective components of current and future chemical, biological, and radiological (CBR) negative pressure protective masks. This system combines all these features in one unit, providing a capability currently not available in the field to

quantitatively test protective masks for defects and to assess the fit on any individual. The device provides the operator with an audible and visual indication if a component is defective or if the fit does not meet accepted service-specific standards.

The JSMLT currently works with M40 series and MCU-2/P masks. Future capabilities are planned to include M42, M45, and the JSGPM. Key features of the JSMLT include ability to locate leaks so repair or replacement decisions can be made; preventive maintenance checks and services serviceability testing for leakage in the mask, outlet valve, and drink tube; option to perform a fit test on human subjects with the same protocol used by the M41 PATS; and two test heads that allow testing for various mask sizes. The US Marine Corps, Air Force, and Navy are current users of the JSMLT.[14,15]

M40A1 Chemical-Biological Field Mask

The M40 series chemical-biological (CB) field mask (Figure 17-5) replaced the M17 series mask as the standard protective mask issued to the US military. The inner layer of the facepiece is composed of molded silicone rubber that fits tightly against the face, and has an in-turned peripheral seal, which increases comfort and fit. The mask's two-ridged eye lenses are approximately 35% larger than the type used in the M17 series, providing a better field of view. Filtration is provided in the M40A1 mask by one C2A1 filter canister, which can be mounted on either cheek. Two canisters may be mounted on both cheeks for special-purpose activities such as explosive ordnance disposal or technical escort. Any other standard-thread canister issued by NATO countries will fit the M40A1 mask.[14,15]

Communication is provided by two voicemitters. One is mounted in the front to allow face-to-face communication; the second is located in the cheek to permit the use of a radio telephone handset. A drinking system consists of internal and external drink tubes; the external tube has a quick-disconnect coupling that connects with the M1 canteen cap. The system allows personnel to hydrate while wearing the respirator (Figure 17-6). A six-point, adjustable harness with elastic straps located at the forehead, temples, and cheeks comes together at a rectangular head pad for ease of fitting.[14,15]

The M40A1 mask comes in three sizes: small,

Fig. 17-5. The M40A1 chemical-biological field mask.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Fig. 17-6. The M40A1 chemical-biological field mask with drinking tube assembly allows the soldier to drink without unmasking. Soldiers wearing mission-oriented protective posture gear must drink water to prevent heat stress. The drinking tube, essentially a flexible straw, couples with the canteen cap. The user holds the canteen upright and inverted, then sips water through the tube. After every few sips, the user must blow exhaled air back into the canteen to equalize the atmospheric pressure without introducing contaminated air.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

medium, and large. Optical inserts are provided for vision correction, and outserts are available to reduce fogging and sun glare and to protect against scratching. A check valve on the nose cup prevents exhaled air from fogging the lenses inside, and an air deflector directs inhaled air over the lenses, which also helps prevent fogging.[14,15] Other components include a carrier, a waterproof bag, and a quick-doff hood to protect the neck and head areas (Figure 17-7).[16] The quick-doff hood is not used when the mask is worn with parka overgarments.

M42A2 Chemical-Biological Combat Vehicle Mask

The M42A2 CB mask, in the same series as the M40A1, is used by combat vehicle crews (Figure 17-8). The materials of construction and the basic features are identical to the M40A1. Filtration is provided by a C2A1 canister attached to the mask by a corrugated hose; the canister is housed in a specially designed canister carrier. The M42A2 integrates with the combat vehicle filtration protection system. The M42A2 also has a dynamic microphone that integrates with the combat vehicle via a microphone cable.[14,15,17]

MCU-2/P Chemical-Biological Mask

The MCU-2/P CB mask is used by US Air Force ground crews and air crews when not in flight, and also by the Navy onboard ship for CBR defense. This mask has a facepiece constructed of molded silicone rubber material, and an integral, molded, polyurethane, one-piece panoramic lens bonded to the facepiece. Filtration is provided by one C2A1 canister mounted on either side of the facepiece. The primary voicemitter is located over the mouth area; a secondary voicemitter in the cheek area can be used with telephone handsets. The mask incorporates a drinking tube, which connects to the M1 canteen cap for hydration while wearing the mask. The mask has a six-point, adjustable head harness suspension made of elastic, which comes together in the center in the back of the head into a rectangular patch of woven material. The mask comes in three sizes: small, medium, and large. Accessories include a carrier bag, a butyl-coated nylon cloth hood, a large outsert to protect the lens in storage, a neutral gray outsert to protect against sun glare, and a waterproof bag.[14,15]

Fig. 17-7. The M40A1 chemical-biological field mask with the quick-doff hood.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Fig. 17-8. The M42A2 chemical-biological field mask.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

M45 Chemical-Biological Mask

The M45 mask consists of close-fitting eye lenses shaped to improve peripheral vision and compatible with most optical sighting and night-vision devices; vision-corrective inserts that can be fitted inside the facepiece; front and side voicemitters for face-to-face and telephone communication; a low profile canister

Fig. 17-9. (a) The M45 mask (aircrew configuration) with hose assembly. **(b)** The M45 Land Warrior mask. Photographs: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

interoperability hose assembly to allow both hose- and face-mounted configurations; a rubber facepiece with an in-turned peripheral seal; a second skin; and a hood (Figure 17-9). The mask provides the required CB protection without the aid of forced ventilation air. It is used by all Army air crew members, except AH-64 Apache helicopter pilots, in the conduct of aviation missions anywhere in a CB environment.[14,15]

The M45 mask supports the Land Warrior program, as well as Joint Special Operations Command requirements, and serves as the mask for personnel who cannot be fitted with the standard M40A1, M42A2, or MCU-2/P protective masks. The M45 Land Warrior mask does not include the hose assembly, hood, canister baffle, microphone, or microphone cable.[14,15,18]

Joint Service General Purpose Mask

The JSGPM (Figure 17-10) is provided in two models with individual national stock numbers to support major operational modes: the M50 for field use, the M51 for use in combat vehicles. The M50 and M51 components are configured to reduce the overall profile of the mask and to improve integration with future protective systems. Common to both models are the mask carrier, bag, individual equipment carrier, facepiece assembly, sunlight outsert, primary CBR filters, waterproof bag, and operator cards.[14,15,19]

The M50 and M51 facepiece assemblies are built on a butyl/silicone rubber faceblank with an inverted peripheral face seal and an integrated chin cup. The facepiece assembly forms a comfortable seal on the wearer's face and protects the face, eyes, and respiratory tract from chemical and biological agents, designated TICs, and radiological particulates. The facepiece assembly incorporates a flexible, single, polyurethane eye lens that provides an overall field of vision greater than 80%. A front module assembly provides a direct speech capability and integrates the exhalation disk valve, drinking system components, and communications interface. Filtration is provided by two filter mount assemblies (left and right) that integrate the air inlet disk valves and self-sealing disk valves, and a nose cup that controls the flow of air throughout the mask and prevents fogging of the eye lens while breathing.[14,15]

The M51 includes the following items: combat vehicle hose assembly (connects the mask to the vehicle collective protection system), protective hood, microphone, microphone adapter, and microphone lead (connects the microphone and microphone adapter to the individual's combat vehicle crew helmet). One

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b

Fig. 17-10. (a) The joint service general purpose mask incorporates state-of-the-art technology to protect US forces from anticipated threats. **(b)** Illustration of the mask's technical design.
Photograph (a): Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Aberdeen Proving Ground, Md. Drawing (b): Courtesy of the Respirator Engineering and Acquisition Team, ECBC-RDECOM, Aberdeen Proving Ground, Md.

end of the hose assembly connects directly to the CBR or secondary TIC filter, if used. The other end has a quick-connect fitting that interfaces with the vehicle's collective protection system.

The M50 and M51 are manufactured in three sizes: small, medium, and large. The masks are equipped with a sunlight outsert for eye protection from bright sunlight. A laser outsert is available as an additional authorization list item for laser eye protection. Both masks use twin primary CBR filters, positioned on either side of the face, to provide protection against CBR threats. Supplemental twin secondary TIC filters are available as additional authorization list items. The secondary filters provide protection from designated TICs and are used in conjunction with the primary filters, as required for mission/operations.[14,15]

M53 Chemical-Biological Protective Mask

The M53 mask (Figure 17-11) is specially designed to meet US Special Operations Command requirements; it is not a standard mask issued to other service members. The M53 facepiece assembly is built on a butyl/silicone rubber faceblank with an inverted peripheral face seal and an integrated chin cup. The facepiece assembly forms a comfortable seal on the wearer's face and protects the face, eyes, and respiratory tract from CB agents, certain TICs, and radiological particulates. The facepiece assembly incorporates a single, flexible, polyurethane eye lens; a variable resistance exhalation unit that allows for operations in negative pressure, powered air purifying respirator, self-contained breathing apparatus, and closed circuit breathing apparatus modes; drinking system components; a communications interface; single filter mount assemblies with a 40-mm NATO thread that integrate the inlet disk valve and air deflector; and a nose cup that controls the flow of air throughout the mask and prevents fogging of the eye lens during operation.[14,15]

The M53 is manufactured in four sizes (extra-small, small, medium, and large) and in either a left- or right-handed version. The mask also incorporates interchangeable nose cups in five sizes: extra-small, small, medium, large, and extra-large. Each mask is equipped with a sunlight outsert for eye protection from bright sunlight and lens protection. A clear outsert is provided for lens protection when the sunlight outsert is not required. A laser outsert is also available as an additional authorization item for laser eye protection. The mask uses a single CBR filter, positioned on the side of the face, to provide protection against nuclear, biological, and chemical threats and certain TICs. A particulate filter, also available as an additional authorization list item, provides protection from biological and riot control agents.[20] A protective hood is provided for

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b

Fig. 17-11. (a) The M53 chemical-biological protective mask is positive-pressure capable and provides an internal variable resistance exhalation unit for operations with self-contained, closed-circuit and powered-air breathing systems. **(b)** Illustration of the M53 mask front facepiece assembly.
Photograph (a): Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md. Drawing (b): Courtesy of the Respirator Engineering and Acquisition Team, ECBC-RDECOM, Aberdeen Proving Ground, Md.

joint service lightweight integrated suit technology (JSLIST) type VII users to protect the head and neck from exposure to agents, because these suits lack a hood. An audio frequency amplifier and microphone assembly (microphone and microphone adapter) are provided for amplified voice communication. Each facepiece assembly has serial number bar code as well as human-readable lot and serial numbers located on the filter mount assembly. [14,15]

Protective Clothing

An overgarment can be made to protect skin from chemical agents by either physical or chemical means, depending on the type of fabric:

- the fabric may be impermeable to most molecules, even to air and water vapor, or
- the fabric may be permeable to most molecules but chemically alters or physically removes chemical agents before they reach the skin.

An overgarment made of the first type of fabric, which can be butyl rubber or an impermeable plastic, offers complete protection against threat agents but places a significant heat load on the wearer and limits movement. Because the individual's skin does not contact the outside air, sweating does not cool the body and heat is retained. Most fielded military garments utilize the second type of fabric technology, which allows some limited air exchange through the fabric but filters the air through a charcoal lining, which also absorbs agent.

The decision to place a service member into full chemical protective equipment—mask, overgarment, gloves, and boots—must take into account not only the provided protection but also the added heat stress and potential for dehydration.[1] To guard against dehydration, personnel must begin a drinking regimen before encapsulation. The physical burden of a full ensemble can add 5 to 7 lbs to a normal load; this added weight combined with heat stress, dehydration, and physical exertion can cause significant impairment to any mission. Because of these factors, the military developed MOPP levels to stratify the levels of required protection based on the anticipated threat risk (Figure 17-12). There are seven MOPP levels; Exhibit 17-1 describes each level in detail. More information on the applications of the various MOPP levels can be found in Field Manual 3-11.4, *Multiservice Tactics, and Procedures for NBC Protection*.[14] The MOPP level must be coordinated with the workload if personnel are to remain effective. Overgarments are continuously redesigned to reduce heat stress, reduce weight and bulk, and provide increased comfort as well as reduce the logistical burden.

Fig. 17-12. Mission-oriented protective posture gear, from left to right: levels 1, 2, 3, and 4.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

EXHIBIT 17-1

LEVELS OF MISSION-ORIENTED PROTECTIVE POSTURE

MOPP Ready Applies to US Army/Marine Corps only. Personnel carry their protective masks with their load-carrying equipment. Individual mission-oriented protective posture (MOPP) gear is labeled and stored no farther back than a logistics site (eg, brigade support area) and is ready to be brought forward to the individual when needed. The time necessary to bring the MOPP gear forward should not exceed 2 hours. Units at MOPP ready are highly vulnerable to persistent agent attacks and will automatically upgrade to MOPP 0 when they determine or are notified that chemical, biological, radiological, or nuclear (CBRN) weapons have been used or that the threat exists for CBRN weapons use. When a unit is at MOPP ready, personnel have field-expedient items, such as wet weather gear, identified for use in the event of an unanticipated CBRN attack. Additionally, Air Force personnel stationed in or deployed to CBRN medium- and high-threat areas are issued individual protective equipment (IPE) capable of bringing them to the MOPP 4 level of protection. Therefore, when the theater commander declares MOPP ready, Air Force personnel will automatically assume MOPP 0 as opposed to MOPP ready.

(Exhbit 17-1 *continues)*

Exhibit 17-1 *continued*

MOPP 0 IPE is issued to and inspected by the individual and prepared for use. Personnel carry their protective masks with their load-carrying equipment. The standard-issue overgarment and other IPE are carried or are readily available. To be considered readily available, equipment must be carried by each individual, stored within arm's reach, or be available within 5 minutes; for example, within the work area, vehicle, or fighting position. Units at MOPP 0 are highly vulnerable to persistent agent attacks and will automatically upgrade to MOPP 1 when they determine or are notified that persistent chemical agents have been used or that the threat exists for CBRN weapons use. The primary use for MOPP 0 is during periods of increased alert when an enemy has a chemical-biological (CB) employment capability, but there is no indication of use in the immediate future. MOPP 0 is not applicable to forces afloat.

MOPP 1 When directed to MOPP 1, personnel immediately don the overgarment. In hot weather, the overgarment jacket may be left open and the overgarment may be worn directly over underwear and other IPE making up the individual MOPP gear (eg, footwear, mask, and gloves are readily available or carried). M8 or M9 paper is attached to the overgarment; the nerve agent antidote kit and decontamination kit must be carried or kept on hand. MOPP 1 provides a great deal of protection against persistent agents. MOPP 1 is primarily used when a CB attack in theater is possible. Personnel must remove contact lenses and wear protective mask optical inserts. Leaders also monitor hydration levels. For forces afloat, MOPP 1 means IPE is available.

MOPP 2 Personnel wear and/or put on their footwear, overgarment, and protective helmet cover. As in MOPP 1, the overgarment jacket may be left open, but trousers must remain closed. The mask with mask carrier and gloves are carried. The primary use for MOPP 2 is when a CB attack in theater is possible.

MOPP 3 Personnel wear the overgarment, footwear, protective mask, and protective helmet cover. Again, flexibility is built into the system to allow for relief at MOPP 3, particularly in hot weather. Personnel may open the overgarment jacket, and those with hood attached to the mask can roll the protective mask hood for ventilation, but the trousers must remain closed. The primary use of MOPP3 is for personnel operating inside areas where a chemical-agent contact hazard does not exist. MOPP 3 is not appropriate if a contact hazard is present. At MOPP 3, forces afloat don protective suits and boots and activate intermittent countermeasure washdown.

MOPP 4 Personnel completely encapsulate themselves by closing their overgarments, adjusting all drawstrings to minimize the likelihood of any openings, and putting on their protective gloves. MOPP 4 is used when the highest degree of protection is required, or if CB agents are present but the actual hazard is not determined. As with every other MOPP level, flexibility is built into the system to provide relief to the individual. Once the hazard is identified and risk assessment measures are employed, the overgarment may be left open. During coalition operations, US forces familiarize themselves with the protection levels used by personnel from other nations.

MOPP Options A MOPP option involves the mask only. The mask is worn with the long-sleeve duty uniform (for limited skin protection). The mask-only command may be given under these situations: (*a*) When riot control agents are being employed and no CB threat exists. (*b*) In a downwind vapor hazard of a nonpersistent CB agent. Mask only is not normally an appropriate command when blister agents (vesicants) or nerve agents are involved.

Adapted from: Departments of the Army, Marine Corps, Navy, and Air Force, and Marine Corps. Multiservice Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear (NBC) Protection. Washington, DC: DoD; 2003. FM 3-11.4, MCWP 3-37.2, NTTP 3-11.27, AFTTP (I) 3-2.46.

Protective Ensembles

Several types of chemical protective clothing are available, depending on the protection required to perform a specific mission and whether the fabric should be permeable or impermeable. Most military units use permeable protective clothing, which allows air and moisture to pass through the fabric without hindering the chemical protection capabilities of the clothing.[1]

The standard CB protective overgarment is the JSLIST, which provides protection from the effects of liquid, solid, and vapor CB agents, toxins, radioactive alpha and beta particles, and TIM (Figure 17-13). The JSLIST is a two-piece garment (coat and trousers), weighing between 5 and 7 lb, depending on size (approximately 1 lb lighter per size than previous generation protective garments). The JSLIST overgarment has an outer shell made of a 50% nylon and 50% cotton poplin ripstop material with a durable water-repellant finish. Its liner layer consists of a nonwoven front laminated to activated carbon spheres and bonded to a tricot knit back that absorbs chemical agents. This overgarment provides increased durability, reduced weight, improved fit, enhanced suit closures, and a 15% reduction in heat stress for the wearer compared to previous protective garments. The overgarment can be worn over individual underwear or a conventional duty uniform.[21]

The JSLIST is designed to permit efficient communications and to be compatible with existing and planned clothing and equipment, including load-bearing equipment, helmets, handwear, footwear, body cooling systems, and protective masks of each service and the special operations forces. The garments are launderable up to six times by field methods, can be

a

b

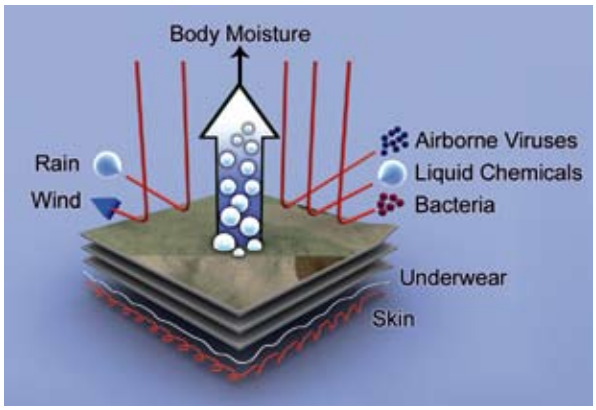

Fig. 17-13. **(a)**The joint service lightweight integrated suit technology overgarment type II (type II has an integrated hood). **(b)** The garments allow body moisture to evaporate while repelling rain, wind, airborne viruses, liquid chemicals, and bacteria. Personnel wearing the overgarment and an Army combat uniform are afforded five layers of protection: (1) The overgarment's outer layer, made of 50% nylon and 50% cotton poplin ripstop material, in woodland or desert camouflage pattern with a durable water-repellant finish; (2) the garment's inner layer, consisting of a nonwoven front laminated to activated carbon spheres and bonded to a tricot knit back; (3) the Army combat uniform, made of a 50% cotton and 50% nylon rip-stop fabric; (4) drawers and undershirt made of 100% cotton; and (5) human skin surface.
Photograph and drawing: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

worn for a maximum of 45 days, and provide up to 24 hours of protection against CB challenges within the stated maximum wear time.[22]

Two distinct versions of the suit exist: type II and type VII. The JSLIST type II overgarment (see Figure 17-13) has an integrated hood, bellows-type pockets, high-waist trousers, adjustable suspenders, an adjustable waistband, and a waist-length jacket. This design improves system compatibility, user comfort, and system acceptance by wearer, as well as maximizing individual equipment compatibility. The JSLIST type II is used for most applications. The JSLIST overgarment type VII has a similar design but no integrated hood; this type also has eyelets with a drawstring at the leg cuff. Type VII coats and trousers must be paired to maintain their effectiveness. It is used by special operations personnel and, on an interim basis, by combat vehicle crew personnel.[21,23]

Protective Boots and Gloves

A service member wearing the chemical protective boots and gloves discussed here will soon realize that mobility is compromised by the boots and tactile ability is degraded by the gloves. Also, the protective overboots currently worn by service members, although providing good protection against chemical warfare agents, cause serious risk of falls because of the lack of adequate traction, and their weight contributes to the increased fatigue from complete protection ensemble wear. Furthermore, the overboots do not protect against heat or cold; in some cases they may contribute to medical problems such as trench foot, frostbite, or other cold weather injuries. The military hopes to develop a new boot that provides chemical protection while being easy to don, comfortable, able to provide steady footing, and capable of rapid and thorough decontamination for reuse. The current protective gloves, in addition to degrading tactility, also fail to protect against heat or cold. Failing to wear a work glove over the protective glove may increase the chance of cold weather injuries.[1,21]

Black vinyl overboot. The black vinyl overboot (Figure 17-14) is used to protect the individual's combat boots against all known chemical and biological agents, vectors, and radioactive (alpha and beta) particles. The overboots also provide protection from the environmental effects of snow, rain, and mud. However, vinyl overboots issued and worn for environmental protection should not be used for CBR protection; a new pair should be issued with CBR protective gear. Following contamination by liquid agent, the overboots will provide protection for a limited time. Subsequently, they should be decontaminated with a 5% household bleach or a 5% high-test hypochlorite solution. If signs of deterioration occur after decontamination, the overboots should be replaced.[21] Additional information about wear-times and protective capabilities can be found in Field Manual 3-11.4, *Multiservice Tactics, and Procedures for NBC Protection*.[14]

Fig. 17-14. The black vinyl overboot.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Alternative footwear system. The alternative footwear system (AFS) is a lightweight, low-volume overboot for use by ground and shipboard forces. AFS is worn over standard combat boots and provides a minimum of 24 hours protection from chemical agents in liquid and vapor form. The overboot has an antislip ridge tread pattern for improved traction, an antistatic surface, and fully sealed and vulcanized seams, as well as three sets of buttons with a butyl rubber securing strap for each set (Figure 17-15). The adjustable securing strap is symmetrical and can be released from either side of the overboot. Other features include mobility, agility, and reduced combat load.[15,21]

Chemical protective glove set. The chemical protective glove set consists of an outer glove for chemical protection and an inner glove for perspiration absorption. The outer glove is made of impermeable butyl rubber, and the inner glove is made of white cotton. The gloves come in three thicknesses: 7, 14, and 25 mil. Service members such as medical, teletypist, and electronic repair personnel, whose tasks require extreme tactility and sensitivity and who do not expose the gloves to harsh treatment, use the 7-mil glove set. Aviators, vehicle mechanics, weapons crews, and other personnel whose tasks require tactility and sensitivity use the 14-mil glove set. Personnel who perform close

Fig. 17-15. The alternative footwear system.
Photograph: Courtesy of the Joint Program Management Office-Individual Protection (JPMO-IP), Quantico, Va.

combat tasks and other heavy labor tasks use the 25-mil glove set (Figure 17-16). All of the sets protect against liquid chemical agents and vapor hazards. However, if the 7-mil set is contaminated, it must be replaced or decontaminated within 6 hours after exposure. The 14-mil and 25-mil sets will provide protection following contamination for 24 hours. All three glove sets can be decontaminated with a 5% bleach or a 5% high-test hypochlorite solution, then inspected and reused. All gloves become sticky and soft if exposed to petroleum-based fluids and must be replaced. Gloves must be replaced after any damage or degradation.[14,21]

Joint service lightweight integrated suit technology block 2 glove upgrade. The JSLIST block 2 glove upgrade (JB2GU) provides 24 hours of CB protection from battlefield concentrations of all known agents for up to 30 days of wear. The glove provides enhanced tactility, dexterity, durability, and comfort over existing systems and can be worn in all climates. These qualities satisfy a broader spectrum of ground, shipboard, and aviation requirements. The JB2GU comes in two variants (Figure 17-17): flame-resistant (FR) and

Fig. 17-16. The 25-mil chemical protective glove set with cotton liners.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

non–flame-resistant (nFR). The FR variant combines a Nomex (DuPont, Wilmington, Del)/leather outer glove with an inner chemical protective liner for aviators and combat vehicle crews. The nFR variant is a molded glove made from compounded butyl rubber and comes with a removable protective liner for sweat management. The nFR glove is primarily for ground forces.[15]

Fig. 17-17. The joint service lightweight integrated suit technology block 2 upgrade glove, non–flame-resistant variant.
Photograph: Courtesy of AirBoss Defense (Acton Vale, Québec, Canada).

Psychological Factors

The threat of CBRN warfare creates unique fears in personnel, and protective gear isolates them from the environment. Individuals encapsulated in MOPP ensembles are subject to both physiological and psychological stresses. MOPP 4 reduces the ability to see and hear clearly and makes it more difficult to recognize and communicate with others, which creates or increases feelings of isolation and confusion. Chemical filters in the protective mask make breathing more difficult, which can create feelings of claustrophobia or panic in many personnel.[14] In some cases, these personnel hyperventilate, causing the eyelenses to fog up, which further inhibits the ability to carry out tasks. As a result, many service members either break the seal and lift the protective mask off the face or remove it completely.[1] Such problems can be corrected by training personnel to relax and avoid taking deep or rapid breaths while wearing the protective mask.

Personnel wearing MOPP 4 will take about one-half times longer to perform most tasks,[14] which can cause frustration and stress. The adverse impact of psychological stress during MOPP operations can be minimized by the experience and confidence provided by realistic training in MOPP gear with the protective mask. Training in MOPP gear should allow for gradual increase of wear time and should focus on tasks personnel are expected to accomplish while encapsulated in MOPP ensemble in CBRN environments.

DETECTION AND WARNING

Detection of a chemical attack, with subsequent warning of affected forces downwind, can allow adoption of an effective protective posture and continuation of military operations with minimal degradation. This section will discuss instruments that have the greatest impact on military medical operations; special purpose items are not discussed.[1] The Army has a wide range of chemical agent detectors and alarms available to protect the force. These detectors are divided into two groups: point detectors and standoff detectors.

Point Detectors

Point detectors sample the immediate area to determine the presence of chemical agents. The sample is most often taken from the atmosphere; however, specialized detection kits can be used to sample soil or water. In addition to monitoring the atmosphere, point detectors provide monitoring after an attack, identify the contaminated area, monitor collective protection areas, monitor effectiveness of decontamination, and identify chemical contamination during reconnaissance efforts.[1,14,24]

M8 Chemical Agent Detection Paper

M8 chemical agent detection paper detects and identifies liquid chemical agents. The tan paper comes in a booklet containing 25 perforated sheets (2 × 3 in), which are heat sealed in a polyethylene envelope. Three sensitive indicator dyes are suspended in the paper matrix. The paper is blotted on a suspected liquid agent and observed for a color change, which will occur within 30 seconds: VX turns the paper dark green, the G series agents turn the paper yellow, and blister agent turns it red (Figure 17-18). M8 paper will change color with many interferents, such as sodium hydroxide and petroleum products; thus, it is not a reliable way to check the completeness of personnel decontamination, which should always be verified with another means. The M8 paper has a 10-year shelf life from the manufacture date, which is stamped on the back cover of the booklet (the integrity and the quality of the paper is compromised past the shelf life).[14,24]

M9 Chemical Agent Detection Paper

M9 chemical agent detection paper is a portable, single roll of paper that comes with a Mylar (DuPont, Wilmington, Del) adhesive-backed and -coated tape.

Fig. 17-18. The M8 chemical agent detection paper detects and identifies GA (G series nerve agent) simulant from the vial by changing color in less than 30 seconds.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

It contains a suspension of an agent-sensitive dye in a green-colored paper matrix. The dye turns pink, red, reddish brown, or red-purple when exposed to agent but does not identify the specific agent. M9 paper, which is similar to masking tape, is used by attaching strips to an overgarment or equipment such as vehicle controls, then inspecting the strips routinely for color change (Figure 17-19**)**. The paper should not be attached to surfaces above 125°F (52°C). Excessive heat will discolor the tape and lead to a false positive reaction. M9 paper is more sensitive to nerve and blister agents and reacts more rapidly than M8 paper, although it also reacts to a wide range of interferents such as petroleum products, brake fluid, aircraft cleaning compounds, insect repellent, defoliant, and antifreeze.[14,24]

Improved Chemical Agent Monitor

The improved chemical agent monitor (ICAM) is a hand-held device designed for monitoring chemical agent contamination on personnel, equipment, and surfaces (Figure 17-20). It uses ion mobility spectrometry technology to detect and discriminate between mustard and nerve agent vapor. The concentrations of agents detected by the ICAM areas are as follows: for sarin (GB), 0.03 mg/m^3; for VX, 0.1 mg/m^3; and for mustard (HD), 0.1 mg/m^3.[1,14,24]

Fig. 17-19. M9 paper is attached to a protective overgarment to detect the presence of liquid chemical warfare agents. Note: The paper should not be attached to hot surfaces, which will discolor the tape and lead to a false positive reaction. Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

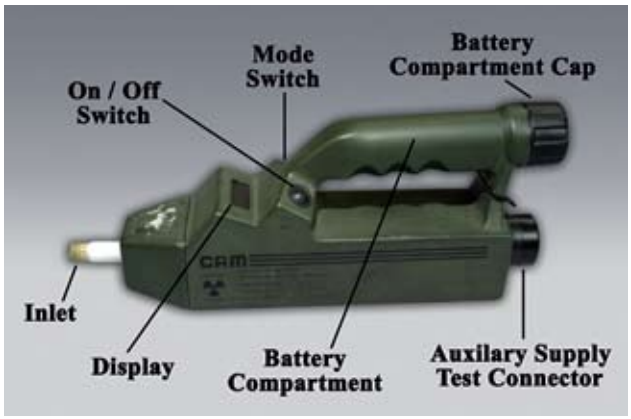

Fig. 17-20. The improved chemical agent monitor. Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

The unit is simple to operate, can be held in either hand while the user is wearing chemical protective equipment, and can be operated day or night. Relative vapor hazard and malfunction information is displayed by bars on a liquid crystal display. The ICAM is a point monitor only and cannot give an assessment of an area vapor hazard. It may give false readings when used in enclosed spaces or near strong vapor sources such as dense smoke, aromatic vapors, cleaning compounds, exhausts from some rocket motors, and fumes from some munitions. Because of the technology employed, the ICAM is subject to saturation; it must be cleared before each use to function properly.[14,24–26]

Chemical Agent Detector Kit

The M256A1 chemical agent detector kit is a portable, expendable item capable of detecting and identifying hazardous concentrations of nerve and blister agents and cyanide. The kit is used after a chemical attack to determine whether personnel can safely unmask or reduce the protective posture level. Each kit consists of 12 disposable plastic sampler-detectors (ticket or card), one booklet of M8 paper, and a set of instruction cards (Figure 17-21). Each ticket or card contains laboratory filter paper test spots for the various agents**.** The technology used is wet chemistry, enzymatic substrate-based reactions, in which the presence of agents is indicated by a specific color change. Response time is about 15 minutes. Some smokes, petroleum products, and high temperatures may produce false readings.[27] The M256A1 kit cannot be used to detect

Fig. 17-21. (a) The M256A1 chemical agent detector kit. **(b)** The sampler/detector is used to test for vapor contamination.
Photographs: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

agent in water. It can, however, be used to check an area before a military unit moves in or to define clean areas or routes. Some chemical ingredients in the kit are considered possible carcinogens and should be handled as such. The emissions produced by the kit are also toxic; a mask and gloves must be worn while the kit is being used.[1,14,24]

The detection limits for the M256A1 are as follows: for the G series nerve agents, 0.005 mg/m^3; for VX, 0.02 mg/m^3; for the vesicants mustard (HD) and lewisite, above threshold concentrations of 3.0 mg/m^3 and 14 mg/m^3, respectively; for hydrogen cyanide (AC), 11 mg/m^3; and for cyanogen chloride (CK), 10 mg/m^3.

Chemical Agent Water Testing Kit

The M272 chemical agent water testing kit is designed to detect and identify, via colorimetric reactions, hazardous levels of nerve agents, mustard, lewisite, and cyanide in treated or untreated water. A full kit contains enough supplies to perform 25 tests for each agent, and simulants are included for training use (Figure 17-22). About 20 minutes is required to perform all four tests. Some kit chemicals can be very harmful; all bodily contact with the chemicals should be avoided, and the kit should only be handled while wearing protective gloves and equipment. Detection limits are as follows: for the G-series nerve agents and VX, 0.02 mg/L; for the vesicants lewisite and mustard (H and HD), 2.0 mg/L; and for the cyanides (AC and CK), 20 mg/L.[14,24]

M22 Automatic Chemical Agent Detector and Alarm

The M22 automatic chemical agent detector and alarm is an off-the-shelf automatic chemical agent alarm system capable of detecting and identifying standard blister and nerve agents simultaneously. The M22 system is portable and operates independently after system start-up. The system consists of the M88 detector and up to five M42 alarms, which provide both an audible and visible warning (Figure 17-23). The M22 system is used primarily to alert stationary units when a cloud of nerve agent vapor has arrived or is about to arrive at their position, providing a communications interface for automatic battlefield warning and reporting. The M22 can be located within a hospital complex, with alarm units placed to cover all critical care, treatment, and support areas. It can also augment the ICAM as a survey instrument.[14,24]

Standoff Detectors

Early warning of chemical agents provides troops the necessary time to increase protective posture and to avoid contaminated areas. Standoff detectors provide this early warning at line-of-sight distances. Optical remote sensing technologies, employing infrared spectral analysis techniques, have been used in the development of chemical agent standoff detection technologies, including two types of remote sensing systems: passive and active (laser). The passive system discussed below employs a Fourier transform infrared spectrometer.[1,14,24]

Fig. 17-22. The M272 chemical agent water testing kit and its components. New kits have a test strip instead of a thermometer.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Fig. 17-23. The M22 automatic chemical agent detector and alarm consists of the M88 detector (left) and the M42 alarm (right).
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

M21 Remote Sensing Chemical Agent Alarm

The M21 remote sensing chemical agent alarm is the first standoff chemical agent detector approved for fielding to military personnel. The M21 is a passive infrared device that detects nerve and blister agent clouds based on changes in the background infrared spectra caused by the presence of the agent vapor. In a stationary position, the M21 alarm automatically scans a horizontal 60° arc and can recognize agent clouds at line-of-sight ranges up to 5 km (Figure 17-24). It reacts both audibly by horn and visually by illuminating

a

b

Fig. 17-24. (a) The M21 remote sensing chemical agent alarm (RSCAAL) deployed in a stationary position. **(b)** The RSCAAL mounted on a Fox nuclear, biological and chemical reconnaissance system allows commanders to identify contaminated areas and maneuver around them.
Photographs: Courtesy of Joint Product Manager, NBC Contamination Avoidance, Aberdeen Proving Ground, Md.

either a blister or nerve agent light.[14,24]

Usually, the M21 is placed facing into the wind. It measures and stores a background spectrum that is then analyzed by an onboard microcomputer, which makes agent/no agent decisions based on ambient radiance levels. Response time is 1 minute or less. The sensitivity of the M21 for detecting nerve agents (GA, GB, and GD) is 90 mg/m^3; for vesicants its sensitivity is 500 mg/m^3 for lewisite and 2,300 mg/m^3 for sulfur mustard.[14,24]

Joint Services Lightweight Standoff Chemical Agent Detector

The joint services lightweight standoff chemical agent detector is a state-of-the-art detection system designed to provide US forces with enhanced capability in detecting chemical warfare agents, significantly improving on the capabilities of the currently fielded M21 alarm. The lightweight, passive, and fully automatic system scans the surrounding atmosphere for chemical warfare agent vapors. The detector provides standoff detection and warning for nerve, blister, and blood agent vapor clouds. It furnishes on-the-move, 360° coverage from a variety of tactical and reconnaissance platforms at distances up to 5 km (Figure 17-25). This system will provide enhanced early warning to allow personnel to avoid chemically contaminated battlespace or, when avoidance is not possible, provide extra time to don MOPP gear or achieve the appropriate MOPP level.[14,24,28]

Fig. 17-25. Joint services lightweight standoff chemical agent detector (JSLSCAD) mounted on a Stryker nuclear, biological, chemical reconnaissance vehicle (NBCRV).
Photograph: Courtesy of Joint Product Manager, NBC Contamination Avoidance, Aberdeen Proving Ground, Md.

TOXIC INDUSTRIAL MATERIAL PROTECTION

TIM, especially TICs, are often available in enormous quantities, do not require extensive research, and can be mass-produced. TIM, which can be released from industrial plants or storage depots through accidental or deliberate damage, can be used as improvised weapons and have the potential for inclusion in clandestine weapons programs or contingency plans. Deliberate or inadvertent release of TIM significantly increases hazards to the indigenous population and deployed US forces. Military personal protection, detection, and medical countermeasures are not specifically designed for TIM hazards. Often there are no specific antidotes for TICs. Each TIM should be evaluated individually to establish protection and response procedures and to select associated equipment requirements.[29]

Individual Protection

Military individual protective equipment (IPE) is designed to protect personnel from CBR agents in a combat environment, but it provides only limited protection from other hazards. Personnel equipped with standard military IPE are not protected in a TIC environment and should seek a clean area as soon as possible. The military chemical protective mask does not afford sufficient protection within the immediate hazard zone, where extremely high concentrations of industrial chemicals such as ammonia may occur and where the lack of oxygen requires a self-contained breathing apparatus (Figure 17-26). The military respirator should only be used for emergency protection against the immediate effects of a toxic release and during evacuation from the immediate hazard zone.[30] When planning for operations in areas where TIM may be present, commanders must include considerations of the potential hazards and the appropriate level of protection and equipment for effective response.

The US Environmental Protection Agency has established four levels of protection, A, B, C, and D, according to 29 CFR 1910.120. The Occupational Safety and Health Administration and the National Fire Protection Agency have developed guidelines for each level. The level of skin and respiratory protection provided by the selected chemical protective ensemble determines the protection furnished to the responder (see Chapter 16, Decontamination of Chemical Casualties, Exhibit 16-3).[14]

Detection and Identification

Numerous technologies are available for the detection and identification of TIM. The applicability of this equipment to potential user groups depends on the characteristics of the detection equipment, the type of TIM, and the objective of the user.[31] Standard military chemical detectors are designed only to detect chemical agents. Detection of TICs can, in some circumstances, be made by in-service military chemical detection systems.

Several industrial detectors are available for the rapid detection of specific industrial chemicals. Detectors such as Dräger-Tubes (Draeger Safety Inc, Luebeck, Germany) can be used for detecting and determining the concentration of a large number of dan-

Fig. 17-26. The self-contained breathing apparatus is used when the highest level of respiratory protection is necessary.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

gerous chemicals. This detector comes in the form of a simply operated kit using individual reagent tubes to detect a variety of specific industrial chemicals. Such detectors can be supplied to units operating in an area with a known hazard from industrial chemicals.[30]

TIC and TIM detector technology is constantly being upgraded as developers seek devices that are easier to use, provide more accurate readings, and can identify a wider array of hazards. The National Institute of Justice's *Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders*[31] is more practical than technical and provides information on a variety factors to be considered when purchasing detection equipment, including sensitivity, detection states, and portability.

DECONTAMINATION EQUIPMENT

The physical properties of chemical agents are highly variable. Chemical agents range from nerve agent vapor, which usually dissipates in a few minutes to a few hours, to vesicants such as mustard, which can remain active for weeks (or in some cases, years; buried and recovered World War I mustard projectiles are often still toxic). These various properties make timely decontamination of skin and personal equipment that has been exposed to agent, especially liquid agent, imperative. Skin decontamination should ideally take place within 2 minutes, and equipment decontamination should be completed within 1 hour. For more detailed information on decontamination and decontamination equipment used for the thorough decontamination of patients, refer to Chapter 16, Decontamination of Chemical Casualties.

Personnel Decontamination

Personnel decontamination, performed to reduce the level of contamination so it no longer presents a hazard to the individual, consists of removing contaminated clothing and decontaminating the skin. To expedite this procedure, personnel decontamination kits are used to remove gross contamination. Thorough decontamination, which is conducted by specialized decontamination units, is provided to troops to reduce the requirement for wearing complete IPE. Additionally, when both crews and equipment are contaminated, combined complete personnel and equipment decontamination operations are scheduled as the situation and mission permit, bearing in mind the lengthy time required for such an operation. During this complete decontamination commanders can give their soldiers rest and a change of IPE.[33] The personnel decontamination items described below would be used to quickly decontaminate the skin of an exposed individual. Open wounds, however, should be decontaminated with water or saline.[32–35]

M291 Skin Decontamination Kit

The M291 kit consists of a wallet-type pouch containing six individual packets. Each packet contains a non-woven fiber-fill laminated pad impregnated with the decontamination compound (Ambergard XE-555 resin [Rohm and Haas Co, Philadelphia, Penn]) that reacts with chemical agents to absorb and neutralize in a single step (Figure 17-27). Decontamination is accomplished by opening the packet and scrubbing the skin surface with the applicator pad until an even coating of the resin is achieved. As the pad is scrubbed over the exposed/contaminated skin area, the chemicals are rapidly transferred into, trapped, and retained in the interior of the resin particles. The presence of acidic and basic groups in the resin promotes the destruction of trapped chemical agents. The kit can also be used to decontaminate the outside of protective masks, butyl rubber gloves, and the hood of individual protective equipment.[36] The powder should be kept away from wounds, the eyes, and the mouth. The M291 kit has a 10-year shelf life from the manufacture date stamped on the upper right corner of each packet. Expired or unserviceable kits can not be used for training; they must be discarded according to organization standing operating procedures.[32–35]

Fig. 17-27. The M291 skin decontamination kit.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Joint Service Personnel Skin Decontamination System

The joint service personnel skin decontamination system consists of decontaminants and applicators required to immediately reduce morbidity and mortality resulting from chemical warfare agent contamination of the skin. It is expected to receive US Food and Drug Administration approval as an individually carried skin decontamination kit. The system's applicators are preimpregnated with reactive skin decontamination lotion, a potassium solution dissolved in a special solvent and water (Figure 17-28) that facilitates the reaction of decontamination between the potassium salt and the chemical agent. The lotion decontaminates the warfare agents HD, soman (GD), and VX as well as T-2 mycotoxins on skin to a level that eliminates toxic effects better than the M291 kit. Each packet will decontaminate an area of 1,300 cm^2. The system can be used in temperatures ranging from −25°F/−32°C to 130°F/54°C. When approved, the system will be used by service members to perform immediate decontamination of skin, field protective masks, mask hoods, chemical protective gloves, chemical protective boots, and individual and crew-served weapons under .50 caliber.[37] It is expected that the military services will use this system to replace or augment the M291 kit.[32–35]

Fig. 17-28. A service member using the joint service personnel skin decontamination system with reactive skin decontamination lotion to decontaminate his hands.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Equipment Decontamination

Equipment decontamination items are used to destroy, remove, or neutralize most of the CBRN hazards from personal gear or unit equipment. Of the many items available to decontaminate equipment, those most useful to the medical community are described below.

M295 Equipment Decontamination Kit

The M295 is a hand-held kit used to apply decontaminant to an individual's personal equipment, including mask, hood, and boots. Each kit consists of a carrying pouch containing four sealed, soft-pack packets designed to fit comfortably within a pocket of the chemical protective overgarment. Each individual wipe-down mitt in the kit is comprised of 22 g of decontaminating powder (A-200-SiC-1005S) contained within a pad material and a polyethylene film backing (Figure 17-29). In use, powder from the mitt is allowed to flow freely through the pad material. Decontamination is accomplished through sorption of contamination by both the pad and the decontaminating powder.[32–35]

M100 Sorbent Decontamination System

The M100 sorbent decontamination system replaces the M11 and M13 portable decontamination appara-

Figure 17-29. The M295 individual equipment decontamination kit. Wipe-down mitt on right.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md

tuses previously employed in spray-down procedures associated with operational decontamination. Each M100 system consists of two 0.7-lb packs of reactive sorbent powder, two wash mitt-type sorbent applicators, a case, straps, and detailed instructions (Figure 17-30). The system uses the same nontoxic and noncorrosive reactive sorbent powder as in the M295 kit to remove and neutralize chemical agent from surfaces. The sorbent powder is first poured onto the palm of the mitt, then the mitt is used to rub and wipe the contaminated surfaces until target areas are visually dry. The system removes gross liquid contamination, limits the spread of chemical agent, preserves the integrity of MOPP gear, and minimizes casualties while decreasing decontamination time and eliminating the need for water.[32–35]

M17 Lightweight Decontamination System

The M17 lightweight decontamination system is a rugged, simple-to-use, powerful, multipurpose CB system for decontaminating and preserving military materiel in a contaminated environment. The system is designed to draw water from any source and deliver it to the two installed spray wands at pressures up to 100 psi and temperatures up to 120°C (Figure 17-31). The M17 can also be used as a personnel showering system and for cleaning vehicles and food handling and hospital equipment.[32–35]

The M17 is capable of dispensing Easy DECON 200 (Envirofoam Technologies Inc, Huntsville, Ala) as a liquid or as a foam (using a foam nozzle), and it can be used in an anticorrosion mode. It is designed for ease of operation, with one soldier operating each of its two outfitted wands. The M17 has a 3,000-gallon collapsible water tank that can be prepositioned and filled for hot water showers or hospital use.[38,39] A diesel version—a portable, lightweight, compact, engine-driven pump and multifuel-fired water heating system—is under development and will be capable of performing the same immediate and operational decontamination procedures as required of any of the M17 series systems.[32–35]

Fig. 17-30. The M100 sorbent decontamination system provides vehicle and crew-served weapon (≥ .50 caliber) operators the capability to perform operator wipe-down (previously referred to as operator spray-down) during immediate decontamination operations.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

Decontamination Methods in Development

A need still exists for an effective and environmentally safe reactive decontaminant that does not harm equipment and personnel. Bacterial enzymes, catalytic-type compounds, and other stable decontaminants (eg, quaternary ammonium complexes) are under consideration. Sorbent compounds and nonaqueous decontaminants are also being investigated for use on electronic components and other sensitive equipment.[1] A joint platform interior decontamination system is being investigated for use in decontaminat-

Fig.17-31. The M17 lightweight decontamination system. The system is designed to decontaminate equipment but can also be used as a personnel showering system.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

ing chemical and biological warfare agents on the interior of aircraft, vehicles, ships, and buildings. This system will have two increments: increment I will provide capabilities to decontaminate interior areas and equipment, and increment II will focus on improving decontamination processes, speed, efficacy, TIM decontamination, and other system capabilities.[32–35]

COLLECTIVE PROTECTION

Collective protection (COLPRO) provides a protective capability to personnel who must operate in an environment where wearing IPE is not possible. COLPRO is typically incorporated into chemically protected medical treatment facilities, command centers, or rest areas. The use of COLPRO allows for sustained operations in a contaminated environment.

COLPRO systems are categorized according to their tactical application: fixed-site, transportable, and mobile. Fixed-site COLPRO consists of hardened, semihardened, or unhardened systems. Transportable COLPRO shelters can be moved as needed to achieve mission requirements. Transportable shelters are generally unhardened. Mobile COLPRO shelters include facilities that are armored or soft-skinned; this type of system may or may not have the capability to be used on the move. Mobile systems may not have integrated airlocks or contamination control areas. COLPRO shelters are constructed of rigid-wall, soft-wall, or hybrid materials and should include design features that will facilitate tactical functions without the restrictions of IPE.[14, 29] This section addresses COLPRO systems that have been specifically designed for, or systems that are ideally suited for, applications in health service support.

Chemically Protected Deployable Medical System

The chemically protected deployable medical system (DEPMEDS) was fielded in 2003 under the Mission Force 2000 configuration, which protects 236 beds of a 298-bed DEPMEDS hospital (Figure 17-32). All Mission Force 2000 chemically protected DEPMEDS will be upgraded to the medical reengineering initiative configuration, which protects a complete 248-bed DEPMEDS combat support hospital. This configuration also allows simultaneous split-base hospital operations through 84-bed and 164-bed hospital companies. The 84-bed company will use the Army Medical Department shelter system. The 164-bed company will use the tent, extendable, modular personnel system. The 248-bed DEPMEDS combat support hospital uses both types of shelter from each hospital company. Chemically protected DEPMEDS consists of the M28 collective protection equipment, designed to protect areas within the hospital from CB contamination. The M28

Fig. 17-32. (a) The chemically protected deployable medical system as shown in the 236-bed configuration is capable of sustaining continuous operations for up to 72 hours in a contaminated environment. This system provides medical personnel a contamination-free work space allowing them to operate without wearing cumbersome individual protective equipment items. The system is also equipped with two 12-person latrines and 20,000 gallons of water. **(b)** Intensive care units in the system are equipped to perform complex lifesaving medical procedures. This figure illustrates the inside of a treatment unit. Photographs: Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

collective protection equipment is used with both shelter systems. The entire composite hospital ensemble consists of expandable tentage, passageways, environmental control units, and International Organization for Standardization shelters.[40]

The M28 collective protection equipment consists of the following items: end section liners; center section liners; 32.5-ft liners; 19.5-ft liners; vestibule liners fabricated from a plastic film that is resistant to liquid and vapor agents; a protective entrance airlock (Figure 17-33) for ambulatory personnel made from a butyl-coated material and hung in a collapsible aluminum frame, creating a triangular shape; a tunnel airlock for litter-borne patients consisting of a collapsible frame with entry and exit doors at opposite ends fabricated from a CBR protective cover; a supply airlock for mission resupply while operating under collective protection; a hermetically sealed filter canister and the accessory package, which support the purge requirement during collective protective entry; and a a portable self-contained recirculation filter designed to filter any chemical agent vapors brought in through the entry or exit.[40,41]

Collectively Protected Expeditionary Medical Support

The US Air Force uses the collectively protected expeditionary medical support (CP EMEDS) system (Figure 17-34), a direct replacement for the chemically hardened air transportable hospital. CP EMEDS provides an air transportable medical facility that allows healthcare providers, support staff, and patients to interact in a protected environment without the need for individual protection equipment. Composed of an Air Force small shelter system with a CB liner to harden the shelter, CP EMEDS provides filtered air with slight positive pressure to keep out vapor. The system was designed to be adaptable and can be deployed in a variety of configurations, ranging from a single 32-ft shelter to a complex of ten 32-ft shelters with a 25-bed hospital; its capabilities can be extended to include surgical operations and additional capacity. CP EMEDS is capable of providing medical care to a population of 3,000 to 5,000 service members.[40,42]

Chemical and Biological Protected Shelter

The chemical and biological protective shelter is designed to provide a highly mobile, 300-sq-ft, contamination-free, environmentally controlled work area for forward deployed medical treatment. This shelter is employed at levels I and II medical treatment facilities and forward surgical teams. The system is comprised of a modified high-mobility multipurpose wheeled vehicle, lightweight multipurpose shelter, air beam shelter, and a high-mobility trailer with a 10-kW tacti-

Fig. 17-33. The M28 collective protection equipment is outfitted with multiple entry points capable of receiving litter and ambulatory casualties. These entry points function as positive pressure airlocks; thoroughly decontaminated casualties are directed through the airlocks for an air purge and decontamination check prior to receiving medical treatment.
Photograph: Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

Fig. 17-34. The collectively protected expeditionary medical support system provides protection from chemical and biological warfare agents to health care providers and patients in a contaminated environment. The system provides filtered air that allows occupants to operate without the need for individual protective equipment while inside the shelter. It has been designed for maximum versatility and can be configured to meet the demands of many mission requirements.
Photograph: Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

Fig. 17-35. The chemical and biological protective shelter is a highly mobile system that can be established or disestablished by a crew of four in fewer than 20 minutes. Systems are fielded to meet demands of various modified table of organization and equipment requirements. Outfitted with organic medical equipment sets unique to a specific level of care, the system is employed at levels I and II medical treatment facilities.
Photograph: Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

cally quiet generator with frame (Figure 17-35).

The vehicle serves as a power platform for the system; it includes an environmental control unit and CBR filtration system. The lightweight multipurpose shelter, mounted on the rear of the vehicle, contains controls and indicators for inflating and pressurizing the air beam shelter; it also provides a platform for radio communication (Figure 17-36). The 18-sq-ft semicylindrical air-beam–supported shelter, constructed of chemical-agent–resistant fabric, is clamped to an aluminum retainer attached to the rear of the multipurpose shelter. The system is equipped with two air locks that allow passage of both ambulatory and litter bound patients, as well as removable side entrances that permit systems to be joined together as needed to meet mission requirements. The trailer carries the generator, medical supplies, and other items if needed. The generator is available to provide supplemental power to the system.[40]

M20 Simplified Collective Protection Equipment

The M20 simplified collective protective equipment provides 200 cu ft of contamination-free work space. The M20, an inflatable shelter designed for use in a fixed structure, provides protection from chemical and biological agents and radioactive particles, allowing personnel to perform duties without wearing IPE. The system consists of a recirculation filter, shelter assembly, protective entrance, air ducts, and other basic issue items. Tactical application may include command and control, rest relief, communication, and intelligence.

a

b

Fig. 17-36. (a) The high-mobility multipurpose wheeled vehicle serves as the main power platform for the chemical and biological protective shelter. The vehicle, which includes the environmental controls and chemical, biological radiological, and nuclear filtration systems, is attached to the tent structure and may not be separated to perform patient evacuation or other vehicular missions. When the shelter is pressurized personnel inside can work without encumbrances of individual protective equipment. This allows healthcare providers ease of movement while providing emergency lifesaving treatment. **(b)** Casualties enter the shelter for treatment through either the ambulatory or litter entrance. These entry points function as positive-pressure airlocks; thoroughly decontaminated casualties are directed through the airlocks for an air purge and decontamination check prior to receiving medical treatment.
Photographs: Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

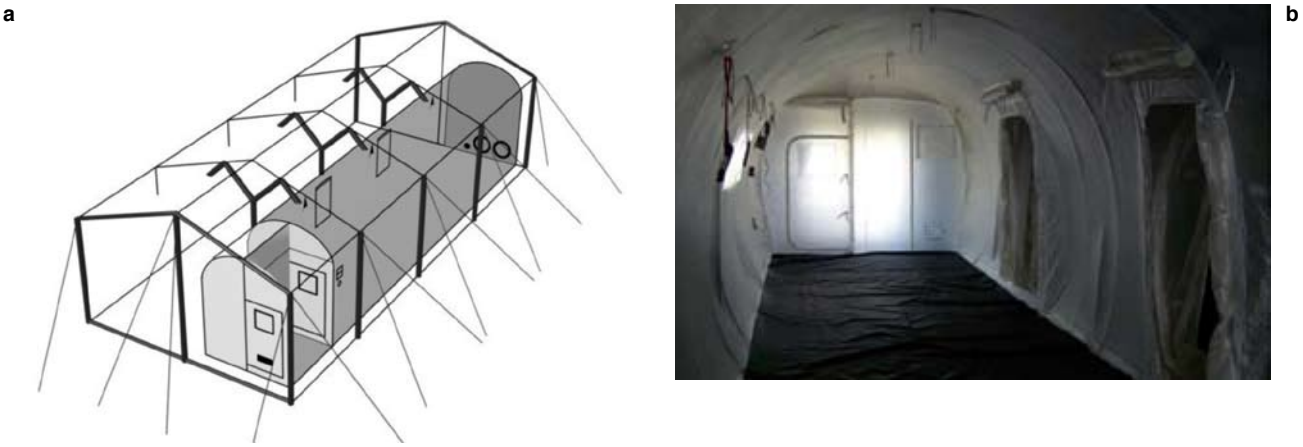

Fig. 17-37. **(a)** The modular general purpose tent system chemical-biological protective liner can be placed in operation in approximately 60 minutes and prepared for movement in approximately 30 minutes. **(b)** The liner is equipped with an integrated airlock that functions as an air purge, allowing decontaminated personnel or casualties requiring treatment, rest, rehydration, or command control to enter the system.
Drawing (a): Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md. Photograph (b): Courtesy of the Joint Program Management Office for Nuclear Biological Chemical Collective Protection, Naval Surface Warfare Center Dahlgren, Dahlgren, Va.

Primary users of this system are the US Army and Marine Corps.[40,43]

Modular General Purpose Tent System Chemical-Biological Protective Liner System

The modular general purpose tent system CB protective liner system (general purpose tent system, CB liner, and filtration system) provides 324 sq ft of toxic-free space, allowing occupants to conduct operations without IPE (Figure 17-37). Its positive-pressure environment provides filtered air for protection against chemical and biological warfare agents and radioactive particles. The liner system occupies half of the tent system; depending on mission requirements, the system is capable of accommodating two liners per tent to provide additional space as needed. Each liner system is equipped with pressure gauges, a high/low pressure alarm, a motor blower, a filtration unit, and an integrated air lock. Tactical applications for this equipment may include rest and relief, command and control, and medical treatment.[40,44]

ADDITIONAL PATIENT PROTECTION AND TRANSPORT EQUIPMENT

Patient Protective Wrap

Patient protective wrap is designed to protect a patient during evacuation after the chemical protective overgarment has been removed and the patient has received medical treatment. A patient can remain in the wrap for up to 3 hours. Whenever a patient is evacuated in the wrap, the M48 motor blower must be attached to provide fresh air to the patient and reduce carbon dioxide build-up (Figure 17-38). Patient protective wrap is for one patient only, weighs approximately 5.5 lb, and comes in woodland and desert camouflage patterns. It incorporates layered fabric with a charcoal lining. The top layer is made of a material similar to that used in the battle dress overgarment, and the bottom layer is made of chemically resistant plastic material. The wrap has a continuous zipper along the outer edge for ease of patient insertion; a large, transparent window in the top to view the patient (or for the patient to see out); and a pocket for medical records.[40]

Individual Chemical Patient Resuscitation Device

Developed according to US military specifications, the individual chemical resuscitation device is a ventilatory system consisting of a compressible butyl rubber bag, a NATO standard C2A1 canister filter, a nonrebreathing valve, a cricothyroid cannula adapter, and a flexible hose connected to an oropharyngeal mask (Figure 17-39). The mask is removable from the distal end of the flexible hose for connection of the hose to the cannula adapter. The butyl rubber bag resists the penetration of liquid chemical agent that may be on the

Fig. 17-38. Patient protective wrap with motor blower attached. The blower is used to provide fresh air to the patient and reduce carbon dioxide build-up
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

gloves of operator and is easily decontaminated. The elasticity of the outer cover limits airway pressure to a maximal value of 70 cm H_2O (70 mbar). The device can deliver up to 600 mL of filtered air per cycle at a rate of 30 cycles per minute, and it can be used in contaminated environments as well as all conventional ventilation emergencies.[40]

Decontaminable Litter

Contaminated casualties arriving at the medical

Fig. 17-39. The individual chemical resuscitation device application is demonstrated on a mannequin.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

treatment location will, in most cases, require decontamination prior to definitive care. Traditional canvas litters exposed to liquid blister agents, when decontaminated, still desorb vapors for 72 hours after all surface contaminants are removed. Consequently, the

Fig. 17-40. The decontaminable litter allows liquid to pass through openings in the fabric.
Photograph: Courtesy of the Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Md.

decontaminable litter (Figure 17-40) was developed to replace the canvas litters currently in use. The decontaminable litter is made of a monofilament polypropylene with high tensile strength and low elasticity. The fabric does not absorb liquid chemical agents and is not degraded by decontaminating solutions. The fabric is flame retardant, highly rip resistant, and treated to withstand exposure to weather and sunlight. It has a honeycomb weave, which results in a rough, no-slip surface through which liquids easily pass (40% of the surface is open).[40]

The litter's carrying handles retract into the metal pole frame for a closed total length of 83.5 in (212.1 cm), to allow for loading the litter onto the UH-60 helicopter. The handle lengths are adjustable to conform to NATO standards as well as to allow for litter bearers' comfort. The aluminum poles are designed to provide direct gripping surfaces for litter stanchions as well. All metal parts have been painted with chemical agent resistant coating.[40]

SUMMARY

An integrated system of available chemical defense equipment is necessary to adequately protect military personnel. This system includes the following principal elements:

- Real-time detection and warning, preferably from remote sensors, to allow personnel more time to assume the appropriate protective posture and provide for the identification of the specific agent.
- Personal protective equipment consisting of a properly fitted mask and overgarment with gloves and boots as required. This equipment is the most critical component of chemical defense equipment, the first line of defense.
- Collective protection, which is necessary for optimal combat casualty care in a contaminated environment, whether the casualty's injuries are from exposure to CB weapons alone or are combined with injuries from conventional weapons.
- Decontamination, which is required for personnel and equipment to maintain combat operations in a contaminated environment.

Although the focus of this chapter is not on the medical treatment of chemical casualties, it is critical that medical personnel develop a good understanding of chemical defense equipment. Some medical personnel will need to provide care in the contaminated area, others will need to know how to operate equipment in the patient decontamination area, and still others will need to know the limitations of the collective protective environment. Without an adequate understanding of their protective equipment and proper training in its use, medical personnel will become casualties of the same agents that have incapacitated those they treat.

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