Chapter 2

HISTORY OF CHEMICAL AND BIOLOGICAL WARFARE: AN AMERICAN PERSPECTIVE

JEFFERY K. SMART, M.A.*

INTRODUCTION

PRE–WORLD WAR I DEVELOPMENTS

WORLD WAR I

THE 1920s: THE LEAN YEARS

THE 1930s: THE GROWING THREAT OF CHEMICAL AND BIOLOGICAL WARFARE

THE 1940s: WORLD WAR II AND THE NUCLEAR AGE

THE 1950s: HEYDAY OF THE CHEMICAL CORPS

THE 1960s: DECADE OF TURMOIL

THE 1970s: THE NEAR END OF THE CHEMICAL CORPS

THE 1980s: THE RETURN OF THE CHEMICAL CORPS

THE 1990s: THE THREAT MATERIALIZES

SUMMARY

*Command Historian, U.S. Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Maryland 21010-5423

INTRODUCTION

Webster's Ninth New Collegiate Dictionary defines the term "chemical warfare," first used in 1917, as "tactical warfare using incendiary mixtures, smokes, or irritant, burning, poisonous, or asphyxiating gases." A working definition of a chemical agent is "a chemical which is intended for use in military operations to kill, seriously injure, or incapacitate man because of its physiological effects. Excluded from consideration are riot control agents, chemical herbicides and smoke and flame materials."[1(p1-1)] Chemical agents were usually divided into five categories: nerve agents, vesicants, choking agents, blood agents, and incapacitants.

Webster's dictionary likewise defines "biological warfare" as "warfare involving the use of living organisms (as disease germs) or their toxic products against men, animals, or plants." A working definition of a biological agent is "a microorganism (or a toxin derived from it) which causes disease in man, plants or animals or causes deterioration of material."[2(p1-1)] Biological warfare agents were normally divided into three categories: antipersonnel, antianimal, and antiplant.

Prior to World War I, the United States had little knowledge about the potential of chemical and biological warfare. Particularly in terms of preparing soldiers for future wars, the possibility of chemical or biological warfare went virtually unnoticed by the U.S. Army. By the end of World War I, the situation had drastically changed. Chemical warfare had been used against and by American soldiers on the battlefield. Biological warfare had been used covertly on several fronts. In an effort to determine what had gone wrong with their planning and training, U.S. Army officers prepared a history of chemical and biological warfare. To their surprise, they found numerous documented cases of chemical and biological agents having been used or proposed to influence the outcome of a battle or campaign. In addition, they discovered that the technology to protect against chemical and biological agents already existed, and, in some cases, was superior to the equipment used during the war. In hindsight, these officers realized that the army had failed to recognize and prepare for these two already existing types of warfare.

[This chapter focuses primarily on the development of chemical and biological weapons and countermeasures to them, thus setting the stage for Chapter 3, Historical Aspects of Medical Defense Against Chemical Warfare, which concentrates on medical aspects of chemical warfare. To avoid excessive duplication of material, protective equipment of the modern era is illustrated in Chapter 16, Chemical Defense Equipment.—Eds.]

PRE–WORLD WAR I DEVELOPMENTS

The chemical agents first used in combat during World War I were, for the most part, not recent discoveries. Most were 18th- and 19th-century discoveries. For example, Carl Scheele, a Swedish chemist, was credited with the discovery of chlorine in 1774. He also determined the properties and composition of hydrogen cyanide in 1782. Comte Claude Louis Berthollet, a French chemist, synthesized cyanogen chloride in 1802. Sir Humphry Davy, a British chemist, synthesized phosgene in 1812. Dichloroethylsulfide (commonly known as mustard agent) was synthesized in 1822, again in 1854, and finally fully identified by Victor Meyer in 1886. John Stenhouse, a Scotch chemist and inventor, synthesized chloropicrin in 1848.[3]

Many biological agents were naturally occurring diseases thousands of years old. Others were generally discovered or recognized in the 19th and 20th centuries. For example, plague was recognized about 3,000 years ago. Smallpox was known in China as early as 1122 BC. Yellow fever was first described in the 1600s. Carlos Finlay, a Cuban biologist, identified mosquitoes as the primary carrier of yellow fever in 1881, while Walter Reed, a U.S. Army physician, proved the agent to be a virus. Casimir-Joseph Davaine isolated the causative organism of anthrax in 1863, followed by Robert Koch, a German scientist, who obtained a pure culture of anthrax in 1876. Koch also discovered the causative agent for cholera in 1883. Rocky Mountain spotted fever was first recognized in 1873; Howard T. Ricketts, an American pathologist, discovered the causative agent in 1907. Ricketts also identified the causative organism of typhus in 1909. F. Loffler and W. Schutz identified glanders in 1882. Sir David Bruce, a British pathologist, discovered the causative organism of brucellosis (it was named after him) in 1887. Ricin toxin was identified in 1889. Tularemia was first described in Tulare County, California (after which it was

named), in 1911, and the causative agent was identified the next year.[3]

Early Chemical Weaponization Proposals and Usage

There are numerous examples of chemical weapons used or proposed during the course of a campaign or battle. The Chinese used arsenical smokes as early as 1000 BC. Solon of Athens put hellebore roots in the drinking water of Kirrha in 600 BC. In 429 and 424 BC, the Spartans and their allies used noxious smoke and flame against Athenian-allied cities during the Peloponnesian War. About 200 BC, the Carthaginians used Mandrake root left in wine to sedate the enemy. The Chinese designed stink bombs of poisonous smoke and shrapnel, along with a chemical mortar that fired cast-iron stink shells. Toxic smoke projectiles were designed and used during the Thirty Years War. Leonardo da Vinci proposed a powder of sulfide of arsenic and verdigris in the 15th century.[3]

During the Crimean War, there were several proposals to initiate chemical warfare to assist the Allies, particularly to solve the stalemate during the siege of Sevastopol. In 1854, Lyon Playfair, a British chemist, proposed a cacodyl cyanide artillery shell for use primarily against enemy ships. The British Ordnance Department rejected the proposal as "bad a mode of warfare as poisoning the wells of the enemy."[4(p22)] Playfair's response outlined a different concept, which was used to justify chemical warfare into the next century:

> There was no sense in this objection. It is considered a legitimate mode of warfare to fill shells with molten metal which scatters among the enemy, and produced the most frightful modes of death. Why a poisonous vapor which would kill men without suffering is to be considered illegitimate warfare is incomprehensible. War is destruction, and the more destructive it can be made with the least suffering the sooner will be ended that barbarous method of protecting national rights. No doubt in time chemistry will be used to lessen the suffering of combatants, and even of criminals condemned to death.[4(pp22–23)]

There were other proposals for chemical warfare during the Crimean War, but none were approved.

During the American Civil War, John Doughty, a New York City school teacher, was one of the first to propose the use of chlorine as a chemical warfare agent. He envisioned a 10-in. artillery shell filled with 2 to 3 qt of liquid chlorine that, when released, would produce many cubic feet of chlorine gas.

> If the shell should explode over the heads of the enemy, the gas would, by its great specific gravity, rapidly fall to the ground: the men could not dodge it, and their first intimation of its presence would be by its inhalation, which would most effectually disqualify every man for service that was within the circle of its influence; rendering the disarming and capturing of them as certain as though both their legs were broken.[5(p27)]

As to the moral question of using chemical weapons, he echoed the sentiments of Lyon Playfair a decade earlier:

> As to the moral question involved in its introduction, I have, after watching the progress of events during the last eight months with reference to it, arrived at the somewhat paradoxical conclusion, that its introduction would very much lessen the sanguinary character of the battlefield, and at the same time render conflicts more decisive in their results.[5(p33)]

Doughty's plan was apparently never acted on, as it was probably presented to Brigadier General James W. Ripley, Chief of Ordnance, who was described as being congenitally immune to new ideas.[5] A less-practical concept, proposed the same year by Joseph Lott, was to fill a hand-pumped fire engine with chloroform to spray on enemy troops.[6]

The 1864 siege of Petersburg, Virginia, generated several chemical warfare proposals. Forrest Shepherd proposed mixing hydrochloric and sulfuric acids to create a toxic cloud to defeat the Confederates defending Petersburg.[5] Lieutenant Colonel William W. Blackford, a Confederate engineer, designed a sulfur cartridge for use as a countertunnelling device.[7] The Confederates also considered using Chinese stink bombs against the Union troops. Elsewhere, the same year, Union Army Captain E. C. Boynton proposed using a cacodyl glass grenade for ship-to-ship fighting.[5] Other than possibly Blackford's cartridge, none of the proposals were used on the battlefield.

Two wars at the turn of the century also saw limited use of chemical weapons. During the Boer War, British troops fired picric acid–filled shells, although to little effect.[8] During the Russo–Japanese War, which was closely observed by those who would plan World War I, Japanese soldiers threw arsenal rag torches into Russian trenches.[3]

In 1887, the Germans apparently considered using lacrimators (tear agents) for military purposes. The French also began a rudimentary chemical warfare program with the development of a tear gas

grenade containing ethyl bromoacetate, and proposals to fill artillery shells with chloropicrin.[9]

Early Biological Warfare Proposals and Usage

There were many examples of proposed usage or actual use of biological weapons on the battlefield. Hannibal hurled venomous snakes onto the enemy ships of Pergamus at Eurymedon in 190 BC. Scythian archers used arrows dipped in blood and manure or decomposing bodies in 400 BC. The use of dead bodies as the carrier of the biological agent proved particularly effective against an enemy's water supply. Barbarossa used this tactic at the battle of Tortona in 1155. De Mussis, a Mongol, catapulted bubonic plague–infected bodies into Caffa in 1346. The Spanish tried wine infected with leprosy patients' blood against the French near Naples in 1495. One of the more unique attempts at biological warfare was initiated in 1650 by Siemenowics, a Polish artillery general, who put saliva from rabid dogs into hollow spheres for firing against his enemies. The Russians cast plague-infected bodies into Swedish-held Reval, Estonia, in 1710.

The proposed use of biological weapons was not limited to Europe and Asia. In 1763, during Pontiac's Rebellion in New England, Colonel Henry Bouquet, a British officer, proposed giving the Indians at Fort Pitt, Pennsylvania, blankets infected with smallpox. The disease, whether purposely disseminated or not, proved devastating to the Native American population. A similar plan was executed in 1785, when Tunisians threw plague-infected clothing into La Calle, held by the Christians.

The 19th-century wars continued the same trend. In 1861, Union troops advancing south into Maryland and other border states were warned not to eat or drink anything provided by unknown civilians for fear of being poisoned. Despite the warnings, there were numerous cases where soldiers thought they had been poisoned after eating or drinking. Confederates retreating in Mississippi in 1863 left dead animals in wells and ponds to deny water sources to the Union troops.

A more carefully planned use of biological weapons was attempted by Dr. Luke Blackburn, a future governor of Kentucky, who attempted to infect clothing with smallpox and yellow fever and then sell it to unsuspecting Union troops. At least one Union officer's obituary stated that he died of smallpox attributed to Blackburn's scheme. Yellow fever, however, could not be transferred in this manner. Since more soldiers died of disease during the Civil War than were killed on the battlefield, the effectiveness of Blackburn's work was difficult to judge.

Biological agents were also considered for antianimal weapons during the 19th century. Louis Pasteur, the French chemist and biologist usually recognized for his humanitarian accomplishments, also experimented with the use of salmonella as an agent to exterminate rats. Others successfully used chicken cholera to exterminate rabbits and dysentery to kill grasshoppers.[3]

Early Protective Devices

Parallel to the development and use of chemical and biological weapons was the design of protective equipment for use against toxic chemicals and biological agents. Although conventional protective masks started appearing in the 19th century, the earliest recorded mask proposal was written by Leonardo da Vinci in the 15th century. He envisioned a fine cloth dipped in water for defense

Fig. 2-1. Theodore A. Hoffman patented this respirator in 1866. It is representative of the already developing protective mask designs of the post–American Civil War era. Ironically, these masks were superior to the ad hoc emergency masks used by the Allies after the Germans began chemical warfare in World War I. Reprinted from US Patent No. 58,255; 25 Sep 1866.

against a sulfide of arsenic and verdigris powder he was proposing for a toxic weapon.[10]

The earliest known patent for a protective mask in the United States was filed by Lewis P. Haslett in 1847. His design included a moistened woolen fabric mask with an exhaust.[11] Benjamin I. Lane's patent in 1850 included an air tank, goggles, and a rubber nose piece.[12] John Stenhouse developed a velvet-lined copper mask with a charcoal filter in 1854. The same year, George Wilson, a professor of technology at the University of Edinburgh, proposed that the British Board of Ordnance issue charcoal masks to soldiers to protect them from bombs employing suffocating or poisonous vapors during the Crimean War.[13]

Between the American Civil War and World War I, there were numerous additional patents and designs for protective devices that were used in industry, for fire fighting, and in mines. These included an improved mask by Lane, which had a rubber facepiece with an exhaust; Theodore A. Hoffman's mask, which was made of cotton with an elastic border to protect against aerosols (Figure 2-1); Samuel Barton's mask with a metal-and-rubber facepiece, hood, goggles, and a charcoal filter; and Charles A. Ash's mask, which added an air supply for use by miners.[3]

Attempts to Control Chemical and Biological Warfare

Most of the early attempts to control chemical and biological warfare were bilateral or unilateral agreements directed at the use of poisons. These included the 1675 agreement between the French and Germans, signed in Strassburg, to ban the use of poison bullets, and U.S. Army General Order No. 100, issued in 1863 during the American Civil War, which stated: "The use of poison in any manner, be it to poison wells, or food, or arms, is wholly excluded from modern warfare."[14(p687)]

The first international attempt to control chemical and biological weapons occurred in 1874, when the International Declaration Concerning the Laws and Customs of War was signed in Brussels and included a prohibition against poison or poisoned arms. The First Hague Peace Conference in 1899 also banned the use of poisons and was ratified by the United States. However, a separate proposition stated: "The contracting Powers agree to abstain from the use of projectiles the sole object of which is the diffusion of asphyxiating gasses."[14(p685)] Although 27 nations, including Germany, France, Russia, Austria-Hungary, and Great Britain, eventually agreed to this additional statement, the United States delegation declined to approve it.

Captain Alfred T. Mahan, a U.S. Navy delegate plenipotentiary, gave three reasons for opposing the additional restrictions: (1) currently used weapons were despised as cruel and inhumane when first introduced, (2) since there were no current chemical weapons stockpiles, it was too early to ban them, and (3) chemical weapons were not any more inhumane than any other weapon. The 1907 Second Hague Peace Conference retained the ban against poisons.[15]

WORLD WAR I

When Europe was caught up in the crises of 1914 after the murder of Archduke Francis Ferdinand at Sarajevo and the declarations of war among Austria-Hungary, Serbia, Germany, France, Russia, and Great Britain that followed within a month, few observers expected the 19th-century chemical and biological paper proposals to be transformed into actual battlefield operations. The United States, remaining neutral under the policy of President Woodrow Wilson, certainly made no preparations for chemical and biological warfare.

Early Allied Chemical Warfare Plans

With the outbreak of hostilities, both the French and the British apparently considered, investigated, and tested various chemical weapons at home and on the battlefield. During the German invasion of Belgium and France, the French used their ethyl bromoacetate grenades against the Germans, but with no noticeable effect. Although the grenades were considered of no military worth, the French apparently continued to consider the further use of tear agents against the Germans.

In the early stages of the war, the British examined their own chemical technology for battlefield use. They initially investigated tear agents also but later turned to more toxic chemicals. In January 1915, several chemists at Imperial College successfully demonstrated ethyl iodoacetate as a tear gas to the War Office by gassing a representative.

Another officer suggested using sulfur dioxide as a chemical weapon. Field Marshal Lord Kitchener, Secretary of State for War, was not interested in the concept for the army but suggested trying the navy. At the Admiralty, the idea found a

sympathetic ear in Winston Churchill in March 1915. The suggestion included a plan to use a sulfur dioxide cloud against the Germans, screen the operation with smoke, and provide British troops a gas-proof helmet. Churchill declined to accept the sulfur dioxide plan but did put the officer in charge of a committee the next month to discuss the use of smoke on land and sea.[9]

German Chemical Warfare Plans

Possibly aware of the Allied interest in chemical weapons, the Germans also examined their own chemical technology for war applications. Their strong dye industry and the technical knowledge supplied by university professors in Berlin created the right combination for pursuing the concept of offensive chemical weapons. From the suggestion of Professor Walther Nernst, a physical chemist at the University of Berlin, or one of his colleagues, the Germans filled 105-mm shells with dianisidine chlorosulfate, a lung irritant, for use on the western front. To evade the 1899 international ban, the Germans also put shrapnel in the shell so the "sole" purpose was not gas dissemination.

On 27 October 1914, the Germans fired 3,000 of these projectiles at the British near Neuve-Chapelle, but with no visible effects. The explosive aspect of the shells destroyed the chemical aspect. In fact, the British were apparently unaware that they were the victims of the first large-scale chemical projectile attack.

The Germans continued researching chemical shells, and by November 1914, Dr. Hans von Tappen, assigned to the Heavy Artillery Department, designed a 150-mm howitzer shell containing 7 lb of xylyl bromide and a burster charge for splinter effect (Figure 2-2). The Germans moved these to the eastern front and experimented by firing more than 18,000 of the shells at Russian positions near Bolimov. In this case, the weather came to the aid of the Russians by providing cold temperatures that prevented the vaporization of the gas. The Germans tried the same shells again on the western front at Nieuport in March 1915 with equally unsuccessful results.[9,14,16]

Ypres, April 1915: The First Successful German Chemical Attack

The concept of creating a toxic gas cloud from chemical cylinders was credited to Fritz Haber of the Kaiser Wilhelm Physical Institute of Berlin in late 1914. Owing to shortages of artillery shells,

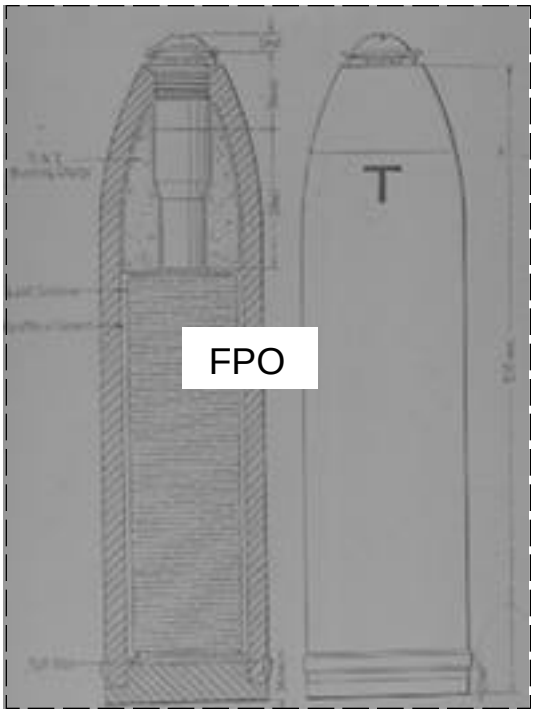

Fig. 2-2. The German 150-mm T-Shell, which mixed xylyl bromide with an explosive charge. Note that the explosive charge was in the front and the chemical agent in the rear compartment. This design is similar to the one proposed in 1862 by John Doughty during the American Civil War (see Figure 3-1). Reprinted from Army War College. *German Methods of Offense*. Vol 1. In: *Gas Warfare.* Washington, DC: War Department; 1918: 59.

Haber thought a chemical gas cloud would negate the enemy's earthworks without the use of high explosives. In addition, gas released directly from its storage cylinder would cover a far broader area than that dispersed from artillery shells. Haber selected chlorine for the gas since it was abundant in the German dye industry and would have no prolonged influence over the terrain.

On 10 March 1915, under the guidance of Haber, Pioneer Regiment 35 placed 1,600 large and 4,130 small cylinders containing a total of 168 tons of chlorine opposite the Allied troops defending Ypres, Belgium. Haber also supplied the entire regiment with Draeger oxygen breathing sets, used in mine work, and a portion of the surrounding German infantry with small pads coated with sodium thiosulfate. Once the cylinders were in place, the Germans then waited for the winds to shift to a westerly direction.[9,14,17]

The Germans believed this means of attack, nonprojectile, was still within the guidelines of the

Hague ban and hoped the cylinders would produce a potent cloud. The comments of General von Deimling, commanding general of the German 15th Corps in front of Ypres, written sometime after the war, however, perhaps better reflect the reason for initiating chemical warfare:

> I must confess that the commission for poisoning the enemy, just as one poisons rats, struck me as it must any straight-forward soldier: it was repulsive to me. If, however, these poison gases would lead to the fall of Ypres, we would perhaps win a victory which might decide the entire war. In view of such a high goal, personal susceptibilities had to be silent.[18(p5)]

On 22 April 1915, the Germans released the gas with mixed success. Initially, the Allied line simply fell apart. This was despite the fact that the Allies were aware of the pending gas attack, and British airmen had actually spotted the gas cylinders in the German trenches. The success of the attack was more significant than the Germans expected, and they were not ready to make significant gains despite the breakthrough. In addition, fresh Allied troops quickly restored a new line further back. The Allies claimed that 5,000 troops were killed in the attack, but this was probably an inflated number for propaganda purposes.[18]

The Germans used chlorine again at Ypres on 24 April 1915 and four more times during May 1915 (Figure 2-3). These additional attacks gained additional ground. As one British soldier stated:

> Nobody appears to have realized the great danger that was threatening, it being considered that the enemy's attempt would certainly fail and that whatever gas reached our line could be easily fanned away. No one felt in the slightest degree uneasy, and the terrible effect of the gas came to us as a great surprise.[19(p3)]

Another observer, in reflecting about the attack at Ypres and the first major use of chemical warfare, wrote: "The most stupendous change in warfare since gunpowder was invented had come, and come to stay. Let us not forget that."[20(p3)] Yet chemical warfare failed to be decisive and the German attack against Ypres was halted short of its objective.

Allied Chemical Warfare Retaliation

That same month, the British and the French began planning to retaliate with chemical weapons. The Allied response to the chemical attacks evolved into three general categories:

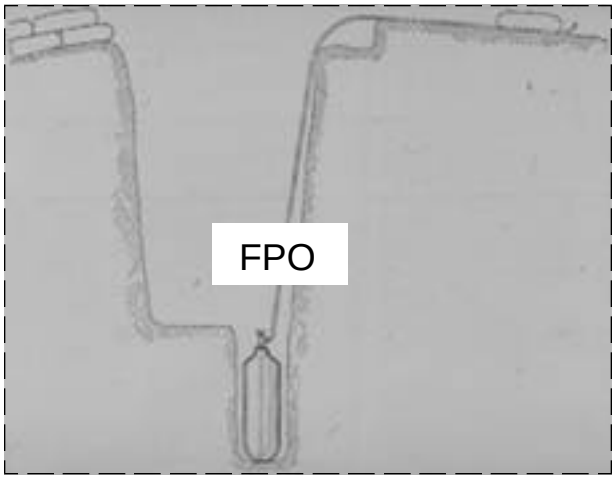

Fig. 2-3. A typical German chemical cylinder set up and ready for discharge. The discharge from thousands of cylinders created the gas cloud. Reprinted from Army War College. *German Methods of Offense*. Vol 1. In: *Gas Warfare.* Washington, DC: War Department; 1918: 14.

1. protective devices for the troops,
2. toxic gases of their own, and
3. weapons to deliver the toxic gases to the enemy lines.

Shortly after the first chlorine attack, the Allies had primitive emergency protective masks. In September, they launched their own chlorine attack against the Germans at Loos (Figure 2-4). This initiated a

Fig. 2-4. A French cylinder attack on German trenches in Flanders. The critical importance of the wind is apparent. Condensation of water vapor caused the cloudlike appearance of the gas. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

deadly competition to develop better protective masks, more potent chemicals, and long-range delivery systems to more widely disperse the agents.

The Germans quickly escalated to phosgene to replace the less-effective chlorine. In May 1916, the Germans started using trichloromethyl chloroformate (diphosgene), while the French tried hydrogen cyanide 2 months later and cyanogen chloride the same year. In July 1917, the Germans introduced mustard agent to provide a persistent vesicant that could attack the body in places not protected by gas masks. To further complicate defensive actions, both sides mixed agents and experimented with camouflage materials to prevent quick identification.[3]

German Biological Warfare Plans

While the German chemical warfare program was extensively documented after the war, the German use of biological weapons during World War I unfortunately was poorly documented and much debated. Apparently in 1915, the Germans initiated covert biological warfare attacks against the Allies' horses and cattle on both the western and the eastern fronts. In that year, they also allegedly used disease-producing bacteria to inoculate horses and cattle leaving U.S. ports for shipment to the Allies. Other attacks included a reported attempt to spread plague in St. Petersburg, Russia, in 1915.[3,21]

The activities of German agents operating in the United States in 1915 came to light after the war. Erich von Steinmetz, a captain in the German navy, entered the United States disguised as a woman. He brought with him cultures of glanders to inoculate horses intended for the western front. After trying unsuccessfully, he posed as a researcher and took the cultures to a laboratory, where it was determined the cultures were dead.

Anton Dilger was an American-educated surgeon who specialized in wound surgery at Johns Hopkins University, Baltimore, Maryland. After joining the German army in 1914, he suffered a nervous breakdown and was sent to his parents' home in Virginia since the United States was still neutral in the war. At the request of the German government, he brought along strains of anthrax and glanders to begin a horse-inoculation program. With his brother Carl, he set up a laboratory in a private house in Chevy Chase, Maryland, to produce additional quantities of the bacteria.

The bacteria from "Tony's lab" were delivered to Captain Frederick Hinsch, who was using a house at the corner of Charles and Redwood Streets in Baltimore, Maryland. Hinsch inoculated horses in Baltimore that were awaiting shipment to Europe. Dilger also attempted to establish a second biological warfare laboratory in St. Louis, Missouri, but gave up after a cold winter killed the cultures. Although the impact of these German agents' activities was not determined, the year 1915 is considered to be the beginning of 20th-century antianimal biological warfare.[22]

Additional biological attacks reportedly occurred throughout the war. In 1916, a German agent with intentions to spread a biological agent was arrested in Russia. German agents also tried to infect horses with glanders and cattle with anthrax in Bucharest in 1916. In 1917, Germany was accused of poisoning wells in the Somme area with human corpses, and dropping fruit, chocolate, and children's toys infected with lethal bacteria into Romanian cities. German agents tried to infect horses with glanders and cattle with anthrax in France. A more successful attack was the infection of some 4,500 mules with glanders by a German agent in Mesopotamia. Another reported attack was with cholera in Italy. A 1929 report also accused the Germans of dropping bombs containing "plague" over British positions during the war. Many of these reports were of questionable authenticity and were vehemently denied by the Germans. As had happened during the American Civil War, the rampant spread of naturally occurring disease during World War I made the impact of planned biological warfare attacks impossible to determine.[3,21]

Pre-War Interest in the United States in Chemical Warfare

The production and use of offensive chemical weapons in the European war did not go completely unnoticed in the United States. The combination of the use of chemical warfare at Ypres in April, followed by the sinking of the *Lusitania* by a German U-boat off the Irish coast on 7 May 1915, shocked the nation. Americans began to take greater interest in the nature of warfare taking place in Europe and elsewhere. In May 1915, President Woodrow Wilson proposed that Germany halt chemical warfare in exchange for the British ending their blockade of neutral ports. Germany (and Great Britain) refused to comply.

Helpful suggestions from armchair scientists proved to be of little help to the army. The *Army and Navy Register* of 29 May 1915 contained the following report:

> Among the recommendations forwarded to the Board of Ordnance and Fortifications there may be found many suggestions in favor of the asphyxiation process, mostly by the employment of gases contained in bombs to be thrown within the lines of the foe, with varying effects from peaceful slumber to instant death. One ingenious person suggested a bomb laden to its full capacity with snuff, which should be so evenly and thoroughly distributed that the enemy would be convulsed with sneezing, and in this period of paroxysm it would be possible to creep up on him and capture him in the throes of the convulsion.[23(p12)]

By the fall of 1915, the War Department finally became interested in providing American troops with some form of a protective mask. By then, the British already had the P helmet, a flannel bag treated with sodium phenate and sodium hyposulfite that fitted over the head and was effective against chlorine and phosgene gases. The Germans were slightly ahead with a rubberized facepiece, unbreakable eyepieces, and a drum canister.[24]

In the United States, the mask project was assigned to the Army Medical Department. The Medical Department sent several medical officers to Europe as observers, but accomplished little else. Since the United States was not at war, no particular emphasis was placed on the project. Ultimately, all major participants in World War I attempted to develop protective masks (Figure 2-5).

As relations with Germany declined over its unrestricted use of submarines, the war overtones did energize several key civilians in the U.S. government. One, Van H. Manning, Director of Bureau of Mines, Department of the Interior, called together his division chiefs on 7 February 1917 to discuss how they could assist the government if the country was drawn into war. At this meeting, George S. Rice suggested that the bureau might turn its experience in mine gas and rescue apparatus toward the investigation of war gases and masks.

The next day, Manning sent a letter to Dr. C. D. Walcott, Chairman of the Military Committee of the National Research Council (NRC), which had been created the year before, offering the Bureau's services in creating a chemical warfare program for the army. On 12 February 1917, Dr. Walcott replied to Manning's letter, stating that he would bring the matter to the attention of the Military Committee.

Events, however, moved quicker than the Military Committee. On 2 April 1917, President Wilson addressed the U.S. Congress and called for a declaration of war. The next day, the Military Committee acted on Manning's proposal and established the Subcommittee on Noxious Gases under the chairmanship of the director of the Bureau of Mines, and to include ordnance and medical officers from both the army and the navy, as well as two members of the Chemical Committee of the NRC. Their mission was to investigate noxious gases, the generation of chemical warfare agents, and the discovery of antidotes for war purposes. Three days later the United States declared war on Germany when congress approved the president's request.[17,25,26]

Fig. 2-5. A potpourri of World War I–vintage protective masks. This extraordinary photograph gives some indication of the great effort made by the warring parties to develop an effective and practical (and frequently unsuccessful) defense against the chemical warfare threat. Top row, left to right: U.S. Navy Mark I mask; U.S. Navy Mark II mask; U.S. CE mask; U.S. RFK mask; U.S. AT mask; U.S. KT mask; U.S. model 1919 mask. Middle row, left to right: British Black Veil mask; British PH helmet; British BR mask; French M2 mask; French artillery mask; French ARS mask. Bottom row, left to right: German mask; Russian mask; Italian mask; British Motor Corps mask; U.S. Rear Area mask; U.S. Connell mask. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

The United States Organizes for Chemical Warfare

The new Subcommittee on Toxic Gases got off to a quick start. Within a short time, the subcommittee began organizing research into chemical agents at universities and industries across the nation, while mobilizing a large portion of the chemists in the country. This initial phase was the groundwork that later led to the establishment of the Chemical Warfare Service, the forerunner of the Chemical Corps. Thus the country's civilian scientists, engineers, and chemistry professors rescued the army from its unpreparedness for chemical warfare.

Eventually, the War Department also began to plan for chemical warfare. The Medical Department was assigned responsibility for chemical defense and the Ordnance Department responsibility for chemical munitions. The Corps of Engineers was designated to provide engineers to employ the new weapons. This diversified arrangement did not last long.

When General John J. Pershing faced the task of organizing the American Expeditionary Forces (AEF) in France in the summer of 1917, he decided to place responsibility for all phases of gas warfare in a single military service, and he recommended that the War Department at home do likewise. On 3 September 1917, the AEF established a centralized Gas Service under the command of Lieutenant Colonel Amos A. Fries.[25,26] The new organization had many hurdles to overcome. The troops had virtually no chemical warfare equipment of U.S. design and relied on the British and French to supply equipment from gas masks to munitions.

U.S. Troops Introduced to Chemical Warfare

Despite the Allied support, the U.S. Army was not ready for chemical warfare. For example, on 26 February 1918, the Germans fired 150 to 250 phosgene and chloropicrin projectiles against the Americans near Bois de Remieres, France. The first attack occurred between 1:20 AM and 1:30 AM. There was a blinding flash of light and then several seconds elapsed before the projectiles reached their target. Some exploded in the air and others on the ground. A second and similar attack occurred about an hour later. The attack and its casualties were recorded by many observers, including the following selected accounts[27]:

- A corporal saw the projectiles burst 10 ft in the air with flash and smoke. As the shells burst, he got his mask on without smelling any gas. When he took his mask off an hour and a half later, however, he could smell gas.
- One private said the gas smelled like sour milk and had a sharp odor. It hurt his eyes and nose. Another private forgot to hold his breath while putting on his mask. The gas smelled sweet and he became sick to the stomach and his lungs hurt. Still, he kept his mask on for 4 hours.
- One man in panic stampeded and knocked down two others who were adjusting their masks. The panicked man rushed down the trench screaming and made no attempt to put on his respirator; he died shortly after reaching the dressing station.
- Another man threw himself in the bottom of the trench and began to scream. Two others, trying to adjust his respirator, had their own pulled off and were gassed. The screaming man was finally carried out of the area but died not long after.
- An officer was gassed while shouting to the men to keep their respirators on.

The Americans suffered 85 casualties with 8 deaths, approximately 33% of their battalion. The problem was a lack of discipline. Because a good American mask was not yet available, the soldiers were issued two gas masks: a French M2, which was comfortable but not extremely effective; and a British small-box respirator (SBR), which was effective but uncomfortable with its scuba-type mouthpiece and nose clip. At the first sign of gas, some of the men could not find their gas masks in time. Others were able to get their SBRs on, but then either removed their masks too quickly or decided to switch to the more comfortable French mask and were gassed in the process.[27]

An editorial later summed up the lesson learned from this first fiasco:

> A stack of standing orders a mile high will not discipline an army. Neither can you so train men at the outbreak of hostilities that they can protect themselves against the gas which will be used by the enemy. We must train our Army to the last degree during peace.[28(p2)]

Creation of the Chemical Warfare Service

In the spring of 1918, the U.S. government began centralizing gas warfare functions in the War Department under a senior Corps of Engineers of-

Fig. 2-6. Major General William L. Sibert was the first commanding general of the U.S. Army Chemical Warfare Service. He had previously commanded the 1st Division in France in early 1918. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

ficer, Major General William L. Sibert (Figure 2-6). When President Wilson transferred the research facilities that had been set up by the Bureau of Mines to the War Department, the stage was set for the inauguration of a new consolidated organization. On 28 June 1918, the War Department formally established the Chemical Warfare Service (CWS) under Sibert as part of the National Army (ie, the wartime army, as distinguished from the regular army), with full responsibility for all facilities and functions relating to toxic chemicals.

The CWS was organized into seven main divisions. The Research Division was located at American University, Washington, D. C. Most of the weapons and agent research was conducted by this division during the war. The Gas Defense Division was responsible for the production of gas masks and had a large plant in Long Island City, New York. The Gas Offense Division was responsible for the production of chemical agents and weapons, with its main facility located at Edgewood Arsenal, Maryland. The Development Division was responsible for charcoal production, and also pilot-plant work on mustard agent production. The Proving Ground Division was collocated with the Training Division at Lakehurst, New Jersey. The Medical Division was responsible for the pharmacological aspects of chemical defense.

The offensive chemical unit for the AEF was the First Gas Regiment, formerly the 30th Engineers. This unit was organized at American University under the command of Colonel E. J. Atkisson in 1917, and was sent to France in early 1918.[17,25]

The U.S. Army finally had an organization that controlled offensive chemical production, defensive equipment production, training, testing, and basic research, along with a new chemical warfare unit, the First Gas Regiment, under one general. This organization helped lead the AEF to victory, although much of its work, including the construction of toxic gas–production and –filling plants and gas mask factories, was only partially completed by the end of the war.

Agent Production

Agent production and shell-filling were initially assigned to the Ordnance Department and then to the CWS. The primary facility was Edgewood Arsenal, Maryland, erected in the winter of 1917–1918. The plant was designed to have four shell-filling plants and four chemical agent production plants. The first shell-filling plant filled 75-mm, 155-mm, 4.7-in., and Livens projectiles with phosgene. A second filling plant was added to fill 155-mm shells with mustard agent or chloropicrin (Figure 2-7). Two additional shell-filling plants were started but not completed before the end of the war.

The four agent production plants produced the highest priority agents thought to be required for the western front in 1917. These were chlorine, chloropicrin, phosgene, and mustard agent (Figure 2-8). By 1918, the first two were no longer critical agents, although chlorine was used in the production of phosgene. Over 935 tons of phosgene and 711 tons of mustard agent were produced at the arsenal by the end of the war. Government contractors also produced these four agents and Lewisite, named after Captain W. Lee Lewis, a member of the CWS Research Division. The Lewisite, however, never reached the front: it was dumped somewhere in the Atlantic Ocean (ie, sea dumped) after the armistice.[3,17,26]

Chemical Weapons

During the war, the CWS used foreign technology for offensive weapons. The initial mode of of-

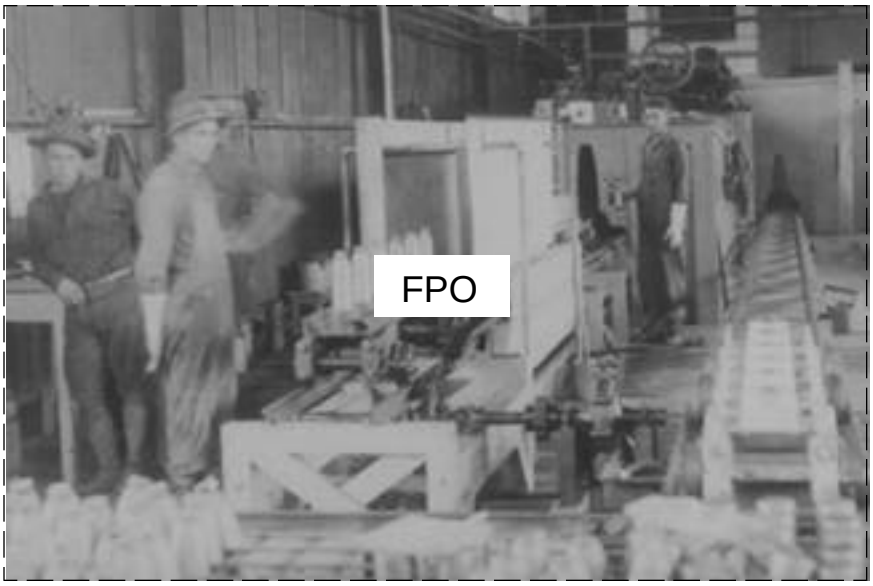

Fig. 2-7. Filling 75-mm artillery shells with mustard agent at Edgewood Arsenal, Md. Facilities designed to fill shells with chemical agents were notoriously hazardous. Anecdotal reports from mustard shell-filling plants indicated that over several months, the *entire* labor force could be expected to become ill. These workers' apparent nonchalance to the hazards of mustard would not be tolerated by the occupational medicine standards of a later era (see Figure 2-31). Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

fensive chemical attack was the portable chemical cylinder, designed to hold 30 to 70 lb of agent. Soldiers simply opened a valve and hoped the wind continued to blow in the right direction. The resulting cloud could drift many miles behind enemy lines, or, if the wind changed, could gas friendly troops.

The British improved on the delivery system, developing the Livens projector, an 8-in. mortarlike tube that shot or projected the cylinder into the

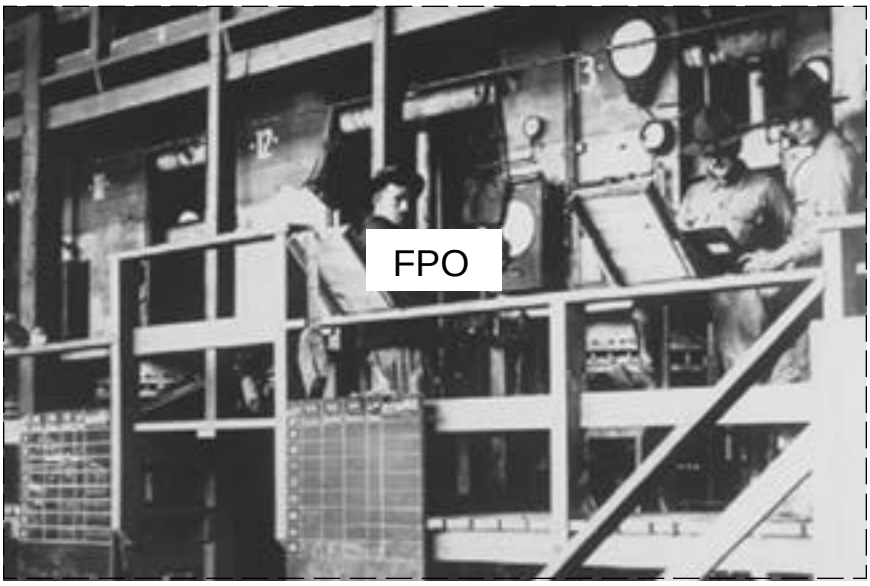

Fig. 2-8. Interior view of the Mustard Agent Production Plant at Edgewood Arsenal, Md. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-9. A battery of dug-in Livens projectors, with one gas shell and its propellant charge shown in the foreground. Electrically controlled salvo firing was the usual mode of operation. Emplacement was a slow process, and it limited the surprise factor for attack. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

enemy's lines (Figures 2-9 and 2-10). The range was a respectable 1,700 yd, with a flight time of 25 seconds. There were several problems with the system.

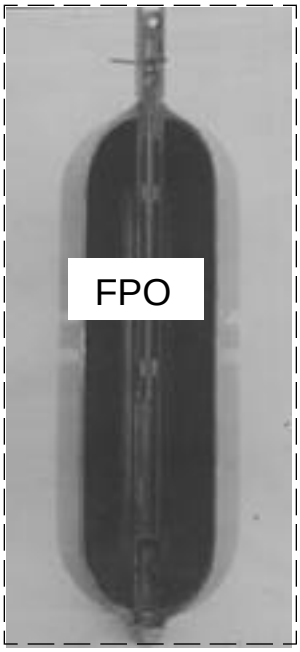

Fig. 2-10. Sectionalized view of a Livens projectile. The central tube contains a small explosive charge, which, when detonated by the contact fuze, breaks the shell and aids in the dissemination of the chemical agent. The usual weight of the chemical agent was 30 lb; the shell weighed an additional 30 lb. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Being electrically fired, a battery of Livens projectors required extensive preparation and could not be moved once set up. Normally, a battery could only be emplaced and fired once a day. This limited mobility required the element of surprise to prevent the Germans from taking counter actions.

British 4-in. trench mortars, called Stokes mortars (Figure 2-11), provided a solution to some of the problems with Livens projectors. The Stokes mortar did not require extensive preparation and could be moved as needed. Since it was not rifled, the range was only 1,200 yd, which meant about a 14-second flight time. The small size of the shell only held about 6 to 9 lb of agent, but experienced gunners could fire 25 rounds per minute. American troops used both Livens projectors and Stokes mortars during the war. Ordnance officers tried making their own Stokes mortars, but none reached the front before the end of the war.

In addition to the special chemical weapons, the CWS fired chemical rounds from 75-mm, 4.7-in., 155-mm, and larger-caliber guns. Many of these had ranges of 5 to 10 miles, with payloads of as much as 50 lb of agent. Owing to a shortage of shell parts and the late completion of U.S. shell-filling plants, U.S. troops primarily fired French phosgene and mustard agent rounds.[3,14,26]

Biological Warfare Weapons

By 1918, the United States was apparently aware of the German biological warfare program, but the only agent examined was a toxin for retaliatory

Fig. 2-11. A complete Stokes mortar with ammunition and accessories for firing. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

purposes. Ricin, derived from castor beans, could be disseminated two ways. The first involved adhering ricin to shrapnel bullets for containment in an artillery shell. The results of this work were stated in a technical report in 1918:

> These experiments show two important points: (1) easily prepared preparations of ricin can be made to adhere to shrapnel bullets, (2) there is no loss in toxicity of firing and even with the crudest method of coating the bullets, not a very considerable loss of the material itself. ... It is not unreasonable to suppose that every wound inflicted by a shrapnel bullet coated with ricin would produce a serious casualty. ... Many wounds which would otherwise be trivial would be fatal.[29(p112)]

The second involved the production of a ricin dust cloud, but due to limited amounts of ricin being produced and the inefficient delivery via the respiratory tract, little work seems to have been pursued in this means of dissemination. Although both approaches were laboratory tested, neither was perfected for use in Europe before the end of the war.[29]

Protective Equipment

The early unsuccessful efforts to produce a gas mask were resolved by CWS researchers at American University and other CWS research facilities. In the spring of 1918, the CWS issued the Richardson, Flory, and Kops (RFK) mask, which was an improved version of the British SBR. Over 3 million were produced for U.S. troops. Late in 1918, the CWS merged the best aspects of the RFK mask with a French design that eliminated the scuba-type mouthpiece. Designated the Kops Tissot Monro (KTM) mask, only 2,000 were produced before the end of the war.[14,30–32] Humans were not the only creatures requiring protection against chemical agents: the CWS developed protective masks for horses, dogs, and carrier pigeons.

Other efforts at individual protection were not very successful. Sag Paste derived its name from Salve Antigas and was intended as an ointment that would prevent mustard agent burns. It was made of zinc stearate and vegetable oil and, for a short period, provided some protection against large doses of mustard agent. However, once the paste absorbed the mustard, injuries occurred. In addition, there was the problem of an individual's having to apply the paste to all the parts of his body using his contaminated hands and while remaining on the battlefield. Over 900 tons of Sag Paste was shipped to the AEF during the war.[14,26]

The early concerns with collective protection primarily concentrated on providing a group of soldiers a gas-proof place in the trenches where they could remove the uncomfortable early gas masks. To accomplish this objective, studies were conducted on blankets to hang over dugout doorways, and various coatings or impregnates were examined for agent resistance. The result was a regular cotton blanket treated with dugout-blanket oil, a special heavy oil (Figure 2-12). Over 35,000 such blankets were shipped to the AEF.[26]

For ventilation of the dugout, there was the special antigas fan known as the Canvas Trench Fan. A 1918 War College gas warfare manual dedicated seven pages to the use of the fan, although all the fan really did was disperse the gas (Figure 2-13). Still, over 25,000 trench fans were sent to the front.[26,33]

Decontamination

There was also the problem of cleaning up the chemical agents after the gas attack. Mustard agent was a significant problem when it came to decontaminating the ground. The Germans apparently used chloride of lime to decontaminate the ground after an explosion at Germany's first mustard agent factory in Adlershof. For the AEF, bleaching pow-

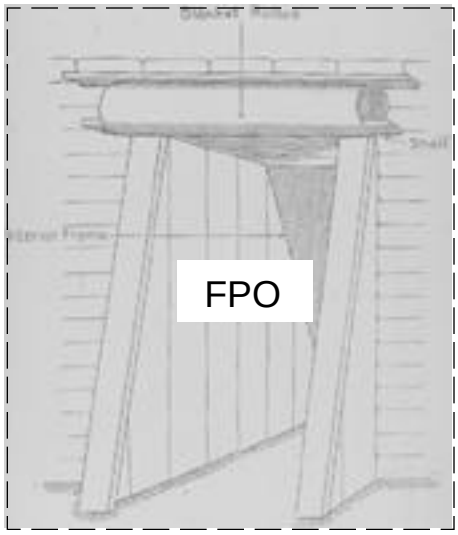

Fig. 2-12. Early attempts at collective protection during World War I included the dugout blanket, which was used to cover the doorways to dugouts. Reprinted from Army War College. *Methods of Defense Against Gas Attacks*. Vol 2. In: *Gas Warfare.* Washington, DC: War Department; 1918: Figure 18.

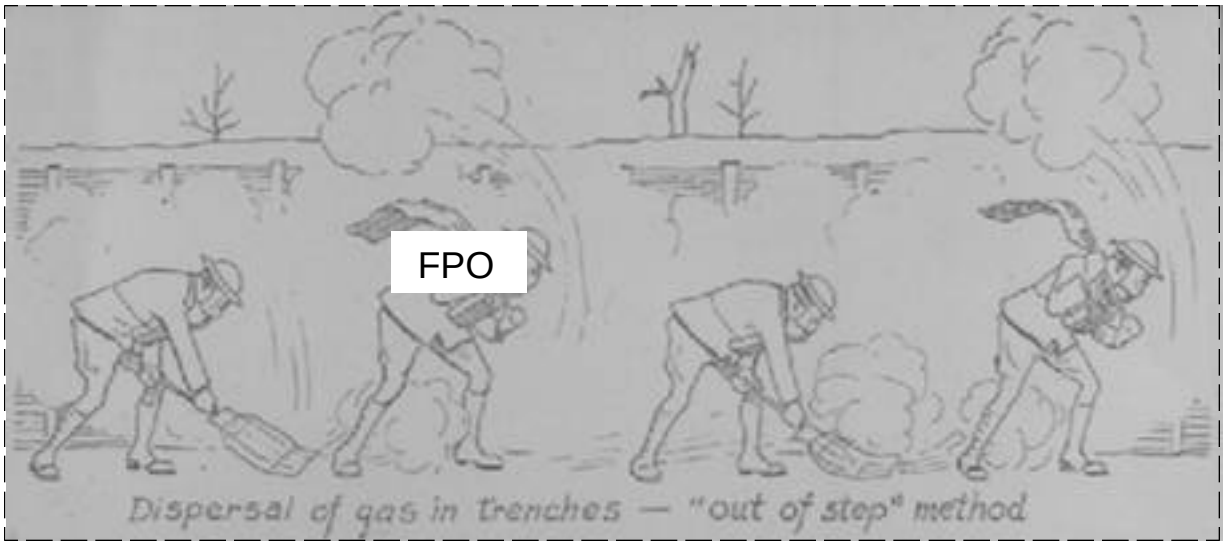

Fig. 2-13. Procedures for using the trench fan to remove chemical agents from trenches. The fan was a failure. Reprinted from Army War College. *Methods of Defense Against Gas Attacks*. Vol 2. In: *Gas Warfare.* Washington, DC: War Department; 1918: Figure 25.

der (also known as chloride of lime or calcium hypochlorite) was the primary decontaminant during the war. Obtained from the bleaching industry, this white powder proved effective in neutralizing mustard agent on the ground. Almost 2,000 tons of bleaching powder was sent to the AEF during the war.

As for mustard-contaminated clothing, the recommendation was to expose it to the open air for 48 hours or longer if the weather was cold. A quicker method was to leave the clothing inside a steam disinfecting chamber for 3 hours, but steam chambers were normally not available to front line troops.[14,26,34]

Detection and Alarms

The CWS also studied the critical need for chemical agent detectors and alarms. Initially, World War I soldiers relied on their own senses (smell, and throat and nose irritation) to detect chemicals. Eventually, the CWS was able to produce various dyes that changed color when contaminated with mustard agent. Most of the formulas for the detector paints, however, were British, and the CWS had trouble duplicating their work.[35]

At least one organic detector was also studied. One of the more interesting investigations was that of using snails as detectors. U.S. Army scientists reported that in the presence of mustard gas, snails waved their tentacles wildly in the air and then withdrew into their shells. When a prominent French physiologist was asked about this, he burst out laughing and said that French soldiers would eat the snails first. A test was conducted using French snails, but the conclusion was that the foreign snails were more conservative in their impulse to wave their tentacles.[36]

Once chemical agents were detected, the alarm was sounded by horns, rattles, bells, or whatever loud noise was available. These alarms created problems of their own, as the rattles often sounded like machine-gun fire, and it was difficult to distinguish from other nonchemical alarms. By the end of the war, the ability to detect chemical agents and alert the troops was still in a very primitive state.

Gas Casualty Treatments

A month after the United States entered the war, the U.S. Army War College issued *Memorandum on Gas Poisoning in Warfare with Notes on its Pathology and Treatment*,[37] a short manual for medical officers written by a committee of consultant physicians and physiologists. The memorandum directed that "Rest is the most important point of all in the general treatment of gas casualties"[37(p18)] and recommended using morphia to calm gassed soldiers who were too restless. Next in importance to rest were oxygen; protection from cold; special stimulants or drugs (particularly ampules of ammonia for inhalation, but also brandy in small sips, and pituitrin, administered hypodermically every 3 h); venesec-

tion (to relieve headaches); and removing "serous exudate" from the lungs (by drinking water and tickling the back of throat to produce vomiting; later treatments included potassium iodide, atropine, and steam tents with tincture benzoin compound). The manual concluded by admitting: "Knowledge on the various points discussed in this pamphlet is still far from being stable."[37(p32)]

The final version of the manual, issued in November 1918, made many changes to the original and reflected battlefield experience. For example, morphia was recognized as a "dangerous drug to use when the respiration is seriously affected. Its use should therefore be restricted to severe cases."[38(p22)] The most significant addition was information on mustard agent, which included sections for the treatment for the various organs exposed to the agent. For the skin, after cleaning the mustard agent off a soldier with soap and water,

> [a] dusting powder of zinc oxide mixed with boracic acid, chalk, and starch, or a calamine lotion with lime water may be used after the bath to allay skin irritation. The blisters may be evacuated by pricking.[38(p34)]

The delayed action of mustard agent required quick personnel decontamination actions. One solution was to bathe the soldiers thoroughly with soap and water within half an hour of mustard agent exposure. This was thought to prevent or greatly reduce the severity of the mustard burns. The army established degassing units that used a 5-ton truck with a 1,200-gal water tank, fitted with heaters and piping to connect it to portable showers. A second truck held extra uniforms. Two degassing units were assigned to each division. After the showers, the troops were give a drink of bicarbonate of soda water and then had their eyes, ears, mouths, and noses washed with the soda water.[38]

Mustard agent was a significant problem for untrained soldiers. In September 1918, one Field Artillery general instructed his troops:

> In view of the many casualties recently resulting in other commands from German mustard gas, each organization commander will take the following precautions: (a) Each soldier will place a small piece of soap in his gas mask container, (b) Each Chief of Section will keep constantly on hand in each gunpit or gun position, two large bottles of soapy water—empty bottles may be purchased at wine shops from Battery Fund, (c) In case of a gas attack, and if opportunity permits, soapy water will be rubbed under the arms and between the legs around the scrotum, of soldiers affected, this serving to neutralize the pernicious effect of the gas. This effect will be explained to the soldiers of each organization, who can only hope to prevent becoming casualties through the strictest gas discipline.[39]

Despite the many warnings, mustard agent earned its designation of King of the Battlefield by killing approximately 600 U.S. soldiers and injuring over 27,000.[40]

Lessons Learned

The armistice of November 1918 ended the world's first chemical and biological war. Of the approximately 26 million casualties suffered by the British, French, Russians, Italians, Germans, Austro-Hungarians, and the Americans, some 1 million were gas casualties. Of the total 272,000 U.S. casualties, over 72,000 were gas casualties, or about one fourth. Of the total U.S. gas casualties, approximately 1,200 either died in the hospital or were killed in action by gas exposure. There were no casualties or deaths attributed to biological warfare.[40]

Thus the U.S. Army completed its introduction to 20th-century chemical warfare. With the help of the CWS, the army successfully recovered from its early poor performance and survived repeated toxic chemical attacks against its troops. Likewise, by the end of the war, the First Gas Regiment and numerous U.S. artillery units successfully used toxic chemical agents in retaliation and during offensive operations.

At the end of the war, the United States could proudly point to the best protective mask, abundant munitions, and trained troops. The CWS had 1,680 officers and 20,518 enlisted personnel controlling the army's chemical warfare program.[25]

The only negative aspect was the dire prediction of future chemical wars, as expressed by one U.S. Army officer:

> Gas was new and in an experimental stage throughout the war and hence the man who plans for future defense must consider the use of gas to have been in its infancy. He must draw very few lessons for the future use of gas based on past performances. He must only use those lessons as pointing the way and not as approaching a final result. The firing of steel as shell passed its zenith with the passing of the Argonne fight. Never again will the world see such a hail of steel on battlefields, but in its place will be concentrations of gas and high explosives as much greater than the World War as that was greater than the Civil War.[41(p4)]

In contrast, Fritz Haber, the Nobel laureate chemist who, more than anyone else, was responsible for the development and fielding of chemical weapons for use by Kaiser Wilhelm II's army, downplayed the importance of chemical warfare as a weapon of mass destruction after the surprise was gone. In an interview published in New York in 1921, he concluded: "Poison gas caused fewer deaths than bullets."[42(p10)]

General John J. Pershing summed up his opinion of the new chemical warfare shortly after the conclusion of World War I:

> Whether or not gas will be employed in future wars is a matter of conjecture, but the effect is so deadly to the unprepared that we can never afford to neglect the question.[43(p77)]

THE 1920s: THE LEAN YEARS

The Chemical Warfare Service Made Permanent

Following the successful conclusion of World War I, the U.S. Army almost immediately tried to forget everything it had learned during the war about being prepared for future chemical warfare. The first major concern of the new CWS was to ensure that it survived demobilization. The army had organized the CWS as a temporary war measure, a part of the National Army only, and that temporary existence was due to expire within 6 months after the end of the war. This 6 months was later extended to 30 June 1920. During hearings before the U.S. Congress, Secretary of War Newton D. Baker testified, "We ought to defend our army against a gas attack if somebody else uses it, but we ought not to initiate gas."[44(p3)] He and Chief of Staff General Peyton C. March both used this philosophy to recommend both abolishing the CWS and outlawing chemical warfare by a treaty.[45]

Even General Sibert, when asked about the need for a permanent CWS and the possibility of chemical warfare in future wars, replied:

> Based on its effectiveness and humaneness, [chemical warfare] certainly will be an important element in any future war unless the use of it should be prohibited by international agreement. As to the probability of such action, I cannot venture an opinion.[46(p87)]

To persuade congress to keep the CWS, several prominent civilian and military leaders lobbied to include a permanent chemical warfare organization. Lieutenant Colonel Amos A. Fries, a CWS officer and one of the strongest proponents of a permanent organization, stressed the need for a central organization, one that covered all aspects of chemical warfare (Figure 2-14). He drew on the lessons learned from the previous war:

> Had there been a Chemical Warfare Service in 1915 when the first gas attack was made, we would have been fully prepared with gases and masks, and the army would have been trained in its use. This would have saved thousands of gas cases, the war might easily have been shortened six months or even a year, and untold misery and wasted wealth might have been saved.[47(p4)]

Fig. 2-14. Amos A. Fries, shown here as a major general, was chief of the Chemical Warfare Service between 1921 and 1929. "With his dynamic personality and extensive contacts in Congress and the chemical industry, he quite literally kept the CWS alive." Quotation: Brown FJ. *Chemical Warfare—A Study in Restraints.* Princeton, NJ: Princeton University Press; 1968: 130. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

He also stressed that both offensive and defensive research must be conducted:

> Just as developments in masks have gone on in the past just so will they go in the future. Just as from time to time gases were found that broke down or penetrated existing masks, just so in the future will gases be found that will more or less break down or penetrate the best existing masks. Accordingly, for thorough preparation, mask development must be kept absolutely parallel with development in poisonous and irritating gases. Mask development cannot, however, be kept parallel unless those working on masks know exactly what is going on in the development of poisonous gases. Thus a nation that stops all investigation into poisonous gases cannot hope to be prepared on the defensive side should the time ever come when defense against gas is needed.[20(pp7–8)]

Fries also disagreed with the premise that treaties could prevent chemical warfare:

> Researches into poisonous gases cannot be suppressed. Why? Because they can be carried on in out-of-the-way cellar rooms, where complete plans may be worked out to change existing industrial chemical plants into full capacity poisonous gas plants on a fortnight's notice, and who will be the wiser?[20(p3)]

Although Fries was very persuasive and eloquent in his comments, a young lieutenant, who published the following poem in 1919, more graphically expressed the opinion of those who understood the nature of chemical warfare:

> There is nothing in war more important than gas
> The man who neglects it himself is an ass
> The unit Commander whose training is slack
> Might just as well stab all his men in the back.[48(cover iv)]

The chemical warfare specialists won the argument. On 1 July 1920, the CWS became a permanent part of the Regular Army. Its mission included development, procurement, and supply of all offensive and defensive chemical warfare material, together with similar functions in the fields of smoke and incendiary weapons. In addition, the CWS was made responsible for training the army in chemical warfare and for organizing, equipping, training, and employing special chemical troops (Figure 2-15).[25,49]

Despite the encouragement of permanent status and surviving demobilization, the years after 1920 were lean (ie, austere) ones for the CWS, as indeed they were for the army as a whole. The CWS was

Fig. 2-15. The first temporary Chemical Warfare School building at Edgewood Arsenal, Md., shortly after the end of World War I. The school was later moved to a permanent structure. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

authorized only 100 Regular Army officers but never actually achieved that number. The low point was 64 in 1923. Enlisted strength dropped to a low of 261 in 1919 and averaged about 400 the rest of the decade. Civilian employees numbered fewer than 1,000. The low point in funding was in 1923, when the amount was $600,000.[25]

After 1919, almost all the work of the CWS moved to Edgewood Arsenal, Maryland, with only the headquarters remaining in Washington, D. C. Edgewood became the center of training, stockpiling, and research and development. Initially, the CWS was authorized to train only its own troops in all aspects of chemical warfare, while the General Staff permitted only defensive training for other army elements (Figure 2-16). The CWS protested this limitation and finally in May 1930, the Judge Advocate General ruled that both offensive and defensive training were allowed for all troops.[50]

Leftover stocks of chemicals from World War I were deemed sufficient for the army's stockpile. In 1922, to comply with the Limitation of Arms Conference, the War Department ordered that "[t]he filling of all projectiles and containers with poisonous gas will be discontinued, except for the limited number needed in perfecting gas-defense appliances."[51] The CWS was only allowed to continue limited research and development based on perceptions of future wars.[51,52]

To improve its standing with the taxpayers and the growing pacifist movement, the CWS also expanded its research capabilities into nonmilitary

Fig. 2-16. Soldiers wearing protective clothing are firing 75-mm mustard agent shells at Edgewood Arsenal, Md., in 1928. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

projects. These special projects included such activities as preserving wooden dock structures (1923) and fighting boll weevils (1925–1927).[53–55]

New Chemical Weapons

In 1928, the CWS formalized the standardization of chemical agents. Seven chemical agents and smokes were selected as the most important. The seven, with their symbols, were mustard agent (HS), methyldifluorarsine (MD), diphenylaminechlorarsine (DM), chloroacetophenone (CN), titanium tetrachloride (FM), white phosphorus (WP), and hexachlorethane (HC). Phosgene (CG) and Lewisite (L) were considered of lesser importance. Chloropicrin (PS) and chlorine (Cl) were rated the least important.[3]

Delivery systems were also improved. As early as 1920, Captain Lewis M. McBride experimented with rifling the barrel of the Stokes mortar. In 1924, a Stokes mortar barrel was rifled and tested. In truing the inside diameter of the 4-in. barrel preparatory to rifling, the bore was enlarged to 4.2 in. in diameter. This work increased the range of the mortar from 1,100 yd to 2,400 yd. In 1928, the improved mortar was standardized as the M1 4.2-in. chemical mortar and became the CWS's prized ground weapon for the delivery of toxic chemical agents as well as smoke and high explosives (Figures 2-17 and 2-18).[26]

Fig. 2-17. An experimental 4.2-in. chemical mortar, showing (1) the standard, (2) the barrel with the shock-absorbing mechanism, and (3) the tie rods connecting the standard to the baseplate. This weapon differed from the Stokes mortar, its predecessor, in that it was easier to set up and it was rifled; the spiral grooves can be seen on the inside of the barrel at its muzzle. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-18. The chemical weapons of the 1920s and 1930s. From left to right: the 75-mm mustard shell; the 4.2-in. white phosphorus shell; the M1 30-lb mustard bomb; the Mk II 155-mm mustard shell; the Livens phosgene projectile; and the Mk I portable chemical cylinder. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

One much-discussed topic was the role that airplanes would take in the next chemical war. Fries predicted:

> The dropping of gas bombs of all kinds upon assembly points, concentration camps, rest areas and the like, will be so fruitful a field for casualties and for wearing down the morale of armies in the future that it will certainly be done and done on the very first stroke of war.[56(pp4–5)]

To meet this need, the CWS standardized the M1 30-lb chemical bomb. It held only about 10 lb of agent owing to its thick shell. As a test of the use of airplanes in a chemical war, the CWS first demonstrated simulated chemical attacks against battleships in 1921.[3,57]

New Protective Equipment

The CWS concentrated, however, on defensive work. After the war, the CWS continued working on the KTM mask, which became known as the Model 1919. In 1921, the mask officially became the M1 Service Gas Mask (Figure 2-19); it had a rubber facepiece and was available in five sizes.[30,58] The hope was to issue a protective mask to every soldier in the army. One proponent described the reason why:

> To put the matter briefly, a modern army which enters on a campaign without respirators is doomed from the outset. It is asking to be attacked by gas, most certainly will be, and equally certainly will be destroyed. A soldier without a respirator is an anachronism.[59(p129)]

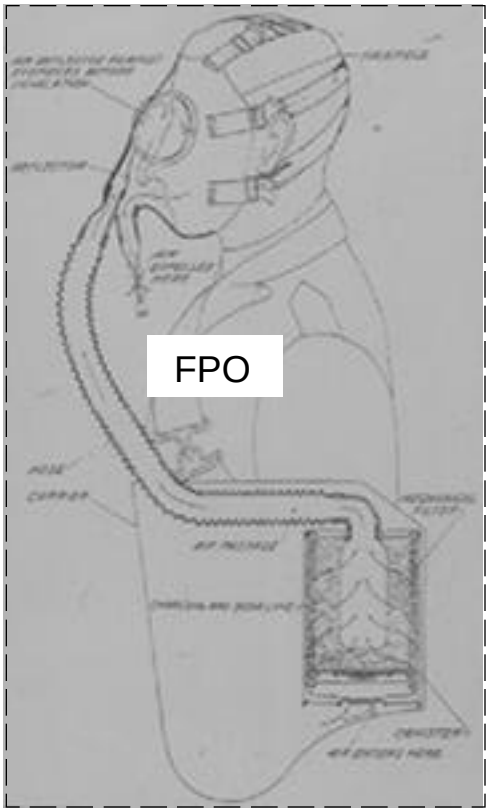

Fig. 2-19. A schematic diagram showing the M1 Service Gas Mask. The M1 eliminated the nose clip and mouthpiece of the box respirators of World War I vintage. By directing the incoming air over the eyepieces, it also helped eliminate lens fogging. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Biological Warfare Program

During the early 1920s, there were several suggestions from within the CWS that it undertake more research into biological agents. Fries, who had been promoted to major general and had replaced Sibert as the Chief Chemical Officer in 1920, however, decided it was not profitable to do so. In 1926, he wrote in the annual report of the CWS:

> The subject of bacteriological warfare is one which has received considerable notice recently. It should be pointed out in the first place that no method for the effective use of germs in warfare is known. It has never been tried to any extent so far as is known.[60(p8)]

The new League of Nations, which had been quoted in the annual report, concluded the same:

> [Biological] warfare would have little effect on the actual issue of a war because of protective methods available; that filtering and chlorinating drinking water, vaccination, inoculation, and other methods known to preventive medicine, would so circumscribe its effect as to make it practically ineffective.[60(p8)]

Chemical–Biological Warfare Use and Plans

Throughout the 1920s, rumors of chemical warfare attacks plagued the world. Besides the United States and the major World War I powers, several other countries began to develop a chemical warfare capability. Some of the countries with chemical weapons used them in their military operations. During the Russian Civil War and Allied intervention in the early 1920s, both sides had chemical weapons, and there were reports of iso-

lated chemical attacks. Later accounts[3,21] accused the British, French, and Spanish of using chemical warfare at various times during the 1920s. One country in particular attracted the attention of the United States. As early as 1924, the CWS began to take note of the growing Italian chemical warfare capability. That was the year the Italians established the Centro Chemico Militaire, a unified chemical warfare service and began production of chemical agents.[61–63]

Two events related to biological warfare probably went unnoticed by the Americans. In 1928, a Japanese officer by the name of Shiro Ishii began promoting biological warfare research and took a 2-year tour of foreign research establishments, including the United States. After his tour, he concluded that all the major powers were secretly researching biological warfare. Although his conclusion was erroneous for the United States, it was probably accurate for the Soviet Union. In 1929, the Soviets reportedly established a biological warfare facility north of the Caspian Sea.[3,21,64,65]

While the CWS struggled to survive and keep the army ready for a chemical war, international attempts were made to prohibit chemical warfare. The Treaty of Versailles, completed in 1919, prohibited Germany from producing, storing, importing, or using poisons, chemicals, and other chemical weapons. The treaty was not ratified by the United States. A separate treaty with Germany did not mention chemical warfare, but the United States agreed to comply with the provisions of the Treaty of Versailles in relation to poisonous gases.

Although the new League of Nations concluded in 1920 that chemical warfare was no more cruel than any other method of warfare used by combatants, the Limitation of Arms Conference, held in Washington, D. C., in 1922, banned the use of poisonous gases except in retaliation. The United States ratified the limitation, but France declined to ratify the treaty and therefore it was never implemented.

This unsuccessful attempt was followed by the 1925 Geneva Protocol, which was signed by 28 countries, including the United States. This agreement condemned the use of gas and bacteriological warfare. The U.S. Senate, however, refused to ratify the Protocol and remained uncommitted by it. The senate had apparently decided that chemical warfare was no more cruel than any other weapon and therefore should not be banned. The general policy of the U.S. government, however, still tended toward the discouragement of all aspects of chemical warfare, but was tempered by a policy of preparedness should chemical warfare occur again.[66–69]

THE 1930s: THE GROWING THREAT OF CHEMICAL AND BIOLOGICAL WARFARE

Further international attempts to ban not only the use of chemical weapons but also all research, production, and training caused a response that developed into a new U.S. policy on chemical warfare. The U.S. Army Chief of Staff, General Douglas MacArthur, stated the policy in a letter to Secretary of State Henry L. Stimson in 1932:

> In the matter of chemical warfare, the War Department opposes any restrictions whereby the United States would refrain from all peacetime preparation or manufacture of gases, means of launching gases, or defensive gas material. No provision that would require the disposal or destruction of any existing installation of our Chemical Warfare Service or of any stocks of chemical warfare material should be incorporated in an agreement. Furthermore, the existence of a War Department agency engaged in experimentation and manufacture of chemical warfare materials, and in training for unforeseen contingencies is deemed essential to our national defense.[45(p118)]

There were no other major attempts to ban chemical and biological warfare during the 1930s.

New Chemical Agents and Weapons

The CWS continued to maintain stockpiles of the key World War I–chemical agents during the 1930s. Captain Alden H. Waitt, then Secretary of the Chemical Warfare School at Edgewood Arsenal and later Chief Chemical Officer, summed up the CWS's planning for the next war in 1935:

> Foreign writers agree that at least for the first few months of any war, should one occur within a few years, the gases that were known at the end of the World War would be used. Of these, the opinion is unanimous that mustard gas would be the principal agent and the most valuable. Opinion in the United States coincides with this.[70(p285)]

In 1937, Edgewood Arsenal rehabilitated their mustard agent plant and produced 154 tons of mustard agent to increase their stockpile (Figure 2-20). The same year, the phosgene plant was renovated for additional production, and the CWS changed phosgene from substitute standard to standard (Figure 2-21).[71]

Fig. 2-20. The Mustard Manufacturing Plant at Edgewood Arsenal, Md. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

The result of the CWS's confidence in these selected agents was that the CWS missed the development of several key new agents. Waitt wrote:

> Occasionally a statement appears in the newspapers that a new gas has been discovered superior to any previously known. Such statements make good copy, but not one of them has ever been verified. Today no gases are known that are superior to those known during the World War. It is unlikely that information about a new gas will be obtained until it is used in war. The chemical agent is too well adapted to secrecy. The only insurance against surprise by a new gas is painstaking research to find for ourselves every chemical agent that offers promise for offensive or defensive uses. It seems fairly safe to say that today mustard gas is still the king of warfare chemicals and to base our tactical schemes on that agent as a type.[70(p285)]

Yet already the reign of mustard agent was ending. In 1931, Kyle Ward, Jr., published an article describing nitrogen mustard, a vesicant agent with no odor. The CWS investigated the new substance and found it to be less vesicant than sulfur mustard. The U.S. Army eventually standardized nitrogen mustard as HN-1, although it was the Germans who took a great interest in the new vesicant.[3]

In 1936, German chemist Dr. Gerhart Schrader of I. G. Farbon Company discovered an organophosphorus insecticide, which was reported to the Chemical Weapons Section of the German military prior to patenting. The military was impressed with the effects of the compound on the nervous system and classified the project for further research. The military assigned various names to the new substance, including Trilon-83 and Le 100, but *tabun* was the name that stuck. After World War II, the CWS designated it GA, for "German" agent "A."

About 2 years later, Schrader developed a similar agent, designated T-144 or Trilon-46 and eventually called *sarin*, which was reportedly 5 times as toxic as tabun. The United States later designated this agent GB. The Germans assigned a large number of chemists to work on these new nerve agents and began building a pilot plant for production in 1939, the year World War II started.[3,72,73]

Fig. 2-21. Interior view of the Phosgene Production Plant at Edgewood Arsenal, Md. The low level of chemical engineering technology apparent in this World War II–era photograph is relevant to the problem of chemical agent proliferation today. Elaborate, expensive equipment is not required for mass-producing the less-sophisticated chemical agents. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-22. A Field Artillery unit prepared for chemical war. Both the men and the horses required protection against the agents. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

During the 1930s, the CWS stockpiled the chemical weapons used by World War I ground forces in preparation for a future war. These were primarily Livens projectors, Stokes mortars, and portable cylinders. In addition, there were chemical shells for 75-mm, 105-mm, and 155-mm artillery pieces (Figures 2-22 and 2-23).

The production of the new 4.2-in. chemical mortar eventually made that weapon the key ground delivery system for the CWS. Between 1928 and 1935, the army attempted to make the 4.2-in. mortar a mechanized weapon by mounting it on various vehicles (Figure 2-24). The CWS also began experiments in 1934 to make the mortar a more versatile weapon by testing high-explosive shells as an alternative to chemical rounds.

Fig. 2-23. Battery D, 6th Field Artillery, firing a 75-mm gun while in protective clothing at Edgewood Arsenal, Md., in 1936. The overgarments of the 1920s were made of rubberized cloth or cloth impregnated with substances such as linseed oil. These overgarments were heavier and hotter than today's protective clothing. Note the lack of overboots. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

In 1935, the improved M1A1 mortar was standardized. The M1A1 had an improved barrel and baseplate, and a new standard connected to the baseplate by two tie-rods for support. The M1A1 had a maximum range of 3,200 yd (1.8 miles). Each shell held 5 to 7 lb of either phosgene, mustard agent, cyanogen chloride, white phosphorus, or smoke agent.[3,26]

Additional new delivery systems also included the first standardized chemical land mine for mustard agent in 1939. Designated the M1, this 1-gal gasoline-type can held 9.9 lb of mustard agent and required detonating cord to burst the can and disseminate the agent.[74]

For air delivery, the CWS standardized the first good airplane smoke tank, the M10, in 1933. This tank held 30 gal of mustard (320 lb), Lewisite (470 lb), or smoke material. The system was rather simple. Electrically fired blasting caps shattered frangible seals in the air inlet and the discharge line, which allowed air and gravity to force the liquid out. The slipstream of the plane then broke up the liquid into a spray.[74]

Biological Warfare Developments

While chemical warfare received some attention during the 1930s, biological warfare received very little. In 1933, Major Leon A. Fox, Medical Corps,

Fig. 2-24. A 4.2-in. chemical mortar mounted on a light cargo carrier in 1928. The carrier had a speed of 20 mph. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

U.S. Army, wrote an article on bacterial warfare for *The Military Surgeon* that began:

> Bacterial warfare is one of the recent scare-heads that we are being served by the pseudo-scientists who contribute to the flaming pages of the Sunday annexes syndicated over the Nation's press.[75(p189)]

He then proceeded to point out the difficulties of trying to weaponize biological agents. For example, bubonic plague would create significant problems for friendly troops as well as the enemy:

> The use of bubonic plague today against a field force, when the forces are actually in contact, is unthinkable for the simple reason that the epidemic could not be controlled. Infected personnel captured would provide the spark to set off possible outbreaks of pneumonic plague in the ranks of the captors. Infected rats would also visit and spread the condition. An advance over terrain infected with plague-bearing rats would be dangerous. Therefore, except as a last desperate, despairing hope of a rapidly retreating army, the use of plague by forces in the field is not to be considered.[75(p202)]

After dismissing the causative organisms of malaria, yellow fever, anthrax, and other such agents, he concluded:

> I consider that it is highly questionable if biologic agents are suited for warfare. Certainly at the present time practically insurmountable technical difficulties prevent the use of biologic agents as effective weapons of warfare.[75(p207)]

The same year that Fox wrote his article, Germany began military training in offensive biological warfare and reportedly covertly tested *Serratia marcescens*, considered a biological simulant, in the Paris Metro ventilation shafts and near several French forts. Three years later they conducted antianimal experiments with foot and mouth disease at Luneburger Heide. The next year the German Military Bacteriological Institute in Berlin began developing anthrax as a biological weapon, while the Agricultural Hochschule in Bonn examined the spraying of crops with bacteria.[3,65]

Even the future allies of the United States in World War II were working on biological warfare programs. By 1936, France had a large-scale biological warfare research program working on bacterial and viral viability during storage and explosive dispersal. The same year, Britain established a committee to examine offensive and defensive biological warfare issues. By 1940, the British chemical laboratory at Porton Down had a biological warfare laboratory. Canada initiated biological warfare research under Sir Frederick Banting at Connaught Laboratories, Ile Grosse, and at Suffield in 1939. The Canadians started work on anthrax, botulinum toxin, plague, and psittacosis.[3,65]

One man who definitely thought differently from Fox was Japan's Ishii. In 1933, he set up an offensive biological warfare laboratory in occupied Manchuria, later designated Detachment 731, which developed and tested a biological bomb within 3 years and also tested biological agents on Chinese prisoners. Additional biological warfare facilities were established in 1939, the same year that Japanese troops allegedly entered Russia to poison animals with anthrax and other diseases.

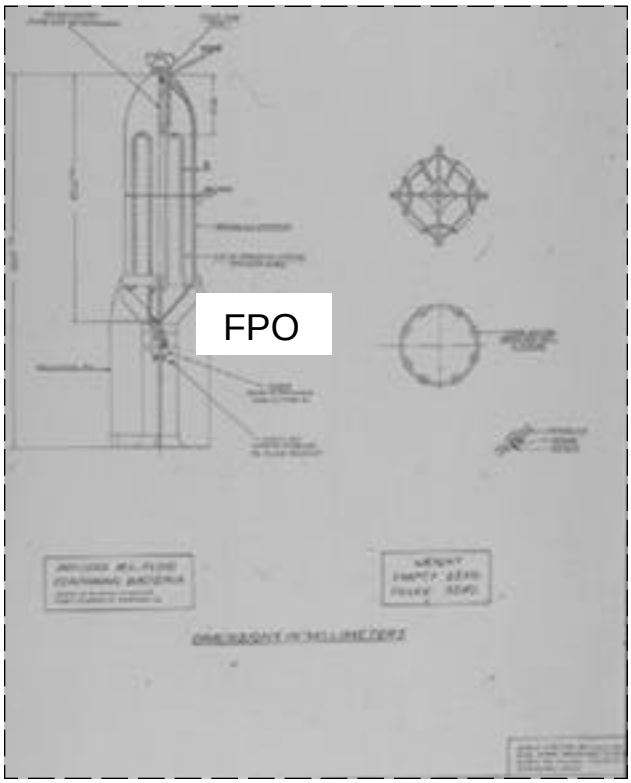

Fig. 2-25. The Japanese UJI bacterial bomb, drawn from sketches given to Lieutenant Colonel Murray Sanders, Chemical Warfare Service, in 1945. Porcelain rather than metal was used to form the "shell" because it could be shattered by a much smaller explosive charge. This protected the biological agent, assuring that it would be subjected to less heat and pressure. Reprinted from Scientific and Technical Advisory Section, US Army Forces, Pacific. *Biological Warfare*. Vol 5. In: *Report on Scientific Intelligence Survey in Japan*. HQ, US Army Forces, Pacific; 1945: appended chart.

By 1940, Ishii had developed and tested in the field nine different kinds of biological bombs and had produced over 1,600 bombs, although some had been expended in research. The 40-kg Ha bomb, filled with a mixture of shrapnel and anthrax spores, and the 25-kg Type 50 UJI bomb, also filled with anthrax spores, were considered the most effective (Figure 2-25). His early discoveries that conventional bombs filled with biological agents failed to disseminate the agent properly did, however, confirm some of Fox's beliefs. The Japanese were able to disseminate typhus rickettsia, cholera bacteria, and plague-infested fleas through Ning Bo in China, where 500 villagers died from plague epidemics. By the beginning of World War II, Ishii was concentrating on the use of vectors such as the common flea to carry the biological agents.[3,64,76]

New Defensive Equipment

The M1 gas mask design proved to be a reliable choice for over a decade. In 1934, minor modifications to the head-harness straps and the mounting of the eyepieces resulted in the M1A1 mask.

In 1935, the first major modification to the original design was introduced as the M1A2 mask. The M1A2 was constructed from a flat rubber faceblank with a seam at the chin. This design allowed the mask to be issued in one universal size, although the small and large sizes of the M1A1 continued in production. This mask became the standard mask for the army up to the beginning of World War II. By 1937, Edgewood Arsenal was producing over 50,000 masks per year (Figure 2-26).[30]

Fig. 2-26. In addition to the standard Service Gas Mask, the Chemical Warfare Service also designed diaphragm masks for speaking capability. Note the hood, which covered the skin of the head, face, and neck. The soldier also wears chemically protective gloves. Since the uniform was impregnated with a substance that hindered the penetration of mustard, in theory, no portion of his skin was subject to mustard injury. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Collective protection during the 1930s began the advancement from the passive dugout blanket of World War I to the modern mechanical systems. Although most major powers initiated work on collective protection for troops in the field during the 1920s, the CWS did not standardize its first unit until 1932. That year, the M1 Collective Protector, a huge, 1,210-lb, fixed installation unit providing 200 cu ft of air per minute, was typed classified for use primarily in coastal forts. The level of protection was the same as that provided by the standard gas mask canister.[77]

For decontamination, the CWS concentrated on mustard agent decontaminants. Ordinary bleach, used during World War I, was considered the most effective but was corrosive to metals and had only a 3-week storage life in the tropics (Figure 2-27).

Early work, starting in 1930, used simple tanks filled with DR1 emulsion, a soap prepared with magnesium carbonate, animal fat, and kerosene, and designed primarily for ship decontamination. The next development involved commercial items such as insecticide sprayers, fire extinguishers, agricultural spreaders, and road sprinklers. The best sprayer was the 3-gal Demustardizing Apparatus, Commercial Type, standardized in 1938. The 1½-qt Demustardizing Apparatus was used for lighter work. This fire extinguisher–type sprayer was recommended for standardization in 1937.

Agricultural spreaders and road sprinklers proved less successful at disseminating the proper amount of decontaminant. Just before the beginning of World War II, the CWS also investigated the power-driven demustardizing apparatus, which was based on a commercial orchard sprayer with a 300-gal tank and an 8-hp engine.

In 1938, the CWS made the important discovery of the decontaminating capability of the compound RH-195, developed by the Du Pont Company, when

Fig. 2-27. Cleaning up mustard agent in the field with bleaching powder and soil. The labor-intensive nature of mustard decontamination is readily apparent. Note that the exercise is being conducted in the winter; no doubt the chemical protective garments shown here would have constituted a considerable thermal load. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

mixed with acetylene tetrachloride. This combination was later designated Decontaminating Agent, Non-Corrosive (DANC). DANC was a whitish powder that liberated chlorine more slowly than ordinary bleaching material and therefore was more stable in storage. One gallon of DANC could decontaminate 15 sq yd of heavily contaminated soil.[34]

Italian–Ethiopian War

The first major use of chemical weapons after World War I came in 1935 during the Italian–Ethiopian War. On 3 October 1935, Benito Mussolini launched an invasion of Ethiopia from its neighbors Eritrea, an Italian colony, and Italian Somaliland. Ethiopia protested the invasion to the League of Nations, which in turn imposed limited economic sanctions against Italy. These sanctions, although not crippling, put a deadline pressure on Italy to either win the war or withdraw.

The initial Italian offensive from Eritrea was not pursued with the proper vigor in Mussolini's opinion, and the Italian commander was replaced. The new commander, Marshal Pietro Badoglio, was ordered to finish the war quickly. He resorted to chemical weapons to defeat the Ethiopian troops led by Emperor Haile Selassie. Despite the Geneva Protocol of 1925, which Italy had ratified in 1928 (and Ethiopia in 1935), the Italians dropped mustard bombs and occasionally sprayed it from airplane tanks. They also used mustard agent in powder form as a "dusty agent" to burn the unprotected feet of the Ethiopians. There were also rumors of phosgene and chloropicrin attacks, but these were never verified.

The Italians attempted to justify their use of chemical weapons by citing the exception to the Geneva Protocol restrictions that referenced acceptable use for reprisal against illegal acts of war. They stated that the Ethiopians had tortured or killed their prisoners and wounded soldiers.[78–90]

Chemical weapons were devastating against the unprepared and unprotected Ethiopians. With few antiaircraft guns and no air force, the Italian aircraft ruled the skies. Selassie emotionally described the nightmare to the League of Nations:

> Special sprayers were installed on board aircraft so they could vaporize over vast areas of territory a fine, death-dealing rain. Groups of 9, 15, or 18 aircraft followed one another so that the fog issuing from them formed a continuous sheet. It was thus that, as from the end of January 1936, soldiers, women, children, cattle, rivers, lakes, and pastures were drenched continually with this deadly rain. In order more surely to poison the waters and pastures, the Italian command made its aircraft pass over and over again. These fearful tactics succeeded. Men and animals succumbed. The deadly rain that fell from the aircraft made all those whom it touched fly shrieking with pain. All those who drank poisoned water or ate infected food also succumbed in dreadful suffering. In tens of thousands the victims of Italian mustard gas fell.[83(pp151–152)]

By May 1936, Italy's army completely routed the Ethiopian army. Italy controlled most of Ethiopia until 1941 when British and other allied troops reconquered the country.

The U.S. Army closely followed the war and sent Major Norman E. Fiske as an observer with the Italian army and Captain John Meade as an observer with the Ethiopian army. Their different conclusions as to the role of chemical warfare in the war reflected the sides they observed. Major Fiske thought the Italians were clearly superior and that victory

for them was assured no matter what. The use of chemical agents in the war was nothing more than an experiment. He concluded:

> From my own observations and from talking with [Italian] junior officers and soldiers I have concluded that gas was not used extensively in the African campaign and that its use had little if any effect on the outcome.[88(p20)]

His opinion was supported by others who felt that the Ethiopians had made a serious mistake in abandoning guerrilla operations for a conventional war.

Captain Meade, on the other hand, thought that chemical weapons were a significant factor in winning the war. They had been used to destroy the morale of the Ethiopian troops, who had little or no protection, and to break up any attempts at concentration of forces. Captain Meade concluded:

> It is my opinion that of all the superior weapons possessed by the Italians, mustard gas was the most effective. It caused few deaths that I observed, but it temporarily incapacitated very large numbers and so frightened the rest that the Ethiopian resistance broke completely.[88(p20)]

Major General J. F. C. Fuller, assigned to the Italian army, highlighted the Italian use of mustard agent to protect the flanks of columns by denying ridge lines and other key areas to the Ethiopians. He concluded:

> In place of the laborious process of picketing the heights, the heights sprayed with gas were rendered unoccupiable by the enemy, save at the gravest risk. It was an exceedingly cunning use of this chemical.[85(p143)]

Still another observer stated:

> I think [where mustard] had [the] most effect was on animals; the majority of the Ethiopian armies consisted of a number of individual soldiers, each with his donkey or mule on which he carried rations. These donkeys and mules ate the grass and it killed them, and it was that which really broke down morale more than anything.[86(p81)]

B. H. Liddell Hart, another military expert, compromised between the two schools of thought and concluded:

> The facts of the campaign point unmistakably to the conclusion that mechanization in the broad sense was the foundation on which the Italians' military superiority was built, while aircraft, the machine gun, and mustard gas proved the decisive agents.[87(p330)]

All observers, however, seemed to agree that the Italians would eventually have won whether chemical agents were used or not.

In general, the U.S. Army learned little new from this war. The annual report for 1937 stated that "situations involving the employment of chemical agents have been introduced into a greater number of problems."[89] The CWS Chemical Warfare School concluded that "the use of gas in Ethiopia did not disclose any new chemical warfare tactics,"[90] but only reconfirmed existing tactical use expectations. The school also initiated a class for Army Air Corps personnel (Figure 2-28).[90] One senior air corps officer, perhaps noting the successful Italian use of spray tanks, commented, "We want that course repeated again and again until all of our people are thoroughly awake to the necessity for training and preparation."[91(p153)]

Japanese Invasion of China

The next war that drew the interest of chemical warfare experts was the Japanese invasion of China in 1937. The Japanese, in addition to their biological work, had an extensive chemical weapons program and were producing agent and munitions in large numbers by the late 1930s. During the resulting war with China, Japanese forces reportedly be-

Fig. 2-28. Aerial spraying of a Chemical Warfare School class with tear gas during a training event. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

gan using chemical shells, tear gas grenades, and lacrimatory candles, often mixed with smoke screens.

By 1939, the Japanese reportedly escalated to mustard agent and Lewisite. Against the untrained and unequipped Chinese troops, the weapons proved effective. The Chinese reported that their troops retreated whenever the Japanese used just smoke, thinking it was a chemical attack.[21,92]

Preparing for the Next War

After the Italian–Ethiopian War, the possibility of war in Europe became the primary concern of the U.S. Army. The CWS closely studied the chemical warfare capabilities of Germany and Italy, although it missed the German development of nerve agents.

The United States, although largely isolationist in policy, followed the declining political situation in Europe and decided to begin a gradual improvement in its military posture. Official policy, however, was against the employment of chemical warfare, and initially the CWS met with much resistance. President Franklin D. Roosevelt detested chemical warfare and in 1937 refused to permit the redesignation of the CWS as a corps. There was no ongoing chemical warfare in Europe to learn from, and public opinion continued to be solidly against any use of chemical weapons. In addition, the issue of whether the CWS should field ground combat units, particularly chemical mortar battalions, distracted policy makers and was only resolved by the U.S. Army Chief of Staff, who finally approved two battalions just before the beginning of World War II.[45]

THE 1940s: WORLD WAR II AND THE NUCLEAR AGE

The start of World War II in 1939 and the rapid collapse of France in the spring of 1940 stimulated a major increase in the rate of American rearmament. Although no major use of chemical and biological agents occurred, rumors and reports of incidents of chemical and biological warfare attracted the attention of intelligence officers. Although much of Germany's and Japan's chemical and biological weapons programs did not become known until after the war, the actual threat was impressive.

During the war, Germany produced approximately 78,000 tons of chemical warfare agents. This included about 12,000 tons of the nerve agent tabun, produced between 1942 and 1945. Germany also produced about 1,000 lb of sarin by 1945. The key nerve agent weapons were the 105-mm and 150-mm shells, the 250-kg bomb, and the 150-mm rocket. The latter held 7 lb of agent and had a range of about 5 miles when fired from the six-barrel Nebelwerfer launcher (Figure 2-29). Mustard agent, however, was still the most important agent in terms of production, and the Germans filled artillery shells, bombs, rockets, and spray tanks with the agent. Phosgene, of somewhat lesser importance, was loaded in 250- and 500-kg bombs. The Germans were the greatest producers of nitrogen mustards and produced about 2,000 tons of HN-3. This was filled in artillery shells and rockets. They also had

Fig. 2-29. The 150-mm German Nebelwerfer rocket projector was developed in the 1930s; one of its intended uses was to disseminate chemical agents. This fact was supposed to be disguised by naming it the Nebelwerfer (literally "smoke-screen layer"). As events transpired during World War II, Nebelwerfers were used exclusively as rocket artillery, firing high-explosive projectiles. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

a large number of captured chemical munitions from France, Poland, USSR, Hungary, and other occupied countries.[3,26]

Germany's biological warfare program was much less extensive than its chemical program. Most of the Germans' work was apparently with antipersonnel agents such as the causative organisms of plague, cholera, typhus, and yellow fever. They also investigated the use of vectors to attack animals and crops.[21,65]

Japan produced about 8,000 tons of chemical agents during the war. The Japanese loaded mustard agent, a mustard–Lewisite mixture, and phosgene in shells and bombs and gained experience in their use during their attacks on China. They also filled hydrogen cyanide in mortar and artillery shells, and in glass grenades. Japan's biological warfare program was also in full swing by World War II, and many weapons had been laboratory- and field-tested on humans.[26]

The possibility that massive chemical or biological attacks could happen any day kept CWS officers pushing for preparedness. A newspaper article reflected the common prediction circulating in the press:

> European military authorities have predicted that gas would be used in the present war, if at any time the user could be sure of an immediate and all-out success from which there could be no retaliation.[93(p37)]

Major General William N. Porter (Figure 2-30), the new chief of the CWS, warned that Hitler was likely to use chemical weapons "at any moment." He also felt that "No weapon would be too bad to stop or defeat Hitler"[94(p31)] and wanted to "fight fire with fire in the event an enemy chooses to use poison gas."[95(p36)]

Fig. 2-30. Major General William N. Porter commanded the Chemical Warfare Service during World War II. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Preparing for Chemical Warfare

During the massive 1941 training maneuvers, the U.S. Army used a scenario that called for no first use of chemical weapons by either side. Troops carried gas masks, but were to wear them only in areas designated as being under gas attack. Simulated chemical agent attacks were made by placing signs stating "Mustard Gas" in various areas and, in some cases, using molasses residuum, a popular mustard simulant. However, in the latter case, the army ran into a serious problem of getting the stains out of their uniforms. Despite this hitch, at least one participant concluded:

> There was clear evidence that distinct progress was made during the maneuvers in arousing interest in the use of chemical warfare means and methods under battlefield conditions. As a result, a greater portion of the command, staff, and rank and file are undoubtedly more cognizant of how chemicals might be used against them, and what countermeasures to take.[96(p17)]

While planning for a more traditional, European-style war, the CWS also monitored Japan's use of chemical weapons in China. U.S. Army interest in chemical warfare preparation rose significantly, since Japan was already employing chemical weapons.[97]

The CWS, however, found itself hardly prepared to fight a major chemical war on the level of World War I. Increased budgets and personnel helped with war planning, but to actually field chemical weapons and build chemical stockpiles first required industrial mobilization and massive production.

The national emergency declared prior to the war increased the size of the CWS to over 800 officers and over 5,000 enlisted men, with civilian strength keeping pace. Appropriations, which had already

passed $2 million per year, jumped to $60 million as successive military supplements increased the fiscal 1941 budget. The CWS rapidly increased its productive capacity and improved nationwide procurement district offices to expand its mobilization basis.[25]

The Growth of the Chemical Warfare Service

When World War II finally engulfed the United States on 7 December 1941, the transition to wartime conditions was much less sudden than in 1917, primarily owing to the extensive mobilization activity of the preceding 2 years. Porter, who served as the chief throughout the war, found under his command not the skeletonized CWS of the 1930s but a large and rapidly growing organization, whose personnel numbered in the thousands, physical facilities were scattered throughout the eastern half of the country, and products were in urgent demand by an army rapidly growing to multimillion-man strength.

More than 400 chemical battalions and companies of varying types were activated during the course of the war, and a large proportion of them saw service overseas. Chemical mortar battalions and companies, using high-explosive and smoke shells in the 4.2-in. chemical mortars, gave close artillery-type support to infantry units in every theater. Smoke generator battalions and companies screened troop movements as well as fixed installations. Depot companies stored, maintained, and issued material; processing companies kept up theater stocks of protective clothing; decontamination companies backed up chemical defense postures; and laboratory companies provided technical intelligence assessments of captured chemical material. Chemical maintenance companies repaired and reworked equipment, performing especially critical tasks in keeping the mortar units firing. Chemical service units, organized to provide a broad spectrum of capabilities, performed most or all of the service and logistical functions already mentioned on a smaller scale where full-sized specialized companies were not authorized, or not available. Finally, a full complement of chemical service units supported the operations of the Army Air Force, especially in the storage and handling of incendiary bombs. In addition to the field organizations, each theater, army group, and army headquarters had a chemical staff in their headquarters elements.

The production and storage needs of a rapidly growing military establishment could not be met by Edgewood Arsenal alone. The CWS quickly constructed new installations: arsenals at Huntsville, Alabama, Denver, Colorado, and Pine Bluff, Arkansas; a chemical/biological proving ground in Utah; protective-clothing plants at Columbus, Ohio, Kansas City, Missouri, and New Cumberland, Pennsylvania; charcoal-filter plants at Zanesville and Fostoria, Ohio; and impregnate factories at Niagara Falls, New York, East St. Louis, Illinois, and Midland, Michigan.[25,26]

Chemical Agents

The CWS agent production initially concentrated on the World War I agents. Approximately 146,000 tons of chemical agents was produced by the United States between 1940 and 1945. Phosgene (CG) was produced at Edgewood Arsenal; the new Huntsville Arsenal; and the Duck River Plant owned by Monsanto Chemical Company in Columbia, Tennessee. These plants produced about 20,000 tons of the agent during the war. Mustard agent (HS) was produced at Edgewood Arsenal; Rocky Mountain Arsenal, Denver, Colorado; Pine Bluff Arsenal; and Huntsville Arsenal (Figures 2-31 and 2-32). By the end of the war, these plants produced over 87,000 tons of the agent. Lewisite (L) was produced at a small pilot plant at Edgewood Arsenal and later at Huntsville Arsenal, Pine Bluff Arsenal, and Rocky Mountain Arsenal. Approximately 20,000 tons of the agent was produced before the plants were shut down in 1943. Cyanogen chloride (CK) was produced at the American Cyanamid Company plant in Warners, New York, and at the Owl Plant in Azusa, California. About 12,500 tons of the agent was procured during the war. Hydrogen cyanide (AC) was produced by Du Pont and the American Cyanamid Company. Only about 560 tons of the agent was procured by the CWS.

The leadership of the CWS took interest in the nitrogen mustards after they learned that the Germans were producing it. HN-1 was produced at Edgewood Arsenal in a small pilot plant and later at Pine Bluff Arsenal, which produced about 100 tons of the agent. The British also investigated HN-2 and HN-3, but the United States did not produce the latter two agents.

Investigation of ways to improve the purity of mustard agent resulted in the discovery that washing the agent with water and then distilling it produced a much more pure product. The new agent was called distilled mustard agent (HD). Edgewood Arsenal used a pilot plant to produce some of the agent in 1944 and then a full-scale plant was completed at Rocky Mountain Arsenal the next year. By

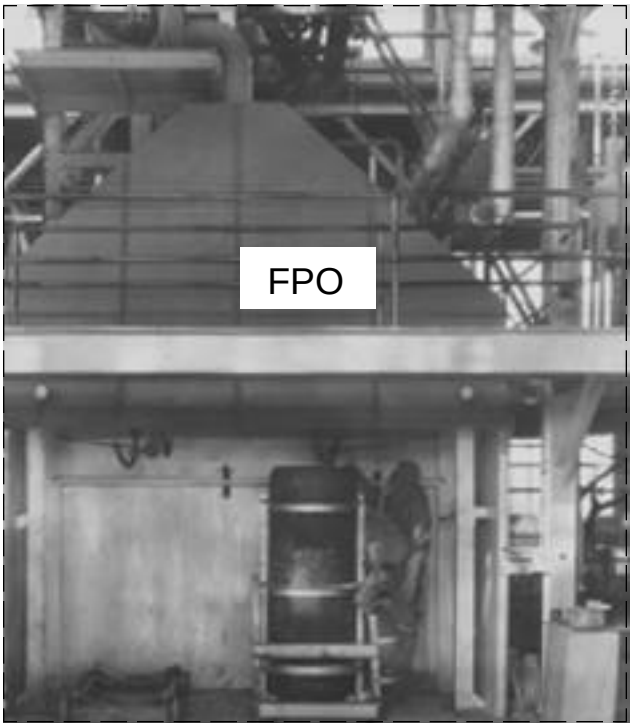

Fig. 2-31. Interior view of the Mustard Agent Plant at Edgewood Arsenal, Md., showing a soldier filling a 1-ton container with the agent. The operator is wearing a protective mask. Concerns regarding occupational hazards evidently dictated a higher standard of personal protection than was apparent during World War I (see Figure 2-7). Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

the end of the war, over 4,600 tons of the agent was produced.[26]

Chemical Weapons

The heart of the CWS offensive capability was the chemical mortar. In December 1941, there were only 44 chemical mortars on hand. This was quickly corrected, as the demand for the versatile weapon increased after each major usage. The continued need for greater range, accuracy, durability, and ease in manufacturing resulted in the improved M2 4.2-in. mortar in 1943. The M2 had a maximum range of 4,400 yd, which was later increased to 5,600 yd by modifying the propellant in test firings at Edgewood Arsenal in 1945. Despite a slow start, the M2 series 4.2-in. chemical mortar rapidly became the central weapon of the CWS, not only for chemical agent delivery if needed, but also for high-explosive, smoke, and white phosphorus rounds. Over 8,000 chemical mortars were procured by the CWS for chemical mortar battalions during the war.[3,26,98]

The other offensive weapons for chemical agent attack were to be delivered by either the artillery or the air force. The artillery had available 75-mm,

Fig. 2-32. Unloading mustard agent from 1-ton containers on flat cars at Pine Bluff Arsenal, Arkansas, in 1943. Apparently unloading and loading mustard agent were considered to constitute different hazards (see Figure 2-31). Note that the operator is wearing a face shield, apron, and gloves, but not a protective mask. Photograph: Chemical and Biological Defense Command Historical Research and Respeonse Team, Aberdeen Proving Ground, Md.

Fig. 2-33. Diagram of the M60 105-mm mustard shell, with the cartridge case attached. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

105-mm, and 155-mm chemical rounds that were filled primarily with mustard agent but that also contained Lewisite (Figure 2-33). In 1945, the CWS standardized the first chemical rockets: a 7.2-in. version used phosgene and cyanogen chloride, fired from a 24-barrel, multiple–rocket launcher platform; and a smaller 2.36-in. cyanogen chloride–filled bazooka round.

The U.S. Army Air Force had 100-lb mustard agent bombs (Figure 2-34); 500-lb phosgene or cyanogen chloride bombs; and 1,000-lb phosgene, cyanogen chloride, or hydrocyanic acid bombs. In addition, the new M33 spray tank could hold 750 to 1,120 lb of mustard agent or Lewisite. None of these chemical weapons were used on the battlefield during the war.[3,99,100]

The prepositioning of chemical weapons in forward areas in case of need resulted in one major disaster and several near disasters. The one major disaster occurred 2 December 1943, when the SS *John Harvey*, loaded with 2,000 M47A1 mustard agent bombs, was destroyed after a German air raid at Bari Harbor, Italy. The only members of the crew who were aware of the chemical munitions were killed in the raid. As a result of the destruction of the ship, mustard agent contaminated the oily water in the harbor and caused more than 600 casualties, in addition to those killed or injured in the actual attack. The harbor clean-up took 3 weeks and used large quantities of lime as a decontaminant.[101]

Fig. 2-34. Open storage of M47 100-lb chemical bombs on Guadalcanal Island in 1944. This important lesson is frequently forgotten: it was necessary to take along the full spectrum of chemical weaponry wherever U.S. troops were deployed. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Defensive Equipment

At the beginning of the war, the CWS designed and issued the M1 Training Mask, which used a small, lightweight filter connected directly to the facepiece. The facepiece was the first to use a fully molded rubber faceblank. The original concept of a training mask was that complete protection from all chemical agents was not required; therefore, there was no need for the state-of-the-art canisters. However, soldiers liked the new facepieces enough that the CWS standardized the M1 Training Mask as the M2 Service Mask in 1941. The mask utilized the original M1A2 mask's M9A1 canister, which was a bulky steel canister that, when combined with the facepiece, weighed 5 lb (Figure 2-35). Over 8.4 mil-

Fig. 2-35. The M2 series Service Mask. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-36. The M3 series lightweight gas mask. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-37. The M5 Combat Service Mask, the first U.S. mask with the canister placed directly on the cheek. The M5 mask was part of the personal equipment of the troops who landed at Normandy on 6 June 1944. Postwar tests indicated that it might have protected against respiratory exposure to the nerve agent tabun if the Germans had chosen to use it against the invasion armada. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

lion of the M2 series masks were procured during the war, but they were used only for training.

The existing M1 and M2 series protective masks, with their molded rubber faceblanks and heavy canisters, proved a significant problem for the military. First, there was a shortage of rubber during World War II. Second, the weight of the mask with canister needed to be reduced, particularly for amphibious assaults. The continued need for a lightweight combat mask resulted in the M3 series mask. First standardized in August 1942, the M3 made several changes to the M2 design. In the facepiece, a nosecup covering the nose and mouth was added to prevent lens fogging. The canister was modified to be carried on the chest instead of the side; was much lighter (the overall weight decreased to just 3.5 lb); and had a more efficient absorbent (Figure 2-36). Eventually, over 13 million M3 series masks were procured during the war.

Production problems with the new molds, however, caused the CWS to issue the M4 series lightweight mask. This mask used a modified M2 series facepiece with a nosecup to prevent lens fogging. Only about 250,000 of the masks were produced.

By 1944, with a major invasion of Europe by U.S. forces pending, the army requested a better assault mask that was even lighter and less bulky than the M3 series. To meet this requirement, the CWS returned to the original German World War I design, which put the canister directly on the facepiece. The result was the M5 Combat Mask, which was standardized in May 1944 (Figure 2-37). Due to the shortage of rubber, the M5 mask was the first to use synthetic rubber (neoprene) for the facepiece. This mask eliminated the hose from canister to facepiece by mounting the new M11 canister directly on the cheek. The M11 canister used ASC Whetlerite charcoal, which proved better protection against hydrocyanic acid, a chemical agent discovered in a Japanese grenade shortly after the attack on Pearl Harbor (Figure 2-38). Although the M5 weighed a mere half-pound less than the M3, more than 500,000 were procured during the war. The U.S. soldiers who landed at Normandy carried this mask with them.

During the war, the CWS also initiated a major civil defense program to protect civilians against both chemical and biological weapons. Of particular concern were protective devices for children. With the help of Walt Disney, a Mickey Mouse gas mask was designed for children, in the hope that they would not be frightened if they had to wear it, and a tentlike protector was designed for infants.[26,30,102–104]

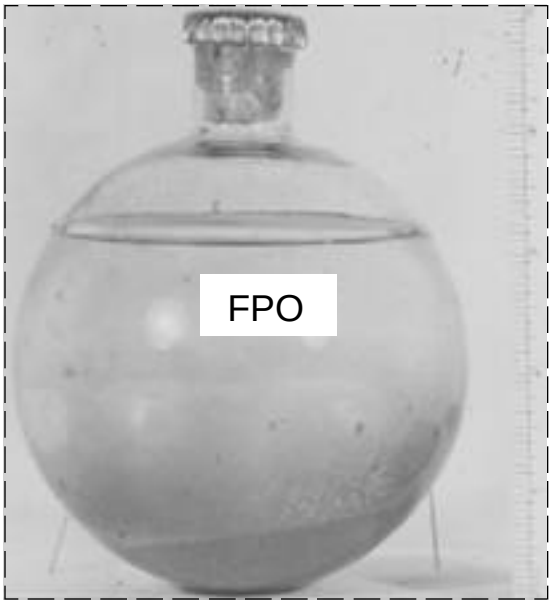

Fig. 2-38. A Japanese frangible hydrocyanic acid grenade, copper stabilized type. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

For collective protection, the CWS concentrated on improving the bulky M1 Collective Protector for field use. A somewhat lighter version, the M2, was standardized in 1942. It provided the same amount of air but weighed just over 600 lb. A still-lighter version, the M3, was also standardized the same year. It weighed only 225 lb and provided 50 cu ft of air per minute.[77]

The CWS also tried to improve the detection capability for toxic chemical agents, particularly blister agents. The early war efforts included the M4 Vapor Detector Kit, which could detect even faint concentrations of mustard agent; M5 liquid detector paint; M6 liquid detector paper; and the M7 detector crayon. These all proved relatively good for detecting mustard and Lewisite. The development of the M9 Chemical Agent Detector Kit in 1943 proved to be one of the most significant developments of the CWS during the war. Described in news releases as being as "effective as a modern burglar alarm,"[105] the kit consisted of a sampling pump, four bottles of reagents, and six clips of detector tubes. The kit could detect small amounts of mustard agent, phosgene, and arsenicals by color changes. It was simple to use and did not require a chemist to make the tests.

An improved version of the World War I orchard sprayer decontamination apparatus was fielded to provide ground and equipment decontamination. It could also be used for plain water showers for soldiers (Figure 2-39). For treatment of gas casualties, the CWS standardized the M5 Protective Ointment Kit. This kit came in a small, waterproof container and held four tubes of M5 Protective Ointment wrapped in cheesecloth and a tube of BAL (British anti-Lewisite) Eye Ointment. The protective ointment was used to liberate chlorine to neutralize vesicant agents on the skin. The BAL ointment neutralized Lewisite in and around the eye by changing it to a nontoxic compound. Over 25 million of the kits were procured for the army.[26,35,105]

Biological Warfare Program

The apparent use of cholera, dysentery, typhoid, plague, anthrax, and paratyphoid by the Japanese

Fig. 2-39. The 400-gal decontaminating apparatus was also used to provide water showers for the troops on Iwo Jima. Like the actual weapons, all the associated paraphernalia of chemical warfare had to go with the deployed combat forces. Useful alternative work was found for decontamination apparatuses, however, in contrast to the bombs shown in Figure 2-34. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

against Chinese troops finally led to an American decision to conduct research and establish a retaliatory biological warfare capability. In response to the potential threat, in 1941 (prior to the attack on Pearl Harbor), Secretary of War Harry L. Stimson asked the National Academy of Sciences to appoint a committee to study biological warfare, appropriately named the Biological Warfare Committee. This committee did not have time to prepare before the war came. This left the army unprepared for the threat of biological warfare by Japan.

Immediately following the attack on Pearl Harbor, the army's Hawaiian Department took special precautions against biological attack by both external enemies and local residents. Guards were placed on the water supplies in Hawaii to protect against sabotage by biological warfare, and daily checks for chlorine content were made. Food production plants were also guarded, and drinking fresh (but not canned) milk, in particular, was banned. A general order was issued prohibiting the sale of poisons to the general public except under special circumstances.

In February 1942, the Biological Warfare Committee recommended that the United States should take steps to reduce its vulnerability to biological warfare. In response, Secretary Stimson recommended to President Roosevelt that a civilian organization should be established to accomplish the mission. After the president approved the plan, the War Research Service (WRS) was formed in August 1942 under the leadership of George W. Merck, president of Merck Company, a pharmaceutical company. The WRS was only a coordinating committee attached to the Federal Security Agency; it used existing government and private institutions for the actual work. It drew its scientific information from a committee of scientists from the National Academy of Sciences and the National Research Council.

In December 1943, U.S. intelligence reports predicted that Japan might use biological warfare. At the same time, tests indicated that masks made in the United States gave poor protection against simulated biological agents. In response to these threats, the CWS (1) developed a special outlet-valve filter for the masks and (2) rushed delivery of some 425,000 under special security conditions to the island of Saipan in case biological warfare actually started.

In January 1944, the complete biological warfare program was transferred from the WRS to the War Department, and the WRS was abolished. The War Department divided the biological warfare program between the CWS and The U.S. Army Surgeon General. The CWS took responsibility for agent research and production, foreign intelligence, and defensive means. The Surgeon General was to cooperate with the CWS on the defensive means. Merck, the former leader of the WRS, became a special consultant to the program.

Fig. 2-40. The first biological warfare agent laboratory at Camp Detrick, Md. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

This arrangement was modified in October 1944, when the secretary of war established the U.S. Biological Warfare Committee with Merck as the chairman. The CWS assigned the biological warfare program to its Special Projects Division. At its peak, this division had 3,900 army, navy, and civilian personnel working on various programs.[26,106]

Initially, the army's biological warfare program was centered at Edgewood Arsenal. In April 1943, Detrick Air Field near Frederick, Maryland, was acquired by the CWS and was activated as Camp Detrick. Four biological agent production plants were started at Camp Detrick to meet the army's needs (Figure 2-40). Pilot Plant No. 1, activated in October 1943 for the production of botulinum toxin, was located in the Detrick Field hangar. Pilot Plant No. 2, completed in March 1944, produced the anthrax simulant *Bacillus globigii* and actual anthrax spores. Pilot Plant No. 3, completed in February 1945, produced plant pathogens. Pilot Plant No. 4 was completed in January 1945 and produced, in embryonated eggs, the bacteria that cause brucellosis and psittacosis (Figure 2-41). Additional smaller pilot plants were set up to explore the many other antipersonnel, antianimal, and antiplant agents examined in Camp Detrick's laboratories.

The existing Vigo Ordnance Plant near Terre Haute, Indiana, was also acquired by the CWS in 1944 for conversion into a biological agent– and

Fig. 2-41. Camp Detrick, Md., 16 July 1945. These technicians at the Egg Plant are disinfecting and drilling eggs prior to inoculating them with *Brucella suis* or *Chlamydia psittaci*, the bacteria that cause brucellosis and psittacosis. Viral agents such as Venezuelan equine encephalitis virus were also produced in eggs. This pilot facility had incubator capacity for approximately 2,000 chicken eggs. Depending on the agent being produced, eggs were incubated for approximately 1 to 10 days between inoculation and harvest. The work was done by hand, in assembly-line fashion, with little mechanical assistance. Preparing biological warfare agents in this manner is a labor-intensive process. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

weapon–production plant. This plant was divided into four main subplants: agent production, munitions assembly, munition packaging and storage, and the animal farm. Although the plant was considered ready to produce biological agents by the summer of 1945, none were actually produced.

Weaponization of biological agents made tremendous progress, considering that the CWS started from nothing. Anthrax was considered the most important agent. Although no dissemination of anthrax in a weapon was accomplished in the United States before the end of the war, anthrax simulant was tested in large 100-lb and 115-lb bombs, and small 10-lb bombs, shotgun shell (SS) bombs, and the 4-lb SPD Mk I bomb. The smaller bombs, suitable for use in larger cluster bombs, proved the most successful in static tests. Only the SPD Mk I bomb was considered ready for production, and the first and apparently only large-scale munition order was placed at Vigo in June 1944 for production of 1 million of the bombs. The order was canceled with the end of the war.

The U.S. Biological Weapons Program also targeted German and Japanese vegetable crops. Tests of anticrop bombs included using spores of brown spot of rice fungus and 2,4-dichlorophenoxyacetic acid (known as VKA, for vegetable killer acid) in the SPD Mk II bomb and a liquid (VKL, for vegetable killer liquid) in the M-10 spray tank. Scientists also worked on defoliants in the program.[3,106]

In 1944 and 1945, there was a sudden interest in the possibility that Japan was attempting to attack the United States by placing biological agents on balloons that then floated across the ocean. In fact, some 8,000 to 9,000 balloons were launched by Japan against the United States, however, those recovered in the United States contained only high-explosive and incendiary bombs meant to start forest fires. These balloons continued to turn up several years after the war.[26]

U.S. Chemical Warfare Policy

President Roosevelt established a no-first-use policy for chemical weapons early in the war. In 1943, this was reiterated in an official statement: "We shall under no circumstances resort to the use of such [chemical] weapons unless they are first used by our enemies."[107(p6)] The policy was backed up by a statement of warning:

> Any use of gas by any axis power, therefore, will immediately be followed by the fullest possible retaliation upon munition centers, seaports and other military objectives throughout the whole extent of the territory of such axis country.[107(pp6–7)]

Neither Germany nor Japan chose to initiate chemical warfare with the United States. The CWS spent the war training troops; designing chemical, incendiary, smoke, high explosive, and flame weapons, and protective equipment; and planning for a chemical war that never occurred. It was a tremendous "just-in-case" effort.

Toward the end of the war with Japan, the combination of President Roosevelt's death, the extremely costly battles of Iwo Jima and Okinawa, and the planned invasion of the Japanese homeland led the army to look at the possibility of initiating chemical warfare to save American lives. One such proposal began:

> Our plan of campaign against the Japanese is one which we think will bring the war against Japan to the quickest conclusion and cut our cost in men and resources to the minimum. Japan's complete defeat is assured providing we persevere in this plan, the only question remaining being how long the war will last and what the cost will be of achieving final victory. These questions will be answered not

> alone by the tactics employed in the execution of the plan but also by the weapons used. Gas is the one single weapon hitherto unused which we can have readily available and which assuredly can greatly decrease the cost in American lives and should materially shorten the war.[108]

The proposal concluded by recommending that the president change the policy on no first use of chemical weapons and coordinate the plan with the British and Russians.[108]

The senior staff, however, concluded that chemical warfare would only complicate the invasion of Japan and would not be a decisive weapon. In addition, coordinating and preparing America's allies for chemical warfare were also perceived as major problems. The use of the atom bomb in 1945 effectively ended the discussion.[45,109]

Lessons Learned

The U.S. Army learned several lessons from this nongas war that the CWS followed. Although perhaps more a finger-pointing exercise, the phrase "had the United States been prepared for war in 1939, there would not have been a war"[110(p24)] was taken as a self-evident truth. The CWS needed to be a permanent organization that concentrated on training, research and development, and chemical warfare preparedness. This same lesson, from a slightly different angle, was reflected in the words of Under Secretary of War Kenneth C. Royall to the chemical warfare specialists, "The better job you do the less likely it is that you will have to put to actual use the products of your work."[111(p41)]

Demobilization and the Creation of the Chemical Corps

The army began demobilization activities almost immediately on the president's proclamation of the end of hostilities. By early 1946, the CWS was effectively demobilized, and its military strength approached prewar levels. One observer commented: "Gas warfare is obsolete! Yes, like the cavalry and horsedrawn artillery, it is outmoded, archaic, and of historical interest only. This is the atomic age!"[112(p3)]

To preserve the CWS from total disintegration, Major General Porter, the chief of the CWS, made a vigorous advocacy of the distinctive character and important role of the CWS before an army board considering postwar organization. The result was the permanency long sought by the chemical program, a corps designation. The army finally agreed that the CWS, along with the other Technical Services, should continue its existence as a distinct entity in the peacetime army. On 2 August 1946, Public Law 607 changed the name of the CWS to the Chemical Corps.[113]

After World War II, as western defense became increasingly based on the threatened use of nuclear weapons, the Chemical Corps's mission expanded to include radiological protection as well as chemical and biological research and development. At the same time, the Corps concentrated on producing and fielding nerve agent weapons and the assorted detection and decontamination equipment required.

Major General Alden H. Waitt, who replaced Porter in November 1945, assessed the future of chemical warfare in 1946:

> The fact that toxic gas was not used in the late war does not justify a conclusion that it will not be used in the future. Gas has not been out-moded as a weapon. The Germans developed new gases during World War II. The magnitude of their preparedness for gas warfare is indicated by the fact that they had amassed more than a quarter of a million tons of toxic gas; their failure to use this gas against us is attributable largely to their fear of our retaliatory power. We cannot count upon other nations refraining from the use of gas when it would serve their purpose. There were numerous instances in the late war in which the use of gas might have had far-reaching results. Thus, there is no good reason for assuming that the considerations which prevented the employment of gas in World War II will prevail in the future.[114]

On the topic of biological warfare, he acknowledged it as a new field that still required much work:

> The tremendous potentialities of biological warfare in the future demand that the necessary tactics and employment in the field be worked out well in advance so that such means may be used immediately and effectively once a decision to do so is made. It is essential that Chemical Officers on the staffs of divisions and higher units, including equivalent Army Air Force elements, be in a position to advise their Commanders relative to the capability, limitations and means of protection against this new method of attack. Further, they must be able to prepare suitable offensive and defensive plans and to supervise such training of troops in these methods as may be required.[114]

Demilitarization of Captured Weapons

Following the occupation of Germany and Japan, the Allies initiated a sea-dumping and weapons disposal program to eliminate the large stockpiles

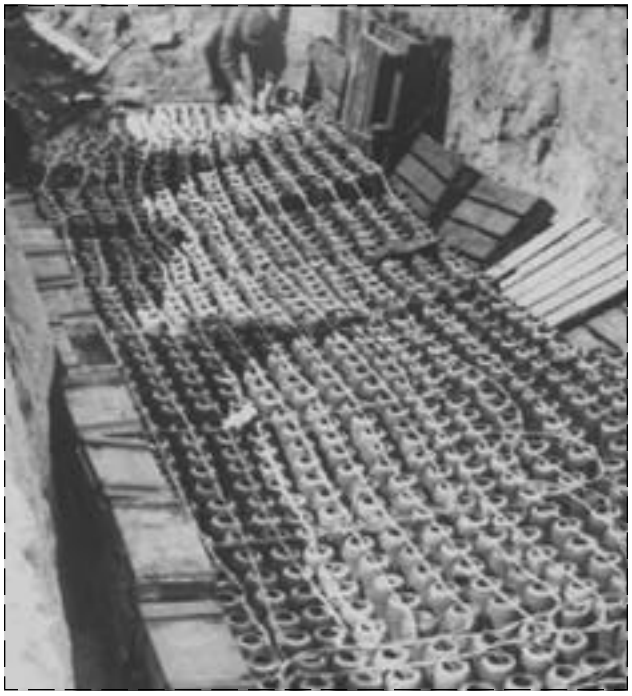

Fig. 2-42. Dumping weapons into the sea was not the Allies' only method of disposing of them. These 150-mm German nitrogen mustard (HN-3) rockets are wired with prima cord for destruction. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

of captured chemical agents (Figure 2-42). Operation Davy Jones Locker involved sinking ships that contained German weapons in the North Sea. However, not all the German weapons were destroyed. Between 1945 and 1947, over 40,000 of the 250-kg tabun bombs, over 21,000 mustard bombs of various sizes, over 2,700 nitrogen mustard rockets, and about 750 tabun artillery shells of various sizes were shipped to the United States. In addition to disposing of the enemy stockpiles, the United States also dumped the U.S. Lewisite stockpile into the sea during Operation Geranium in 1948.[3,115]

Post–World War II Developments

Although the late 1940s was not a time for many dramatic developments, the Chemical Corps was able to issue a new gas mask in 1947. Designated the M9 series, it was an improved version of the M5 mask (Figure 2-43). This mask utilized a superior synthetic rubber composition that worked better in cold weather than the neoprene of the earlier mask.[30]

In 1948, the army partially standardized sarin and the year after, tabun. In 1948, the army also issued a new circular[116] on G-series nerve agents and a technical bulletin[117] on the treatment of nerve agent poisoning.[3] The circular provided current information on detection, protection, and decontamination of nerve agents. For detection, the M9 and the improved M9A1 detection kits, standardized in 1947, could detect vapor after a complicated procedure:

> To make test, tear off lead wrapper and heating pad. Insert blue dot end of the glass tube into pump. Slowly take 25 full pump strokes. Remove from pump, and heat tube with matches or cigarette lighter for about 5 seconds. (Avoid excessive heating of tube, since this will char contents of the tube and invalidate the test results.) After tube is cool, add liquid from blue bottle to unmarked end of the tube. If gas is present, a blue ring will form in the upper end of the tube.[116]

For droplets, the M5 detector paint and the M6 detector paper both turned from olive green to red. None of the detectors provided any advance warning, and all merely confirmed the presence of the agents after the fact.

Fig. 2-43. The M9 series gas mask. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

For protection, the circular simply stated that the current mask "gives protection for the eyes and respiratory tract and for the skin covered by the facepiece."[116] Additional required items were impermeable clothing worn over a layer of ordinary clothing, rubber boots, and rubber gloves.

Decontamination of nerve agents was still a problem. DANC was not suitable. Bleach slurry and dilute water solutions of alkalies were reported as effective decontaminants. Hot soapy water was also recommended, while cold water only partially decontaminated the agents.[116]

The technical bulletin[117] pointed out that contamination by nerve agents could come via breathing the vapors or body contact with the liquid, and that death could occur in a few minutes. The bulletin then outlined the suggested treatment for exposures:

> The treatment of poisoning is based essentially upon the blocking of excessive nervous activity, due to the direct effects of the poison and to apprehension, fear, physical activity, and external stimuli. Quiet, reassurance, and gentle handling of the casualty are therefore essential. Atropine sulfate (1.0 mg) should be given by intravenous or intramuscular injection very promptly. This effectively blocks the excessive activity of smooth muscle and glands, and also controls convulsions.[117]

However, should this not work:

> In the event of impending respiratory failure, all drug therapy may be ineffective. Under such circumstances, artificial respiration may prove to be the only life-saving procedure.[117]

How artificial respiration could be conducted in a contaminated environment was not addressed.

Beginning of the Cold War

The declining relations with the Soviet Union caused that country to become the number one intelligence target for chemical warfare preparations. Intelligence reports noted with alarm that toward the end of World War II, the Soviets had captured a German nerve agent production facility and had moved it back to their country.[15,118]

Other studies described the Soviets as ready to conduct chemical attacks should open warfare break out. In 1949, Waitt reported:

> Intelligence reports indicate extensive preparation for gas warfare by the USSR with current Soviet superiority over the U.S. in this field as to stockpiles of gas munitions, currently operating war-gas plant capacity, and Soviet ability to maintain this superiority for at least 12 months after the start of hostilities, assuming the U.S. gas warfare position is not improved prior to M-Day.[118]

His recommendations were to increase chemical training, replace the aging World War II–era equipment and munitions, and then achieve a much higher state of readiness.[118]

One of the first Cold War actions that involved the Chemical Corps was the Berlin Blockade in 1949. Cold weather caused frost to build up on the airplanes flying to Berlin with supplies. The accepted method of ice removal was to use brooms to sweep the ice off. This slow and dangerous work was replaced by the corps's using decontamination trucks to spray isopropyl alcohol, which was used as a deicer since glycerin was not readily available. A large plane could be deiced in about 5 minutes, and the corps was credited with keeping the airplanes from being delayed by frost.[119]

THE 1950s: HEYDAY OF THE CHEMICAL CORPS

Korean War

In June 1950, with the onset of the Korean War, the Chemical Corps participated in its first military action. The corps quickly implemented an increased procurement program to supply the army with a retaliatory chemical capability and defensive equipment. Major General Anthony C. McAuliffe, the new Chief of the Chemical Corps, concluded that this ability was the number one lesson learned from World War II:

> It required the experiences of World War II to demonstrate that the most important basic factor in a nation's military strength is its war production potential and ability to convert smoothly and quickly its industry, manpower, and other economic resources.[120(p284)]

Within a short time, however, the army's policy on chemical warfare and the lessons learned from the past were hotly disputed, particularly as the military situation in Korea changed. First, the Chemical Corps lost its high-visibility ground

weapon, the 4.2-in. chemical mortar. Responsibility for research, development, procurement, storage, issue, and maintenance of all 4.2-in. mortars and ammunition was transferred to the Ordnance Department on 31 December 1947 by order of the Chief of Staff, Department of the Army. The exception was the responsibility for chemical fillings for mortar shells, which remained with the Chemical Corps. This event represented the end of the Chemical Corps's role in the development of the 4.2-in. chemical mortar. In 1951, the Ordnance Department completed the development of a new 4.2-in. (later designated the 107-mm) mortar, the M30, to replace the M2. The loss of the 4.2-in. mortar moved the Chemical Corps away from being a combat arm and left it a combat support arm.[121]

The action in Korea also brought up the subject of whether to initiate chemical warfare to save lives. Many of the Chemical Corps's supporters favored the use of chemical weapons as humane weapons of war, particularly to offset the enemy's superior numbers. One writer, upset with negative public opinion toward chemical weapons and the army's policy of retaliation only, wrote:

> Has this concept and this attitude been reflected in our military planning and our military preparations? If, in an effort to "make the most" of our military expenditures we have failed to stock up to the fullest requirements in the matter of toxic weapons on the premise that such weapons "might not be used again, as they were not used in World War II," we may have made a major military decision on the basis of a fatally unsound assumption.[122(p3)]

Another officer stated it much more bluntly:

> The use of mustard, Lewisite and phosgene in the vast quantities which we are capable of making and distributing offers the only sure way of holding Korea at the present time. We are not playing marbles. We are fighting for our lives. Let's use the best means we have to overwhelm the enemy scientifically and intelligently.[123(p3)]

Again, however, neither side chose to initiate chemical and biological warfare and the corps supported the war through its many other programs, particularly smoke and flame. Much as it had done during World War II, the United States did not change its policy about no first use of chemical weapons.

Although there were allegations by the North Koreans and the Chinese that U.S. forces employed chemical and biological weapons on the battlefield, the Chemical Corps apparently did not use such weapons. The corps did, however, use riot control agents to quell riots of prisoners of war. In 1968, a Czech general defected to the United States and reported that U.S. prisoners of war were used for biological tests by the Russians in North Korea. These allegations have yet to be confirmed by the Russians and were vigorously denied by the North Koreans.[124]

The Chemical Corps ended the Korean War in a much stronger position than it faced after the end of World War II. The corps reduced its units and manpower somewhat, and terminated many of its procurement contracts in the months following the 1953 armistice. Still, Major General Egbert F. Bullene, the new Chief Chemical Officer summed up the feeling of the corps about the Korean War and the Cold War in general: "Today, thanks to Joe Stalin, we are back in business."[125(p8)]

Changes in the Chemical Corps

During the 1950s, the concept of warfare, and chemical and biological warfare continued to change radically. The phrase that one could "push a button" to start a war became exceedingly popular. The lesson learned from the Korean War—the concept of a limited war, fought without nuclear weapons and possibly against satellite states, not the "real enemy"—determined much of the army's planning. The fact, however, that two wars had come and gone without the employment of chemical and biological weapons made it necessary for successive Chief Chemical Officers to work continually to remind the army and the country that this might not be the case again, and that the capabilities of the Chemical Corps constituted insurance against the possibility of chemical or biological attack in the future.

Throughout the 1950s, the corps conducted several extensive studies to change its organization and improve its training capabilities. One significant improvement was the activation of a new training center at Fort McClellan, Alabama, in 1951, which offered more space and training options. The Chemical School, after more than 30 years in Maryland, moved there early in 1952.[3]

The emphasis on individual training for chemical and biological warfare resulted in the elimination of the unit gas officers in 1954. Originally, an officer or noncommissioned officer had been responsible for chemical and biological training and readiness. With this change, the troop commanders assumed the responsibility and were expected to include chemical and biological training in all their field exercises and maneuvers.[126]

Nerve Agent Production and Development

In 1950, the Chemical Corps began construction of the first full-scale sarin production complex based on pilot plant work accomplished at the Army Chemical Center, which had formerly been called Edgewood Arsenal (Exhibit 2-1). The production of sarin was a five-step process that was divided between two sites. For the first two steps of the process, the corps constructed a plant at Muscle Shoals, Alabama, later designated Site A or the Muscle Shoals Phosphate Development Works, which was completed in 1953. The last three steps of the process were conducted at a new plant at Rocky Mountain Arsenal, Colorado. In 1951, the corps fully standardized sarin and by 1953 was producing the agent. After only 4 years of production, the plants stopped manufacturing since the stockpile requirements for the agent had been met. The plants then went into inactive status with layaway planned. The related munitions filling plants also went into standby status a year later.[3,127]

EXHIBIT 2-1

NAME CHANGES OF EDGEWOOD ARSENAL

25 Oct 1917	Construction begun on a shell-filling plant called Gunpowder Neck Reservation
2 Apr 1918	Gunpowder Neck Reservation designated Gunpowder Reservation
4 May 1918	Name changed from Gunpowder Reservation to Edgewood Arsenal
10 May 1942	Name changed from Edgewood Arsenal to Chemical Warfare Center
2 Aug 1946	Name changed from Chemical Warfare Center to Army Chemical Center
1 Jan 1963	Name changed from Army Chemical Center to Edgewood Arsenal
1 July 1971	Edgewood Arsenal discontinued as a separate installation and designated Edgewood Area, Aberdeen Proving Ground

Part of the reason for the shut down of the sarin plant was the development of a new nerve agent. Chemists at Imperial Chemicals, Ltd., in the United Kingdom, while searching for new insecticides, came across compounds that were extremely toxic to humans. The British shared the discovery with the United States in 1953. The Chemical Corps examined the new compounds and determined that a new series of nerve agents had been discovered that were more persistent and much more toxic than the G-series agents. This new series was designated the V-series agents in 1955, because they were "venomous" in nature. These agents would enter the body through the skin, thereby bypassing the protective mask. They were 1,000-fold more toxic than sarin when applied to the skin, and 2- to 3-fold more toxic when inhaled. A drop the size of a pinhead on bare skin could cause death within 15 minutes.[3,128]

The Chemical Corps gave top priority to the investigation of these compounds. Of the compounds investigated, VX was selected in 1957 for pilot plant development and dissemination studies. It was standardized in December 1957. The annual report for that year concluded: "The reign of mustard gas, which has been called the King of Battle gases since it was first used in July 1917, will probably come to an end."[129(p100)]

The initial plan was to contract with private industry for a 10-ton per day production plant. A later decision put the plant at the inactivated Dana Heavy Water Plant of the Atomic Energy Commission at Newport, Indiana, within the Wabash River Ordnance Works. A patent dispute that resulted in a restraining order by the Chief Justice of the United States and problems with contractors visiting the new site delayed construction. Finally in 1959, Food Machinery and Chemical Company, the low bidder, got the contract and construction was planned for 1960. Shortly after the approval, the Chemical Corps supplemented the contract to provide for a VX weapon-filling plant.[129,130]

Chemical Weapons

During the 1950s, the Chemical Corps concentrated on the weaponization of sarin. For air delivery, the first items standardized in 1954 were the 1,000-lb M34 and M34A1 cluster bombs (Figure 2-44). These clusters held 76 M125 or M125A1 10-lb bombs, each containing 2.6 lb of sarin (Figure 2-45).

In 1959, the Chemical Corps standardized the first nonclustered bomb, designated the MC-1 750-lb sarin bomb. This was a modified general purpose

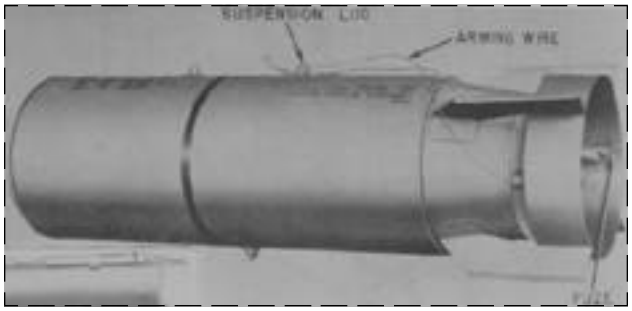

Fig. 2-44. The M34 series sarin cluster bomb was the first major nerve agent bomb standardized by the U.S. military after World War II. Photographs: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

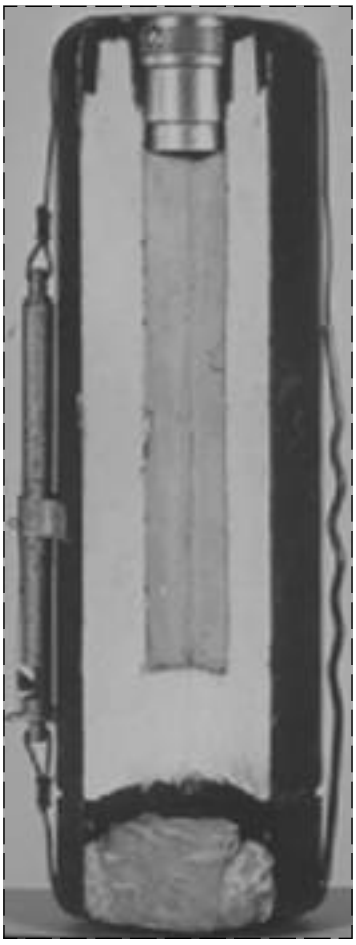

Fig. 2-45. The M125 series sarin bomblet, which was contained in the M34 cluster bomb. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

demolition bomb, suitable for high-speed aircraft, and held about 215 lb of sarin filling. For ground delivery, the Chemical Corps standardized the M360 105-mm and the M121 155-mm shells in 1954. The smaller shell held about 1.6 lb of agent and the larger about 6.5 lb.[3,130]

Although delivery systems for VX nerve agent were initiated during the 1950s, no system was standardized. In addition, many of the sarin delivery systems took longer to develop than planned and some were never standardized.

Biological Agents

During the 1950s, the biological warfare program was one of the most highly classified programs, owing to its nature and the ongoing Cold War, and many of the details of the program have never been declassified. The corps concentrated on standardizing the agents investigated during World War II and weaponizing them at Fort Detrick, the Chemical Corps biological warfare center. The highest priority was placed on the antipersonnel agents, as the antianimal and antiplant programs both experienced major disruptions during the decade.

A number of antipersonnel agents were standardized during the early 1950s, but in 1953, Major General Bullene, Chief Chemical Officer, gave an overriding priority to the development of anthrax, which had also been the highest-priority agent during World War II.

One of the more interesting stories was the standardization in 1959 of the yellow fever virus for use, with a mosquito as vector. The virus came from an individual in Trinidad who had been infected with the disease during an epidemic in 1954. Scientists inoculated rhesus monkeys with the serum to propagate the virus. In tests conducted in Savannah, Georgia, and at the Avon Park Bombing Range, Florida, uninfected mosquitoes were released by airplane or helicopter. Within a day, the mosquitoes had spread over several square miles and had bitten many people, demonstrating the feasibility of such an attack. Fort Detrick's laboratory was capable of producing half a million mosquitoes per month and had plans for a plant that could produce 130 million per month.[130]

Fort Detrick, however, was limited in its production capability and required an expanded facility. Since the World War II–era Vigo Plant, inactivated in the postwar years, was not reopened (and was eventually sold in 1958), Pine Bluff Arsenal was selected to be the site of the new biological agent

production plant. The plant was designated the X-201 Plant, later renamed the Production Development Laboratories, and was completed in 1954. This plant could produce most of the agents standardized by the Chemical Corps, and could fill bombs within 4 days after receipt of an order.

The antianimal program started off strong in 1952 when the Chemical Corps activated Fort Terry, on Plum Island, New York, to study animal diseases. In 1954, however, the army terminated all antianimal agent work with exception of rinderpest and the completion of the foot-and-mouth disease research facility. The Department of Agriculture then took over the defensive aspects of the antianimal program, including Fort Terry, the same year.

The antiplant program made some progress when, in 1955, wheat stem rust became the first antiplant pathogen standardized by the Chemical Corps for use primarily against cereal crops. Additional antiplant agents were standardized shortly thereafter. In 1957, however, the army ordered the corps to stop all antiplant research and development since the air force, primarily, would be delivering the agent. This was accomplished by 1958 with the termination of the program. Then the decision was reversed the next year after additional funding was found. Fort Detrick had to restart the program, which delayed any significant accomplishments for some time. Fort Detrick also began to concentrate more on the chemical defoliants, conducting the first large-scale military defoliation effort at Fort Drum, New York, using the butyl esters of 2,4-D and 2,4,5-T, later designated Agent Purple.[3,131]

Biological Weapons

Although many biological agents were standardized and many delivery systems developed, only a few biological weapons were standardized. The first was the M114 4-lb antipersonnel bomb, which held about 320 mL of *Brucella suis* (Figure 2-46). This was a small, 21-in.-long tube with a 1⅝-in. diameter, similar to a pipe bomb. One hundred eight of the M114s were clustered in the M33 500-lb cluster bomb (Figure 2-47). The bombs were also tested at Dugway Proving Ground, Utah, throughout the 1950s with various other fillings.

The M115 500-lb antiplant bomb was standardized in 1953 for the dissemination of wheat stem rust. This filling consisted of dry particulate material adhered to a lightweight, dry carrier (ie, feathers). Thus, the bomb was normally referred to as the feather bomb.

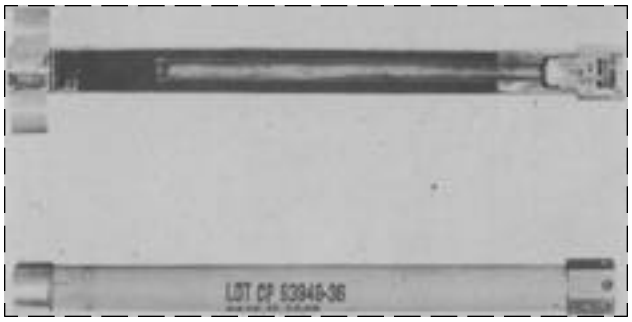

Fig. 2-46. The M114 4-lb biological bomb was the first biological weapon standardized by the U.S. military. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

There were numerous other experimental delivery systems. The E61R4 half-pound antipersonnel bomb held only about 35 mL of agent, but four of the little bomblets produced twice the area coverage of one M114. The E133R3 750-lb cluster bomb held 544 bomblets.

Copying the method the Japanese developed during World War II, the Chemical Corps developed the 80-lb antiplant balloon bomb. The bomb itself was a cylinder 32 in. in diameter and 24 in. high that served as the gondola of the balloon. Inside the insulated gondola were five agent containers, each holding feathers and an antiplant agent. The agent containers were grouped around a chemical-type

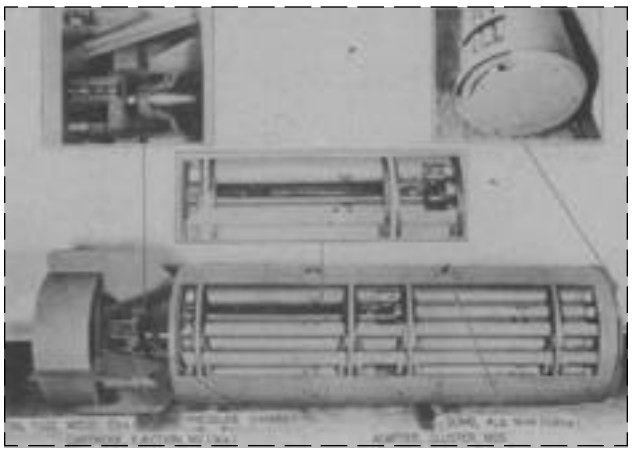

Fig. 2-47. The M33 500-lb biological cluster bomb, which held 108 of the M114 bombs. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

heater. A barometric and mechanical time mechanism opened the gondola at a preselected altitude, releasing the agent.

Other delivery systems included spray tanks, missiles, aerosol generators, drones, and marine mines. Of these, the submarine mine was one of the more covert forms of delivery. It was designed to be fired from a torpedo tube, to sink to the bottom for a specified period up to 2 hours, and then rise to the surface and expel about 42 L of agent. After dissemination of the agent, it scuttled itself.[3,132]

Although both simulants and small amounts of live agents were used in open-air testing during the 1950s, for sheer size, Operation Large Area Coverage (LAC) covered the largest geographical area. To test the feasibility of contaminating a large area of the continent with biological organisms, in 1957 the Chemical Corps dropped a myriad of microscopic fluorescent particles of zinc cadmium sulfide along a path from South Dakota to Minnesota. In the first test, the air stream turned north and took the bulk of the material into Canada. Still, a test station in New York was able to detect the particles. In the second test in 1958, the particles were carried into the Gulf of Mexico. Special collectors were located at 63 Civil Aeronautics Authority sites and 112 Weather Bureau stations. Over 2,200 samples were mailed back to the corps from these sites.

Two additional tests covered from Ohio to Texas, and from Illinois to Kansas. All demonstrated that the particles were widely disseminated. Although it had been only theoretical prior to this test, Operation LAC provided the first proof that biological agents were indeed potential weapons of mass destruction.[129]

Medical Research on Human Volunteers

The Chemical Corps's concern with the effects of nerve and other chemical agents on soldiers led to extensive studies to determine the dangers of exposure and the proper kinds of treatment. This program exposed soldiers to low levels of agents to demonstrate the effects of treatment and to answer questions about how agents affect humans.

Prior to the 1950s, the use of humans in testing had been conducted on a somewhat ad hoc basis, with little documentation surviving. A more-formal volunteer program was established at the Army Chemical Center during the 1950s. This program drew on local military installations and utilized a specific consent procedure that ensured that each volunteer was prebriefed and was truly a volunteer in the experiment. Between 1955 and 1975, over 6,000 soldiers participated in this program and were exposed to approximately 250 different chemicals.[133]

Although biological agents had been tested on animals, the question arose as to whether the same agents would be effective on humans. In 1954, the Chemical Corps received permission to use human volunteers in the evaluation of biological agents. The plan to assess the agents and vaccines, which was approved by both the U.S. Army Surgeon General and the Secretary of the Army, was produced at Fort Detrick. A medical school under contract conducted most of the investigation. By 1955, the corps had tested many of the known agents on the volunteers in laboratory situations.

The army, however, also wanted to know the effects of biological agents in natural settings. After receiving approval from the secretary of the army, the first open-air test was conducted at Dugway Proving Ground, Utah, where 30 volunteers were exposed to an aerosol containing *Coxiella burnetii*, the rickettsia that causes Q fever. These open-air tests gave valuable data on the infectivity of biological warfare agents.[134,135]

The Incapacitant Program

During the 1950s, the Chemical Corps became interested in developing chemical weapons that incapacitated rather than killed its targets. In 1951, the corps awarded a contract with the New York State Psychiatric Institute to investigate the clinical effects of mescaline and its derivatives. The contractor tested 6 derivatives, while the corps tested 35 derivatives. The results of the investigation indicated that mescaline and its derivatives would not be practical as agents, because the doses needed to bring about the mental confusion were too large.[131]

In 1955, the Chemical Corps formerly established a new project called Psychochemical Agents. The next year, the program was redesignated K-agents. The objective was to develop a nonlethal but potent incapacitant that could be disseminated from airplanes in all environments. The program was conducted at the Army Chemical Center and examined nonmilitary drugs like lysergic acid (LSD) and tetrahydrocannabinol (related to marijuana). None of these drugs, however, were found to be of military worth.[129,131,134,135]

New Protective Equipment

The changing need for protective equipment created by the new threats of chemical, biological, and radiological warfare was reflected in 1951, when the

Chemical Corps officially changed the name of all its gas masks to "protective masks." The M9A1 mask, standardized the same year, was the first to be so designated.

Starting in 1952, the Chemical Corps began work on a new mask to replace the M9 series. The corps wanted a mask that was more reliable, suitable for any face size and skin texture, and more comfortable in any climate. Utilizing previous work on canisterless civilian masks and an earlier military prototype, Dr. Frank Shanty, a young engineer assigned to the Army Chemical Center, thought of the concept for a new mask on a late-night train to Cincinnati, Ohio. The final result was the M17 Protective Mask, the first canisterless military mask, which was standardized in 1959. The new mask eliminated the problem of having left- and right-handed masks, weighed less, and had reduced breathing resistance.[30]

Other mask work included the first tank mask, the M14, standardized in 1954 as part of the M8 3-Man Tank Collective Protector. In 1959, the corps standardized an improved head-wound mask, designated the M18, that allowed soldiers with head wounds to wear protective masks in contaminated environments.[3]

Chemical Agent Detection

The inability to instantly detect nerve agents and sound an alarm to alert surrounding troops was the primary concern of the Chemical Corps during the 1950s. Many detector kits from World War II were updated to improve detection of nerve agents, but these only provided confirmation, without providing advance warning.

The M5 Automatic G-Agent Fixed Installation Alarm, standardized in 1958, was the first detector and alarm for G-series agents. The unit could detect a G-series agent and sound an alarm in about 10 seconds. Unfortunately, the unit was 7 ft high and 2 ft square. It was not suitable for the field and was primarily used at Rocky Mountain Arsenal in sarin production and filling plants.[130]

The M6 Automatic G-Agent Field Alarm, standardized also in 1958, was the first automatic electronic alarm for the detection of G-series agents for field use. Owing to various problems, the alarm was primarily used by the navy for dock monitoring. The alarm was contained in a 24-lb aluminum case approximately 7 in. wide by 15 in. high. The operation of the alarm was based on the color formed when any G-series agent came into contact with a combined solution of *o*-dianisidine and sodium pyrophosphate peroxide. Design of the alarm provided that a drop of this combined solution was placed on a paper tape, which was moved (every 5 min) under two sampling spots, one of which sampled ambient air while the other acted as a monitor to minimize the effects of variations in light reflected from the paper and fluctuations in electronics. The two spots on the paper were viewed by two balanced photo cells. If color developed on the sample side, unbalance occurred between the cells and the buzzer alarm triggered. As designed, it would function continuously unattended for a 12-hour period, at which time it required fresh solutions and new tape. One problem with the alarm was that it did not function at temperatures below 32°F and therefore was not what the army needed.[134,136]

A secondary approach to detection and alarm was the beginning of the remote sensing capability. In 1954, the Chemical Corps began development of a small, simple alarm commonly called LOPAIR (***lo***ng-***pa***th ***i***nfra***r***ed) (Figure 2-48). The principle behind the operation of this device was that the G-series agents absorb certain portions of the infrared spectrum. Such a device would scan the atmosphere continuously in advance of troops and sound a warning alarm when G-series agents were spotted. The prototype performed satisfactorily up to about 300 yd, but it weighed over 250 lb and used too much electrical power. An improved version

Fig. 2-48. A prototype ***lo***ng-***pa***th ***i***nfra***r***ed (LOPAIR) alarm, the E33 Area Scanning Alarm consisted of an infrared source, optical reflector, optical collecting system, grating monochromator, and associated electronics. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

reduced both the weight (to 34 lb) and the power consumption. Its response time was 3 to 10 seconds. A third version combined the best of each unit, with a slight increase in weight but less power consumption, and a range of a quarter mile. Although the corps worked continuously on this approach, it would not come to completion for another 40 years.[135]

Decontamination

Although the Chemical Corps concentrated on nerve agent programs during the 1950s, there was one significant improvement for mustard agent decontamination. In 1950, the corps standardized super tropical bleach (STB) as the best decontaminant for persistent agents. The new bleach was more stable in long-term storage, particularly in temperature extremes, and was easier to spread from a decontaminating apparatus, owing to its more uniform consistency.[137]

Treatment for Nerve Agents

As a result of the introduction of nerve agents, the Chemical Corps added atropine, an antidote to G-series agent poisoning, to the World War II M5 Protective Ointment Set by replacing one of the four ointment tubes. The modified kit was designated the M5A1 Protective Ointment Set in 1950. Since atropine had to be circulated by the blood stream to overcome the effects of the G-series agent, it was packaged in syrettes, small collapsible metal tubes filled with a solution of atropine and fitted with a hypodermic needle at one end. A soldier was required to jab the needle into his thigh muscle and force the atropine out by squeezing the tube. Later in the decade, the M5 ointment was also found to be effective against V-series agents.[74]

Many soldiers, however, reportedly were afraid to stick a needle into themselves. Therefore, a new injector was developed: an aluminum tube, about the size of a small cigar, containing a spring-driven needle and cartridge containing atropine solution. The soldier had simply to push the tube against his thigh and pull a safety pin, and the spring drove the needle into his leg. The new kit was standardized in 1959 as the M5A2 Protection and Detection Set.[130]

The recognized need for respiratory support for the apneic victim of nerve agent exposure resulted in the development of a resuscitation device that could be attached to the M9 series of protective masks (Figure 2-49).

Fig. 2-49. With the advent of nerve agents and the recognition that they cause respiratory paralysis, the army saw the need to develop first-aid methods capable of providing artificial ventilation on the battlefield. The M28 mask-to-mouth resuscitator was one such development. It consisted of three parts: (1) a hose, which connected the casualty and the rescuer; (2) a modified M9A1 protective mask; and (3) an anesthetist-type oronasal mask. The expiratory valve of the M9A1 mask was removed and replaced by the hose. The rescuer inhaled through a standard canister (out of sight in the photograph) and exhaled into the hose. Positive pressure in the hose connecting the casualty and the rescuer opened a double-acting, demand-type, inlet-and-expiration valve in the oronasal mask. This allowed the rescuer's exhaled breath to enter the casualty's lungs. The second canister (seen on the casualty's chest) protected the casualty from inhaling contaminated air when he began to breathe spontaneously. Note that none of the soldiers in this staged photograph are protected against skin absorption. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

The Growing Soviet Threat

The growing Soviet threat concerned the Chemical Corps and the U.S. Army throughout the decade. Soviet Defense Minister Georgi Zhukov, while addressing the Communist Party Congress in Moscow in 1956, warned: "[A]ny new war will be characterized by mass use of air power, various types of rocket, atomic, thermo-nuclear, chemical and biological weapons."[138(p26)]

In 1959, Major General Marshall Stubbs, the new Chief Chemical Officer, assessed the growing Soviet chemical threat:

> Soviet chemical weapons are modern and effective and probably include all types of chemical muni-

> tions known to the West, in addition to several dissemination devices peculiar to the Russians. Their ground forces are equipped with a variety of protective chemical equipment and they are prepared to participate in large scale gas warfare. They have a complete line of protective clothing which will provide protection in any gas situation and a large variety of decontaminating equipment.[139(pp8–9)]

As for the biological threat, he added:

> We can assume from available knowledge that they are equally capable in biological warfare. The mass of medical and technical reports published recently by their scientists indicates increased activity in this area. Soviet microbiologists and military authorities have conducted BW tests at an isolated location over a long period of time. It is also known that the Communists have conducted research and development leading to the large scale production and storage of disease producing and toxic agents.[139(p9)]

He concluded: "I believe that I have given you enough to make you aware that they pose a threat to the free nations of the world."[139(p9)]

THE 1960s: DECADE OF TURMOIL

In 1960, Major General Stubbs talked to various groups around the country on the need for a greater sense of urgency in attaining chemical, biological, and radiological preparedness. Contending that—to both military and civilian populations—the threat of chemical and biological warfare was as great as the threat of nuclear warfare, he quoted a Soviet source who, in 1958, had described the next war as being distinguished from all past wars in the mass employment of military air force devices, rockets, weapons; and various means of destruction such as nuclear, chemical, and bacteriological weapons. Stubbs also reported that the Soviets had about one sixth of their total munitions in chemical weapons.[140]

In January 1961, Secretary of Defense Robert S. McNamara initiated about 150 projects aimed at giving him an appraisal of military capabilities. Two of these—project 112 and project 80—had significant impact on the chemical and biological weapons program.

Project 112 had as its objective the evaluation of chemical and biological weapons both for use as strategic weapons and for limited war applications. The result of this study was a recommendation to highlight chemical and biological weapons and particularly to increase long-term funding. In 1961, these recommendations were basically approved for immediate action by the deputy secretary of defense. One of the responses was the creation of Deseret Test Center, Utah, which was intended for extracontinental chemical and biological agent testing, including trials at sea, and arctic and tropical environmental testing. The new center was jointly staffed by the army, navy, and air force, with testing scheduled to begin in 1962.

Project 80 resulted in a committee to review the organization of the army. The conclusion of this committee was to eliminate the technical services and distribute their functions to various elements of the new army organization. Secretary of Defense McNamara felt that the Chemical Corps's knowledge, experience, and training was not being "infused" into the rest of the army. The problem appeared to be that the combat troops were "structurally separated" from the Chemical Corps, particularly in the areas of research and development, and training.[141]

The chemical training of combat troops was a major concern. Colonel John M. Palmer, commanding the Chemical Corps Training Command, reflected on the problem in 1960:

> The quickest way to reduce the effectiveness of a military training program is to train without purpose or sense of urgency. Unfortunately, for 40 years an aimless approach has largely characterized unit chemical warfare training in the U.S. Army.... Much of the Army still appears to visualize chemical warfare, and related biological warfare training, as an annoying distraction from normal combat training.[142(p28)]

Based on these problems, the Defense Department ordered a far-reaching realignment of functions in 1962. Most of the Technical Service headquarters establishments, including that of the Chemical Corps, were discontinued, and their functions merged into three field commands. Thus, the training mission of the Chief Chemical Officer was assigned to the Continental Army Command; the development of doctrine to the new Combat Development Command; and the logistical function, including all arsenals, laboratories, and proving grounds, to the equally new Army Materiel Command (AMC).

The effects of the reorganization were quickly felt. Within 2 years, the chemical warfare training program had been improved significantly. One junior officer described the changes:

> We have set up special 40-hour or 80-hour schools so that we can have a trained CBR [chemical-biological-radiological] officer and noncommissioned officer in every company-sized unit. We have assigned a chemical officer down to brigade, and a chemical operations sergeant down to battalion. We set aside a certain number of hours annually for classroom instruction for the troops. We set up special blocks of instruction for surveying and monitoring teams. We list CBR defense as a subject integrated into our training schedules, and … we may even throw tear gas grenades or other agents at troops in the field.[143(p16)]

The same officer, however, concluded that even more realistic field training was still required to prepare soldiers for the modern battlefield with nuclear weapons, nerve agents, and biological weapons.[143]

Beginning of the Vietnam War

A growing guerrilla war in South Vietnam soon made the army again reexamine its training program, chemical warfare readiness, and its no-first-use policy. One observer stated in 1963: "After years of almost total lack of interest, the United States has taken up guerrilla warfare training as though it were something new under the sun."[144(p12)] As part of that sudden interest, the role of chemical weapons again came under intense scrutiny and debate. In 1963, one author stated: "The best way for the U.S. to achieve its military aims in Southeast Asia would be to rely on chemical warfare."[144(p12)] He described how soldiers could "sanitize" a particular area with gases and sprays that killed everything from vegetation to humans.[144]

In 1966, a retired U.S. Army general suggested that mustard gas be used as an invaluable weapon for clearing Vietnamese tunnels. He thought the use of low-lethality chemicals would save both American and Vietnamese lives by rendering the tunnels useless.[145]

Other observers and authors also recommended revising the no-first-use policy. Public opinion and national policy opposing the use of toxic chemicals apparently was the deciding factor against their employment. The army did, however, utilize defoliants and nonlethal riot control agents in large quantities. This caused a worldwide response that required the army to quickly explain the differences between lethal and nonlethal chemicals.

The expansion of hostilities in Vietnam caused a gradual rise in the level of development and procurement of chemical warfare–related items. By virtue of their training and their specialized equipment, Chemical Corps personnel were able to make a number of contributions, primarily in the areas of riot control and flame weapons.

Yemen Civil War

While the United States was still involved in the Vietnam War, another small war in the Middle East brought the subject of chemical warfare back from being only hypothetical. In 1962, Yemeni dissidents overthrew the monarchy and declared a republic. Royalist forces then retreated into the mountains of northern Yemen and initiated a counterrevolt against the republican forces. Egypt (which probably had had a hand in the revolt) recognized the new republic and sent military forces to help defeat the royalist troops, who were supported by the kingdoms of Saudi Arabia and later Jordan.[146]

Egyptian efforts to defeat the royalist forces and destroy their civilian support bases proved particularly difficult in the mountainous terrain. Apparently growing impatient with the successful royalist guerrilla tactics, the Egyptian air force allegedly dropped chemical-filled bombs on pro-royalist villages to terrorize or kill not only the local inhabitants but also, possibly, the royalists who were hiding in caves and tunnels. The Egyptians denied ever using chemical warfare during their support of republican forces.

Most of the early accounts of chemical warfare came from journalists in the area. The first reported incident occurred in July 1963. This alleged attack took place against the village of Al Kawma and killed seven civilians. The United Nations investigated the allegation by sending an observation team to Yemen, but their report concluded there was no evidence of a chemical attack.[147]

Newspaper articles described additional chemical attacks taking place from 1963 to 1967, although most disagreed on the dates, locations, and effects of the attacks. The United States, involved in its own controversy concerning the use of riot control agents in Vietnam, took little notice of the reports.

Much like the progression of chemicals used during World War I, the Egyptians allegedly started with tear gases, which were meant to terrorize more than kill; then progressed to mustard agents, which caused more-serious casualties; and finally to nerve agents, which were meant to kill large numbers quickly. Prior to this, no country had ever used nerve agents in combat. The combination of the use of nerve agents by the Egyptians in early 1967 and the outbreak of war between Egypt and Israel dur-

ing the Six-Day War in June, finally attracted world attention to the events in Yemen.

In January 1967, an attack occurred on the Yemeni village of Kitaf. During this air raid, bombs were dropped upwind of the town and produced a gray-green cloud that drifted over the village. According to newspaper accounts,[148–152] 95% of the population up to 2 km downwind of the impact site died within 10 to 50 minutes of the attack. All the animals in the area also died. The estimated total human casualties numbered more than 200. Still another attack was reported to have taken place on the town of Gahar in May 1967 that killed 75 inhabitants. Additional attacks occurred that same month on the villages of Gabas, Hofal, Gadr, and Gadafa, killing over 243 occupants.

Shortly after these attacks, the International Red Cross examined victims, soil samples, and bomb fragments, and officially declared that chemical weapons, identified as mustard agent and possibly nerve agents, had been used in Yemen. The Saudi government protested the Egyptian use of chemical weapons to the United Nations. U Thant, Secretary-General of the United Nations, sought to confirm the use of chemical weapons with the Egyptians, but they denied it. The United Nations apparently took little further notice of the situation. The civil war officially ended in 1970 with a political agreement between the republican and royalist factions.

Egypt had been a signatory of the 1925 Geneva Convention, which outlawed the use of chemical weapons. Some accounts attributed the chemical weapons to German scientists, usually described as being former Nazis, who had been brought to Egypt by President Nasser. Several sources reported that the Soviet Union, through its friendship with Egypt, used Yemen as a testing ground for its chemical research program. Other reports mentioned Communist China as being the supplier, while still other accounts had Egypt using old chemical munitions left behind from World War II stockpiles.[147–154]

Much of what the U.S. Army learned from the Yemen Civil War was negative. Reports of possible chemical use in certain areas of the world, particularly those inaccessible to official and technical observers, were difficult to confirm or even to condemn without accurate and verifiable information. News reports alone proved informative but unreliable. Even samples from the alleged attacks apparently did not lead to further political or military action. Most importantly, with the world distracted by the Arab–Israeli Six-Day War and events in Vietnam, politics discouraged a universal condemnation and follow-up response. In effect, the world powers let the event pass much as they had when Italy used chemical warfare against Ethiopia in the 1930s.

1967 Arab–Israeli Six-Day War

The 1967 Arab–Israeli Six-Day War was described as having come very close to being the first major war where both combatants openly used nerve agents and biological warfare. Fearing a pending attack from its Arab neighbors, on 5 June 1967, the Israelis launched a preemptive strike against Jordan, Egypt, and Syria. This action included an invasion of the Sinai Peninsula, Jerusalem's Old City, Jordan's West Bank, the Gaza Strip, and the Golan Heights.

Reports soon appeared that the Egyptians allegedly had stored artillery rounds filled with nerve agents in the Sinai Peninsula for use during a war. The Israelis, reflecting on Egypt's possible testing of the weapons in Yemen earlier in the year, suddenly realized that their troops and cities were vulnerable to attack. The fact that chemical weapons were not used during the war was possibly due to the Israelis' preemptive action or possibly to the newspaper reports of the Yemen Civil War. The Israelis felt threatened enough to place frantic orders for gas masks with Western countries. However, this last-minute plea for gas masks and nerve agent antidote came too late to have prevented enormous casualties if nerve agents had been employed. The Egyptians, on the other hand, claimed that Israel was preparing for biological warfare. A United Nations–sponsored cease-fire ended the fighting on 10 June 1967, and the potential chemical–biological war did not occur.[84,148,149,155]

Chemical Agents

While concern over the potential and actual use of chemical agents grew during the 1960s, the United States also continued its chemical agent production program. Construction of the United States's VX agent production plant at Newport, Indiana, was completed in 1961, when the first agent was produced (Figure 2-50). The production plant was only operated for 7 years, and it was placed in standby in 1968.[3]

The first and only incapacitating agent (excluding riot control agents) standardized by the army completed development in 1962. Designated BZ, 3-quinuclidinyl benzilate was a solid but was disseminated as an aerosol. The major problem with the agent for military purposes was its prolonged time of onset of symptoms. The estimate was 2 to 3 hours

Fig. 2-50. The first three steps of VX nerve agent production were completed in these structures at Newport, Indiana. The technological level of chemical engineering needed to make this agent is vastly more complicated than that required to make mustard and phosgene during the World War I era. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

before the enemy would become confused and therefore vulnerable. This was a disappointment to those hoping for a quick-use, nonlethal agent as an alternative to lethal agents. A second problem was its visible cloud of smoke during dissemination, which limited the element of surprise.[141]

New Chemical and Biological Weapons

Having concentrated on nerve agent bombs during the 1950s, the Chemical Corps turned its attention to artillery, rocket, and other delivery systems during the 1960s. In 1960, the corps standardized the first nerve agent land mine, designated the M23 2-gal VX mine (Figure 2-51). This mine resembled the conventional high-explosive land mine, but held about 11.5 lb of agent. It was designed to be activated either by a vehicle's running over it or by an antipersonnel antitampering fuze.

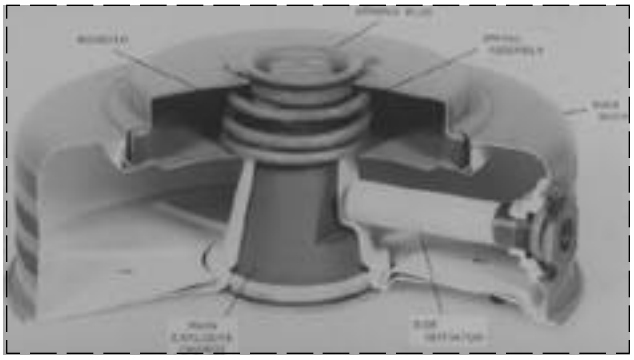

Fig. 2-51. The M23 VX land mine. Most of the interior was to be filled with the nerve agent VX. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 2-52. The M55 115-mm rocket could hold the nerve agents VX or sarin. The problem was the aluminum warhead, which began leaking soon after production. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

In 1961, the Chemical Corps standardized two new VX projectiles for artillery. The M121A1 was an improved version of the earlier sarin round. Each round held about 6.5 lb of agent. The M426 8-in. sarin or VX projectile held more than 15.5 lb of agent.[3]

The early 1960s was the peak of the nerve agent rocket program. The program was first started at the end of World War II to duplicate the German V-2 missiles used against England. The United States eventually developed both short-range and long-range rockets.

For short-range tactical support, the Chemical Corps standardized the M55 115-mm rocket in 1960 (Figure 2-52). Described as the first significant ground capability for the delivery of chemical

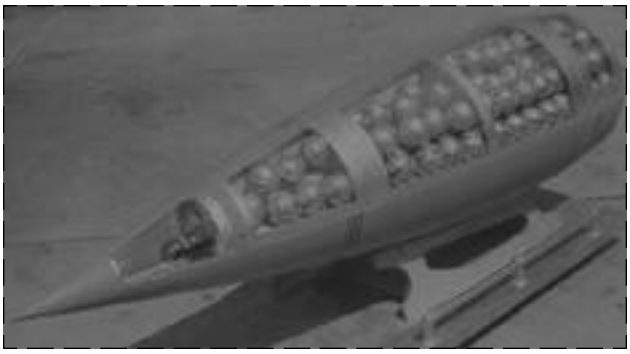

Fig. 2-53. A chemical warhead for the Honest John rocket. It was designed to break apart and disperse the spherical bomblets of nerve agent. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

agents since the 4.2-in. chemical mortar, the M55 was loaded with 11 lb of VX or sarin nerve agent. The range when fired from the M91 multiple rocket launcher was over 6 miles. Each launcher held 45 rockets that could be fired simultaneously. The army initially approved 40,000 sarin-filled and 20,000 VX-filled rockets, but many more were actually filled.[3,156]

For middle-range tactical support, the Chemical Corps standardized the M79 sarin warhead for the 762-mm Honest John rocket in 1960 (Figure 2-53). The rocket had a range of 16 miles, and the warhead held 356 M134 4.5-in. spherical bomblets, each containing about 1 lb of sarin. A smaller warhead was standardized in 1964 for the 318-mm Little John rocket, which held 52 of the improved M139 4.5-in. spherical bomblets, each holding 1.3 lb of sarin (Figure 2-54).

The first long-range rocket warhead was standardized the same year for the Sergeant missile system. The missile had a range of 75 miles and the warhead held 330 M139 sarin bomblets. More developmental projects added chemical warheads to other long-range missiles, such as the Pershing missile, which had a range of over 300 miles.

Development of rockets as delivery systems for biological agents also reached its peak during the 1960s. The M210 warhead for the Sergeant missile held 720 M143 bomblets. The M143 1-lb spherical bomblet was smaller than the sarin version, being only 3.4 in. in diameter. Each bomblet held about 212 mL of agent. If released at about 50,000 ft, the dispersion of the bomblets would cover about 60 square miles.

In addition to the rocket program, the Chemical Corps examined several drones for delivery of chemical and biological agents. The SD-2 Drone was a slow (300 knots), remote-controlled, recoverable drone that could hold over 200 lb of either nerve agent or biological agents. It had a range of about 100 nautical miles and could disperse agent over about 5 to 10 nautical miles. The SD-5 was an improvement that used a jet engine that gave it speeds of over Mach 0.75 and a range of over 650 nautical miles. The added horsepower allowed it to hold about 1,260 lb of chemical or biological agent, which was discharged through a tail nozzle.

The BZ program also reached weaponization status in the 1960s. In 1962, the Chemical Corps standardized the M43 750-lb BZ Bomb Cluster and the M44 175-lb BZ Generator Cluster. The M43 held 57 M138 BZ bomblets. The M44 held three 50-lb thermal generators, each holding 42 BZ canisters.[3]

Biological Agents and Weapons

By the 1960s, the U.S. Biological Warfare Program was in decline. Funding for the program gradually decreased throughout much of the 1960s, from $38 million in 1966 to $31 million in 1969. In 1961, the army announced that new biological agents would be standardized in conjunction with munitions. This proved a further limiting factor, as the demand for biological munitions decreased.[157]

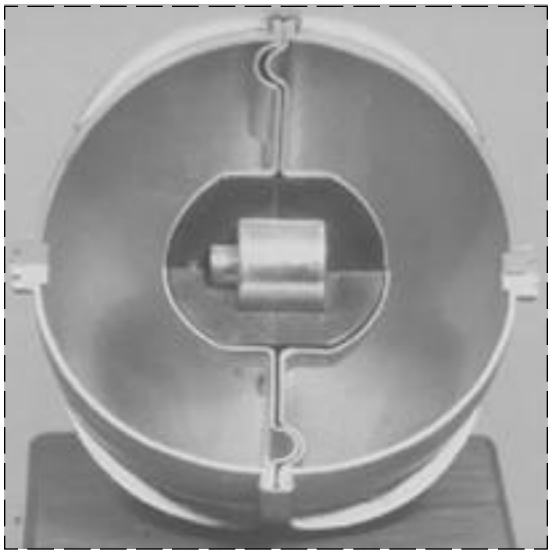

Fig. 2-54. The M139 4.5-in. spherical sarin bomblet used in the Little John rocket. The vanes on the outside of the bomblet created a spin that then armed the impact fuze. The explosive burster is in the center and sarin fills the two outer compartments. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Despite budget and development constraints, the army continued to work on the antipersonnel agents. The standardization of dry *Pasteurella tularensis* was considered a significant improvement over the liquid suspension used by most agents. Dry agents were more adaptable to storage, shipping, and logistical considerations. The research into drying methods for living agents was begun during the Korean War. The method adopted for *P tularensis* was to freeze droplets of a concentrated liquid culture with liquid Freon, drying the resultant pellets, and reducing the product to a particle diameter of about 5.5 µm by means of a milling operation. The stabilizer used as a protective suspension contained skim milk and sucrose. A gram of the packaged product contained about 14.7×10^9 viable cells and had a 3-year storage stability when stored in a dry nitrogen atmosphere at –18°C.[156]

The antiplant program was resumed for the U.S. Air Force in 1962. Agent production was conducted at Pine Bluff Arsenal. Field tests of wheat stem rust and rice blast disease were conducted at several sites in the midwestern and southern United States and on Okinawa. The same year, the Defense Department requested additional work on defoliation and antiplant activities owing to the ongoing events in southeast Asia. In 1962, the Chemical Corps initiated a crash project for the production of wheat stem rust under Rocky Mountain Arsenal supervision. Other work included trying to find pathogens suitable for use against the opium poppy crop.[141]

During the 1960s, the army conducted large-scale tests using the biological simulant *Bacillus globigii* (code name BG) at various places in the public domain to access the dangers of covert biological attacks. For example, in 1965, BG was tested at National Airport and the Greyhound Terminal in Washington, D. C. In 1966, BG was disseminated in New York City within the subway tubes and from the street into the subway stations in mid Manhattan. The results confirmed that a similar real covert attack would have infected a large number of people during peak traffic periods.

The army also conducted antianimal testing using BG at several stockyards in Texas, Missouri, Minnesota, South Dakota, Iowa, and Nebraska between 1964 and 1965. Antiplant testing using the wheat stem rust fungus was also conducted at Langdon, North Dakota, in 1960 and Yeehaw Junction, Florida, in 1968.[157]

By the 1960s, the army was in the process of developing vaccines for most of the biological agents standardized or in development. A 1965 volunteer consent form provides insight into the pertinent agents (Exhibit 2-2). Attached to the consent form for vaccines was an order to also administer selected live agents to the participants.[158,159]

New Defensive Equipment

The most significant advancement in individual protection was a new version of the M17 Protective Mask, designated the M17A1, which introduced two new concepts in 1966 that were long overdue. The first was a resuscitation device for the mask, which was required to allow soldiers to provide artificial respiration without unmasking. Although atropine injections were an effective antidote for the anticholinesterase effects of nerve agents, artificial respiration was required to counteract the effects of the agent on the respiratory system.

The second new concept was a drinking tube. The drinking capability allowed a soldier to drink from his canteen in a contaminated battlefield without unmasking. This was considered critical because of the longer times required to wear protective gear around persistent nerve agents and the possible use of the mask in desert and tropical climates.[30]

The need to provide air conditioning and protection against chemical and biological agents to workers in the army's NIKE missile-control vans resulted in the development of a trailer-mounted unit adopted for limited production in 1961. After some improvements, the unit was standardized in 1963 as the M1 Collective Protection Equipment. Initially, 288 of the units were ordered, but additional similar needs for collective protection quickly became apparent.[160]

For the U.S. Army, one requirement that was further supported by lessons learned from the 1967 Six-Day War was the need for an automatic field-alarm system. In 1968, the army solved the 2-decades-old problem by standardizing the M8 Portable Automatic Chemical Agent Alarm. The 4-year development effort covered the gap that had left U.S. soldiers vulnerable to a surprise nerve agent attack. The unit consisted of the M43 detector unit and the M42 alarm unit. Additional alarms could be connected.[3]

The alarm used an electrochemical point-sampling system that continuously monitored the atmosphere and sounded an audible or visible warning of even very low concentrations of nerve agents. Actual detection occurred when air was passed through an oxime solution surrounding a silver analytical electrode and a platinum reference electrode. Presence of an agent caused a reaction in the solution, which increased the potential between

EXHIBIT 2-2

CONSENT TO INOCULATION WITH EXPERIMENTAL BIOLOGICAL PRODUCTS

It has been explained to me that it is necessary for my safety and protection to be inoculated with certain biological products approved by the Army Investigational Drug Review Board but not yet approved by the Commissioner of Food and Drugs, Department of Health, Education and Welfare. I understand that the administration of these products will provide future additional evidence of their safety and usefulness.

I hereby consent* to inoculation with any or all of the following biological products to include the initial series and booster immunizations as required:

1) Venezuelan Equine Encephalomyelitis Vaccine, Live, Attenuated.
2) Live Tularemia Vaccine.
3) Anthrax Vaccine (non-viable), aluminum hydroxide adsorbed.
4) Botulinum Toxoid, Types A B C D E, aluminum phosphate adsorbed.
5) Tularemia Skin Test Antigen.
6) Rift Valley Fever Virus Vaccine.
7) Q Fever Vaccine.
8) Eastern Equine Encephalomyelitis Vaccine.
9) Western Equine Encephalomyelitis Vaccine.

WITNESSES:

_____ _____

(Date) (Signature) (Signature)

_____ _____

(Date) (Signature) (Signature)

SMUFD FORM 8 (Rev)
May 65

*It is unclear how the volunteer signified consent. Note that this form does not contain a blank for the volunteer's signature.

the electrodes. The change in potential, when amplified, triggered the alarm signal. The unit could detect almost all chemical agents, including the nerve agents.[161]

In 1960, the Chemical Corps made a significant improvement in the area of decontamination. DANC had proven to be particularly corrosive to the brass parts of the M2 Decontaminating Apparatus, so the Chemical Corps spent almost 2 decades developing Decontaminating Solution 2 (DS2, manufactured then by Pioneer Chemical Co., Long Island City, New York). DS2 was a clear solution of 70% diethylenetriamine, 28% methyl cellosolve (ethylene glycol monomethyl ether), and 2% sodium hydroxide. This decontaminating agent did not solve all problems, either. It was known to remove and soften new paint, and to discolor old paint. It was also irritating to the skin. Its good points were that DS2 was less corrosive to metals and less destructive to plastics, rubber, and fabrics.[161] In conjunction with the standardization of DS2, the Chemical Corps also developed the M11 1.5-qt Portable Decontaminating Apparatus, a fire extinguisher–type unit compatible with DS2, which was used to decontaminate vehicles and weapons.[3]

Public Hostility Toward Chemical and Biological Weapons

The growing protests over the U.S. Army's role in Vietnam, the use of defoliants, the use of riot control agents both in Southeast Asia and on the home front, and heightened concern for the environment all gradually increased the public hostility toward chemical and biological weapons. Three events particularly galvanized public attention: the sheep-kill incident at Dugway Proving Ground, Operation CHASE, and an accident with sarin at Okinawa.

Dugway Sheep-Kill Incident

The first event, according to Dugway Proving Ground's incident log, started with a telephone call on Sunday, 17 March 1968:

> At approximately 1230 hours, Dr. Bode, University of Utah, Director of Ecological and Epidemiological contract with Dugway Proving Ground (DPG), called Dr. Keith Smart, Chief, Ecology and Epidemiology Branch, DPG at his home in Salt Lake City and informed him that Mr. Alvin Hatch, general manager for the Anschute Land and Livestock Company had called to report that they had 3,000 sheep dead in the Skull Valley area.[162(pA-1)]

Skull Valley was adjacent to Dugway, one of the army's open-air testing sites for chemical weapons. Although the findings were not definite, the general opinion seemed to be that nerve agents had somehow drifted out of the test area during aerial spraying and had killed the sheep. Whether the army was guilty or not, the end result was bad publicity and, even more damaging, congressional outrage.

Operation CHASE

The second event was actually a series of sea dumps of surplus chemical warfare agents and a problem weapon system (Figure 2-55). These sea dumps created significant environmental concerns throughout the country. The surplus agents were mustard agent (primarily) and some nerve agent. The problem weapon system was the relatively new M55 rocket system. Although the M55 had been standardized only 7 years before, the thin aluminum head design proved faulty for long-term storage. The problem of leaking rockets started in 1966,

Fig. 2-55. The disposal at sea of surplus and leaking chemical munitions and radiological wastes generated environmental concerns that eventually brought sea dumping to a halt. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

and a year later, the army began disposing of the rockets, sealed in concrete vaults in the hulls of ships that were then sunk in ocean-disposal sites.

Operation Cut Holes and Sink 'Em (CHASE), an ongoing program for disposing of conventional ammunition, began accepting chemical weapons in 1967. That year, CHASE 8 disposed of mustard agent in ton containers, and M55 sarin rockets. In June 1968, CHASE 11 disposed of sarin and VX in ton containers, along with additional M55 sarin and VX rockets. In August 1968, CHASE 12 disposed of mustard agent in ton containers.[3]

The sea dumps created two major concerns. The first was that the weapons were being shipped from their storage depots by train to the loading docks. Fear of an accident along the way was paramount. Second, sea dumping and its effects on marine life were sources of environmental and commercial concern and protest.

Accident at Okinawa

The third event was a serious accident. On 8 July 1969, the army announced that 23 U.S. soldiers and 1 U.S. civilian had been exposed to sarin on Okinawa. The soldiers were cleaning sarin-filled bombs preparatory to repainting them when the accident occurred.[3]

Although none of the individuals died, the public announcement created two controversies. First, up until that time, the army had kept secret the forward positioning of chemical weapons on Okinawa. The acknowledgment created international concerns. Second, the accident pointed out the dangers of storing chemical weapons. With chemical weapons known to be stored at sites in the continental United States near cities and residential areas, the fear of an accident escalated. In response to these concerns, the Defense Department announced on 22 July 1969 that they would accelerate the previously planned removal of the chemical agents from Okinawa.[163]

Changes to the Chemical and Biological Warfare Programs

In April 1969, the secretary of defense tried to explain the U.S. chemical warfare policy to both the general public and to congress. In part, he stated:

> It is the policy of the United States to develop and maintain a defensive chemical–biological (CB) capability so that U.S. military forces could operate for some period of time in a toxic environment if necessary; to develop and maintain a limited offensive capability in order to deter all use of CB weapons by the threat of retaliation in kind; and to continue a program of research and development in this area to minimize the possibility of technological surprise.[164(p193)]

The explanation did not help. In July, the United Nations released a report on chemical and biological weapons that condemned production and stockpiling of weapons of mass destruction. Six days later, the United States acknowledged the Okinawa accident.[3]

Congress stepped in and on 11 July 1969 revealed that the army was conducting open-air testing with nerve agents at Edgewood Arsenal (the name of the Army Chemical Center had reverted back in 1963) and at Fort McClellan during training events. Shortly after the disclosure, more than 100 protesters were at the gates of Edgewood Arsenal. Three days later, buckling to the pressure, the army announced suspension of open-air testing at the two sites. Quickly rushing an independent committee together, the army promised to conduct a safety review of all such testing. The positive publicity of creating the new committee was soon forgotten when the army revealed that they had also conducted nerve agent testing in Hawaii between 1966 and 1967, something the army had previously denied.[3]

In October, the secretary of the army announced that the committee had completed its study. The committee reached the following conclusion:

> The lethal testing program at Edgewood Arsenal during the past two decades has compiled an enviable record for safety. The testing procedures that have been evolved are clearly effective in minimizing danger to base personnel and civilians in adjacent areas.[165(p16)]

The committee's only major concern was the movement of chemical agents by truck on public roads; the committee recommended resumption of lethal-agent, open-air testing at Edgewood.[165]

Before testing resumed, however, the U.S. Congress passed Public Law 91-121 in November. This law imposed controls on the testing and transportation of chemical agents within the United States; and the storage, testing, and disposal of agents outside the United States. Further open-air testing of lethal chemical agents was effectively banned.[3]

In November 1969, President Richard M. Nixon took action against chemical and biological warfare. First, he reaffirmed the no-first-use policy for chemical weapons:

> I hereby reaffirm that the United States will never be the first country to use chemical weapons to kill. And I have also extended this renunciation to chemical weapons that incapacitate.[166(p5)]

Second, he decided to resubmit the 1925 Geneva Protocol to the U.S. Senate for ratification. The senate had refused to ratify the treaty when it was first signed, and President Harry S Truman had withdrawn the treaty from the senate in 1947.

Third, President Nixon renounced the use of biological weapons and limited research to defensive measures only:

> I have decided that the United States of America will renounce the use of any form of deadly biological weapons that either kill or incapacitate. Our bacteriological programs in the future will be confined to research in biological defense on techniques of immunization and on measures of controlling and preventing the spread of disease. I have ordered the Defense Department to make recommendations about the disposal of the existing stocks of bacteriological weapons.[166(p5)]

He concluded by explaining his future hopes:

> Mankind already carries in its own hands too many of the seeds of its own destruction. By the examples that we set today, we hope to contribute to an atmosphere of peace and understanding between all nations.[166(p4)]

These actions effectively stopped the production of chemical and biological weapons in the United States.[166]

THE 1970s: THE NEAR END OF THE CHEMICAL CORPS

Throughout the 1970s, the chemical and biological warfare programs experienced further restrictions and tightened controls. In February 1970, President Nixon added toxins to the banned weapons and ordered all existing stocks of toxin agents destroyed. About a month later, the army revealed that it had conducted both chemical and biological testing in Alaska but reported that the testing had stopped. The army also announced that the chemical weapons on Okinawa would be moved to Umatilla Army Depot in Oregon. This triggered a series of lawsuits that attracted the concern of congress. The next year, Public Law 91-672 was enacted, which prohibited the army from moving the weapons from Okinawa to anywhere on the U.S. mainland. Finally, Operation Red Hat moved the stockpile on Okinawa to Johnston Atoll, a small U.S. island in the South Pacific, for long-term storage and eventual demilitarization.

Demilitarization was not an easy project; heightened environmental concerns characterized the 1970s. One last sea dump took place in 1970, when, despite much negative press, CHASE 10 disposed of more M55 sarin rockets. (CHASE 10 had originally been scheduled earlier; although now out of numerical order, the designation was unchanged.) Two years later, Public Law 92-532 was enacted, which prohibited the sea dumping of chemical munitions.

Between 1971 and 1973, all remaining biological weapons were destroyed at Pine Bluff Arsenal, Rocky Mountain Arsenal, and Fort Detrick. In 1972, the United States signed the Convention on the Prohibition of the Deployment, Production, and Stockpiling of Bacteriological and Toxin Weapons. This convention banned development, production, stockpiling, acquisition, and retention of biological agents, toxins, and the weapons to deliver them. The senate ratified the Biological Warfare Convention in 1974 and President Gerald R. Ford signed it in 1975.

Although President Nixon had called in 1969 for the ratification of the Geneva Protocol, it took a few more years. In 1974, the U.S. Senate ratified the Protocol, and President Ford officially signed it on 22 January 1975. He did, however, exempt riot control agents and herbicides from inclusion in the agreement.[3]

The events of 1969 had a severe impact on the future of the U.S. Army Chemical Warfare Program. Two senior department of defense personnel reflected on the impact the restrictions had during the 1970s:

> During most of the 1970s, the United States allowed its chemical retaliatory capability to decline, did little to improve chemical protection, and neglected relevant training and doctrine. The United States has not produced lethal or incapacitating chemical agents, or filled munitions since 1969.[167(p3)]

The army actually made plans to abolish the Chemical Corps entirely. In 1973, with the signing in Paris, France, of the peace pacts to end the Vietnam War, and with the end of the draft, the army recommended reducing the Chemical Corps in size and eventually merging it with the Ordnance Corps. As the first step, the army disestablished the Chemical School at Fort McClellan, Alabama, and combined it with the Ordnance School at Aberdeen

Proving Ground, Maryland. Congress, however, blocked the complete disestablishment of the corps.[168–171] Still, one observer noted: "As an additional ordnance career field, the chemical specialty almost withered and died at Aberdeen."[171(p15)]

1973 Arab–Israeli Yom Kippur War

Then another war quickly brought chemical warfare preparedness back to the forefront. The Arab–Israeli Yom Kippur War lasted only from 6 October to 24 October 1973, but the ramifications for the U.S. chemical program lasted much longer. The Egyptian and Syrian attack against Israel on Yom Kippur and the successful Israeli counterattacks ended with a cease fire. Both sides took enormous losses in personnel and equipment.

Following the Yom Kippur War, the Israelis analyzed the Soviet-made equipment they captured from the Egyptians and Syrians. They discovered (*a*) portable chemical-proof shelters, (*b*) decontamination equipment for planes and tanks, and (*c*) that most Soviet vehicles had air-filtration systems on them to remove toxic chemicals.

Another item of note was a Soviet PKhR-MV Chemical Agent Detector Kit for Medical and Veterinary Services. The set consisted of a hand pump, detector tubes, reagents in ampules, dry reagents, test tubes, and accessories. It was designed to detect nerve, blister, and blood agents. Exploitation by the U.S. specialists determined that it could detect low concentrations of nerve agents, mustard agent, cyanide, Lewisite, and heavy metals in aqueous solutions. It could also detect the same agents in addition to cyanogen chloride and phosgene in the atmosphere. One noted problem with the kit was that the procedures for using it were extremely difficult to carry out while wearing a protective suit. In addition, the glass ampules were fragile and broke easily.[172]

Overall, the experts reported finding sophisticated chemical defense materiel and a "superior quantitative capability for waging a chemical war."[173(p3-4)] The indications were that the Soviets were ready for extensive chemical warfare and might actually be planning to initiate chemical warfare in a future war. Soviet division commanders were thought to already have authority to initiate chemical warfare.[173–176]

Restoring the Chemical Corps

The combination of (*a*) the findings of sophisticated Soviet chemical defense materiel and their capability for waging chemical war and (*b*) the decline of the U.S. Army Chemical Corps called for corrective action. The army concluded the following:

> To offset this, U.S. chemical/biological (CB) defense materiel must not only provide a protective system equivalent to or better than that of any potential enemy but the physiological and logistics burdens must be such as to permit long-term use. To cope with the hazards of any potential CB-threat environment requires the development of an integrated CB defense system. This system must contain items for individual protection, collective protection, decontamination, warning and detection, and safe devices and concepts to achieve realistic training. An effective technological base is needed from which such materiel, responsive to user needs, can be quickly developed.[173(p3-4)]

In 1976, the secretary of the army reversed the decision to abolish the Chemical Corps. He cited the heightened awareness of the Soviet Union's capability to wage chemical warfare as the primary reason. In 1977, the United States started a new effort to reach an agreement with the Soviets on a verifiable ban on chemical weapons. This effort was unsuccessful. Partly as a result, the Chemical School was reestablished at Fort McClellan in 1979.[167,177–181]

Binary Weapons Program

The end of the chemical weapons production program had stopped production but left one type of chemical retaliatory weapon still in development. Back in the 1950s, the army had begun looking at binary weapons. Until that time, chemical weapons were unitary chemical munitions, meaning that the agent was produced at a plant, filled into the munitions, and then stored ready to be used. Since most agent was extremely corrosive, unitary munitions were logistical nightmares for long-term storage. The binary concept was to mix two less-toxic materials and thereby create the nerve agent *within* the weapon *after* it was fired or dropped. Because the two precursors could be stored separately, the problems of long-term storage and safe handling of chemical weapons were therefore solved. The navy took the greater interest in the binary program during the 1960s and requested a 500-lb bomb designated the BIGEYE. Only after the production of unitary chemical munitions was halted did the binary program receive high priority in the army, however. In fact, the last open-air test with lethal agents had taken place at Dugway Proving Ground on 16 September 1969, when a 155-mm projectile

filled with sarin binary reactants was test fired. Throughout the early 1970s, additional test firings took place using simulants. In 1976, the army standardized the M687 Binary GB2 155-mm Projectile.

The binary projectile used a standard M483A1 155-mm projectile as the carrier of the chemical payload (Figure 2-56). Binary chemical reactants were contained in two separate, plastic-lined, hermetically sealed containers. These leakproof canisters were loaded through the rear of the shell and fitted one behind the other in the body of the projectile. The forward canister contained methylphosphonic difluoride (DF) and the rear canister contained isopropyl alcohol and isopropylamine solution (OPA).

To ensure safe handling, M687 projectiles were shipped and stored with only the forward DF-filled canister in place. A fiberboard spacer occupied the cavity provided for the OPA canister. Projectiles were secured horizontally on a pallet, as opposed to the conventional vertical position for other 155-mm projectiles. This orientation permitted rapid removal of the projectile's base using a special wrench. The fiberboard spacers were removed and replaced with the OPA canisters. The fuze was then installed just prior to firing. Upon firing, setback and spin forces caused the facing disks on the canisters to rupture, allowing the reactants to combine to form sarin en route to the target.[182,183]

In addition to the M687 projectile, the army also worked on the BLU-80/B (BIGEYE) VX2 bomb and projectiles of other size, including an 8-in. projectile. None of these, however, were ever standardized. Standardization of the M687 did not lead immediately to production. The same year the M687 was standardized, the U.S. Congress passed the Department of Defense Appropriation Authorization Act, which restricted the development and production of binary chemical weapons unless the president certified to congress that such production was essential to the national interest. Thus, the army would take another decade to locate the production plants, pass environmental inspection, receive presidential approval, and begin production.[3]

Detection Improvements

Although the M8 detector/alarm solved the advance warning problem, soldiers still needed a quick test to confirm the presence of chemical agents. The problem was solved with the standardization of M8 detector paper in 1973. The paper was a Canadian development. It was packaged in booklets of 25 sheets (perforated for easy removal) sized 4 x 2½ in. M8 detector paper turned dark blue for V agents, yellow for G-series agents, and red for mustard agent.[161]

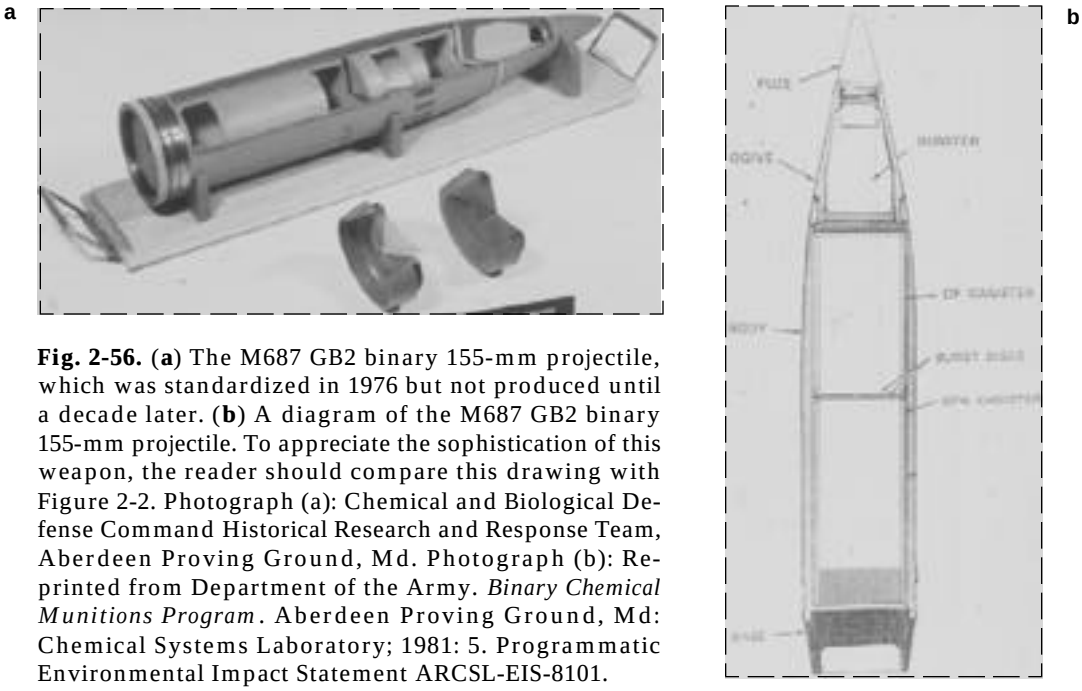

Fig. 2-56. (**a**) The M687 GB2 binary 155-mm projectile, which was standardized in 1976 but not produced until a decade later. (**b**) A diagram of the M687 GB2 binary 155-mm projectile. To appreciate the sophistication of this weapon, the reader should compare this drawing with Figure 2-2. Photograph (a): Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md. Photograph (b): Reprinted from Department of the Army. *Binary Chemical Munitions Program*. Aberdeen Proving Ground, Md: Chemical Systems Laboratory; 1981: 5. Programmatic Environmental Impact Statement ARCSL-EIS-8101.

There were some problems with the paper, the most important of which was that some less-dangerous agents gave responses similar to mustard agent. Benzene, DANC, and defoliating agents produced a red response; sulfuric acid produced a black response; and organophosphate insecticides produced a yellow response.[184]

Collective Protection Improvements

One particular area of development that gained significantly from the resurgent interest in chemical and biological defense was collective protection. Increasing numbers of combat and combat-support vehicles with integrated chemical and biological collective protection systems were reported to be appearing throughout the Warsaw Pact area. These reports resulted in a closer look at the U.S. situation.[185]

The army was already examining collective protection for some military vehicles and, in particular, the missile-control vans. The need for collective protection for vans and vehicles used for command posts, fire direction, rest and relief shelters, and medical aid stations resulted in the standardization of the M14 Collective Protection Equipment in 1970. This equipment was designed to protect occupants of the M291A2 and M292 series of vans against airborne toxic agents.[161]

Work during the 1960s on the CB Pressurized Pod resulted in the standardization of the M51 Shelter System in 1971. The unit was an easily transportable, pressurized enclosure. It could be air-dropped or towed to provide protection from chemical and biological agents in the field for combat, combat support, and combat service support troops. The M51 was a double-walled, air-inflated, self-supporting shelter and airlock structure. When erected, the shelter was semicircular in cross-section with a maximum inside height of 7.5 ft, with inside dimensions of 15 x 14 ft. An airlock entrance (with a set of double doors at each end) on the front was 11 (l) x 4.2 (w) x 6.7 (h) ft in dimension. The filter and support equipment were mounted on a two-wheeled trailer.[186]

Despite these developments, congress got involved in 1977 and included in the Department of Defense Appropriation Authorization Act a section that stated:

> The Secretary of the Army shall submit to the Committees on Armed Services of the Senate and House of Representatives, no later than February 1, 1978, a plan for the funding and scheduling necessary to incorporate by October 1, 1980, collective system protection against chemical and radiological agents for all main battle tanks, mechanized infantry combat vehicles, armored personnel carriers, armored self-propelled artillery vehicles, armored self-propelled air defense artillery vehicles, and other such types of equipment associated with the above in combat operations which will be in development or procurement in fiscal year 1981.[187]

This law launched an intensive effort to determine the chemical vulnerability of all army vehicles. The initial concentration was on ventilated facepieces and a mixture of positive-pressure and hybrid systems for selected rear-area vehicles.

Growing Danger of Chemical and Biological Warfare

Starting in about 1975, reports of the use of chemical and biological agents in various small wars in Southeast Asia and Afghanistan began to attract attention in the United States. Interviews with Hmong villagers in Laos suggested that Vietnamese and Russian forces might have used chemical and possibly toxin weapons against these people. Starting in 1978, similar reports from Kampuchea claimed that the Vietnamese and their allies had killed over 980 villagers using chemical weapons. Prior to the Soviet invasion of Afghanistan in December 1979, reports were already circulating that Soviet troops were using chemical weapons against the mujahidin soldiers.

The Soviets legitimized their use of chemical and biological weapons because, although they had signed the Geneva Protocol in 1928, Laos, Kampuchea, and Afghanistan were not signatories. The Soviet Union, Laos, and Afghanistan signed the Biological Weapons Convention, but the allegations of toxin use were never acknowledged by the Soviets or their allies. In fact, when the Soviets signed the Biological Weapons Convention in 1975, they added the statement: "the Soviet Union does not possess any bacteriological agents and toxins, weapons, equipment or means of delivery."[188(p6)] Other intelligence sources thought that the Soviets considered most toxins to be chemical agents, and therefore not subject to the Biological Weapons Convention. If toxins were considered to be chemical agents, then the Soviets would be permitted under the Geneva Protocol to use them in retaliation or against nonsignatories.[189]

The use of chemical and biological weapons by the Soviets was taken as an indication that the So-

viets were continuing an active chemical and biological program. This program, however, did not continue without costs. In April 1979, a sudden outbreak of anthrax occurred in Sverdlovsk, in the Ural Mountains. At the time, the etiology of the outbreak was explained by the Soviets as human ingestion of beef from cattle that had been contaminated by naturally occurring anthrax spores in the soil. U.S. intelligence officers doubted the story and used the incident to push for better chemical and biological preparedness in the army. In 1992, Russian President Boris Yeltsin confirmed that the epidemic had been caused by military researchers working with the agent. *Izvestiya*, the Russian newspaper, later reported that it took 5 years to clean up the plant after the accident.[190–192]

THE 1980s: THE RETURN OF THE CHEMICAL CORPS

The Haig Report

Despite denials by the governments involved, the United States went public with charges that chemical warfare had been used in Southeast Asia and Afghanistan in 1980. Problems with the collection of samples and the remoteness of the sites, however, prevented definitive evidence from being obtained. Furthermore, the later identification, discussion, and media debate over the origin of possible trichothecene mycotoxins in Southeast Asia also took away a significant portion of the public interest in the alleged use of conventional chemical munitions.

In 1982, Secretary of State Alexander M. Haig, Jr., presented a report titled *Chemical Warfare in Southeast Asia and Afghanistan* to the U.S. Congress. After describing the evidence, he concluded:

> Taken together, this evidence has led the U.S. Government to conclude that Laos and Vietnamese forces, operating under Soviet supervision, have, since 1975, employed lethal chemical and toxin weapons in Laos; that Vietnamese forces have, since 1978, used lethal chemical and toxin agents in Kampuchea; and that Soviet forces have used a variety of lethal chemical warfare agents, including nerve gases, in Afghanistan since the Soviet invasion of that country in 1979.[189(p6)]

Based on this evidence, senior defense department personnel concluded that the Soviet Union "possesses a decisive military advantage because of its chemical capabilities."[167(p3)]

The Haig report, however, was not able to galvanize world opinion. Much like the situation during the Yemen Civil War, the United States was unable to prove beyond a shadow of the doubt that chemical agents and toxins had been used in Southeast Asia and Afghanistan. Instead, the accusation became a political debate between the United States and the Soviet Union during President Ronald Reagan's administration.

Chemical Warfare in the Afghanistan and Iran–Iraq Wars

Afghanistan War

The U.S. Army monitored the war in Afghanistan throughout the 1980s. Often thinking of it as the Soviet's "Vietnam," the lessons learned from this war about chemical warfare provided extensive support to the U.S. chemical defense program.

The Soviets tended to use chemical weapons much like the Italians did in Ethiopia and like the U.S. Army had used nonlethal agents in Vietnam. One military writer summed up the general lesson learned:

> The use of chemical weapons by Soviet forces in Afghanistan is also significant. The use of these weapons in Afghanistan confirms, not surprisingly, that the Soviets find them put to their best use against unprotected subjects incapable of retaliation. Afghanistan is proof positive that the Soviets do not consider these devices as special weapons. Considerations of utility and not morality will govern Soviet use of them in a future conflict.[193(p27)]

Despite the use of chemical weapons, the Soviets were unable to "win" the war and, in December 1988, met with rebel forces to discuss a withdrawal of Soviet troops from Afghanistan. In January 1989 the Soviets announced the final withdrawal, which was completed a month later.[194]

Iran–Iraq War

Although the Soviet Union continued to be the number one potential chemical warfare opponent and, therefore, the United States concentrated on proposed chemical treaties with that country, the beginning of a war in the Middle East gradually began to erode that status. On 22 September 1980, the armed forces of Iraq launched an invasion against its neighbor Iran. The Iraqi army, trained

and influenced by Soviet advisers, had organic chemical warfare units and possessed a wide variety of delivery systems. When neither side achieved dominance, the war quickly became a stalemate.

To stop the human wave–attack tactics of the Iranians, the Iraqis employed their home-produced chemical agents as a defensive measure against the much-less-prepared Iranian infantry. The first reported use of chemical weapons occurred in November 1980. Throughout the next several years, additional reports circulated of new chemical attacks. The result was that by November 1983, Iran complained to the United Nations that Iraq was using chemical weapons against its troops.[195–198]

After Iran repeated the claims and even sent chemical casualties to several western nations for treatment, the United Nations dispatched a team of specialists to the area in 1984, and again in 1986 and 1987, to verify the claims. The conclusion from all three trips was the same: Iraq was using chemical weapons against Iranian troops. In addition, the second mission also stressed that the use of chemical weapons by Iraq appeared to be increasing despite the publicity of their use. The reports indicated that mustard agent and the nerve agent tabun were the primary agents used, and that they were generally delivered in airplane bombs. The third mission also reported the use of artillery shells and chemical rockets and the use of chemical weapons against civilian personnel. The third mission was the only one allowed to visit Iraq.[199–201]

In the letter of transmittal to the United Nations after the conclusion of the third mission, the investigators pointed out the dangers of this chemical warfare:

> It is vital to realize that the continued use of chemical weapons in the present conflict increases the risk of their use in future conflicts. In view of this, and as individuals who witnessed first hand the terrible effects of chemical weapons, we again make a special plea to you to try to do everything in your power to stop the use of such weapons in the Iran–Iraq conflict and thus ensure that they are not used in future conflicts.
>
> . . . .
>
> In our view, only concerted efforts at the political level can be effective in ensuring that all the signatories of the Geneva Protocol of 1925 abide by their obligations. Otherwise, if the Protocol is irreparably weakened after 60 years of general international respect, this may lead, in the future, to the world facing the specter of the threat of biological weapons.[199]

This last comment was mirrored by another analyst:

> In a sense, a taboo has been broken, thus making it easier for future combatants to find justification for chemical warfare, this aspect of the Iran–Iraq war should cause Western military planners the gravest concern.[202(pp51–52)]

The Iran–Iraq War failed to reach a military conclusion despite Iraq's use of chemical weapons. Roughly 5% of the Iranian casualties were caused by chemical weapons. Although there were rumors of Iranian use of chemical weapons also, less attention was devoted to verifying those reports. In August 1988, Iraq finally accepted a United Nations cease-fire plan, and the war ended politically with little gained from the original objectives.[194]

Additional Reports of Chemical Warfare

The end of the Iran–Iraq War, however, did not end chemical warfare reports from circulating. Within a month of the end of the war, Iraq was again accused of using chemical weapons against the Kurds, a minority group in Iraq seeking autonomy. Shortly before, there were rumors that Libya had used chemical weapons obtained from Iran during an invasion of Chad. The United States rushed 2,000 gas masks to Chad in response. There were also reports of the Cuban-backed government of Angola using nerve agents against rebel forces.[203–206]

New Defensive Equipment

In response to the continued use of chemical agents in the Middle East and elsewhere, the army instituted a three-pronged chemical program for the 1980s, intended both to drive the Soviets to the bargaining table and to restore the United States chemical defense and retaliatory capability. First, the army improved its defensive equipment. Second, the army began production of chemical weapons for the first time since the 1969 ban. And third, the army improved its chemical warfare training and updated its training manuals.

A number of physical protection, collective protection, detection, and decontamination developments reflected the improved defensive equipment. Perhaps the most significant development was the type classification in 1987 of a new protective mask for the infantry to replace the M17 series masks. The new mask, designated the M40, returned to a can-

ister design that provided increased protection against everything from chemical agents to toxins, smokes, and radioactive fallout particles. The canister used North Atlantic Treaty Organization (NATO) standard threads and could be worn on either side of the mask. The mask also had improved fit and comfort, voice communications, and drinking capability. It came in three sizes—small, medium, and large—which helped eliminate the logistical burden of four sizes for the M17A2 and six different stock numbers for the M9A1. In conjunction with M40, the army also standardized the M42 Combat Vehicle Mask to replace earlier tank masks from the 1960s.[207–209]

For collective protection, the army standardized the M20 Simplified Collective Protection Equipment in 1986. This system turned one room of a building into a protected area by (1) lining the walls with a chemical/biological vapor–resistant polyethylene liner and (2) providing 200 cu ft of filtered air per minute. In addition, the army concentrated on modular collective protection equipment for chemical threats to vehicles, vans, and shelters. The Department of the Army identified 43 systems in 1980 that required chemical protection. New systems that were developed each year created a major, long-term project to correct the deficiency that had been discovered after the 1973 Yom Kippur War.[207,210]

For detection, the army developed two new detectors, one using low technology and one high technology. M9 Detector Paper was an adhesive-backed paper containing B-1 dye, which turned red when contaminated with any known liquid agent. Type classified in 1980, the paper was attached to a soldier's arms or legs, or to the outside of his vehicle, and provided an indication of a chemical attack.[210]

The M1 Chemical Agent Monitor (CAM), standardized in 1988, was used to detect chemical agent contamination on personnel and equipment. It detected vapors by sensing ions of specific mobilities and used timing and microprocessor techniques to reject interferences. Its developmental history was particularly interesting, in that it was based on a United Kingdom (U.K.) design originally standardized by the U.K. in 1984.[3,211]

There were several developments in the area of decontamination. The M13 Portable Decontaminating Apparatus, designed to decontaminate large military vehicles, was standardized in 1983; and the M280 Individual Equipment Decontamination Kit, designed to partially decontaminate a soldier's personal equipment, including gloves, hood, mask, and weapon, was standardized in 1985. Both items replaced older equipment.[3]

Not all research and development utilizing current technology or foreign intelligence resulted in the standardization of a new item. One example was the truck-mounted, jet-exhaust decontaminating apparatus, designated the XM16. Based on intelligence collected on the Soviet TMS-65 decontamination system, the army started work on a similar project. The U.S. project consisted of a J60-P-6 jet engine with a control cab mounted on a 5-ton military truck. The idea was to direct high-velocity streams of hot exhaust gases onto the outer surfaces of vehicles for decontamination. In addition, the jet engine could be used as a smoke generator by adding smoke liquids to the exhaust. Because of several deficiencies in the system, the project was canceled in 1986, but the principle was continued in related developmental projects.[212]

Production of Binary Weapons

The subject of chemical weapon production was a very sensitive one. In 1984, congress created the Chemical Warfare Review Commission to look at several issues related to the military's chemical warfare preparedness. This committee visited numerous sites, interviewed experts, reviewed policy, and examined intelligence reports. Among their findings, the commission concluded

> that in spite of the approximately $4 billion that the Congress has appropriated since 1978 for defense against chemical warfare, that defense, measured either for purposes of deterrence or for warfighting utility, is not adequate today and is not likely to become so. Chemical combat as it would exist in the late twentieth century is an arena in which—because defense must be nearly perfect to be effective at all, detection is so difficult, and surprise offers such temptation—the offense enjoys a decisive advantage if it need not anticipate chemical counterattack. Defense continues to be important to pursue, because it can save some lives and preserve some military capabilities. But for this country to put its faith in defense against chemical weapons as an adequate response to the Soviet chemical threat would be a dangerous illusion.[213(p50)]

The answer to the problem was simply stated by President Reagan:

> The United States must maintain a limited retaliatory capability until we achieve an effective ban. We must be able to deter a chemical attack against us or our allies. And without a modern and credible deterrent, the prospects for achieving a comprehensive ban would be nil.[214(p23)]

In 1981, the secretary of defense issued a memorandum to proceed to acquire binary chemical bombs. The appropriation restrictions of 1976, however, blocked procurement of binary munitions for several more years. The next step came in 1985 when the U.S. Congress passed Public Law 99-145 authorizing production of chemical weapons. The final step came in 1987, when President Reagan certified to congress that all their conditions had been met to start production of binary chemical weapons.[3]

The production of the M687 binary projectile began on 16 December 1987 at Pine Bluff Arsenal. This was no small feat considering modern environmental and general public concerns. To resolve political concerns, the M20 canisters were filled and stored at Pine Bluff Arsenal, while the M21 canisters were produced and filled at Louisiana Army Ammunition Plant. The filled M21 canisters and shell bodies were then stored at Tooele Army Depot, Utah. In time of need, the parts could be combined and would provide the army with a chemical retaliatory capability.[215]

In addition to the M687 round, development work continued on the BLU-80/B (BIGEYE) bomb and the XM135 Multiple Launch Rocket System (MLRS) Binary Chemical Warhead. Both utilized the binary concept. The BIGEYE was in the 500-lb bomb class and was compatible with fixed-wing aircraft belonging to the air force, navy, and marine corps. The bomb dispersed the persistent nerve agent VX after mixing two nonlethal chemical agents (designated NE and QL). The XM135 binary chemical warhead was designed as a free-flight, semipersistent, nerve agent–dispersing system. The XM135 was fired from the MLRS, a 12-round rocket launcher mounted on a tracked vehicle.[215,216]

Chemical Training

In addition to establishing a retaliatory capability, the army significantly improved its chemical training capability by (*a*) constructing a new facility at the Chemical School and (*b*) conducting more-realistic field training. In 1987, the Chemical Decontamination Training Facility (CDTF) started live–chemical agent training in a controlled environment. Major General Gerald G. Watson, the school's commandant, was "the first American to wear the battledress overgarment in a toxic chemical environment"[217(p15)] when he entered the CDTF on 19 February 1987.

For realistic field training, the army conducted such training as Operation Solid Shield 87 to test how the U.S. troops perform on a chemically contaminated battlefield. Over 40,000 personnel from the U.S. Army, Navy, Marine Corps, Air Force, and Coast Guard participated in the simulated chemical attacks. Many conclusions were drawn from the training. Of particular concern was the impact on the medical personnel trying to help both conventional and chemical casualties:

> Use of chemical weapons in an otherwise conventional warfare scenario will result in significant impact on the medical capability to treat and handle casualties. Many medical facilities might be located near chemical target areas and may be subject to contamination.
>
> These facilities include battalion aid stations, hospital and medical companies, casualty receiving and treatment ships, fleet hospitals, and hospital ships. Provision of medical care in a contaminated environment is extremely difficult due to the encapsulation of medical personnel in their individual protective ensembles.
>
> Medical care is best provided in an environment free of toxic agents. This environment might be provided by a collectively protected facility, or be in an uncontaminated area. Medical units ashore and afloat can expect to receive contaminated casualties and must be prepared to provide contaminated casualties with a comprehensive and thorough decontamination. This procedure is similar whether processing patients into a collectively protected facility or processing from a contaminated area to an area free of contamination.[218(p30)]

The conclusions of the training impacted all aspects of the military forces:

> All organizations must be trained in NBC detection and identification procedures, particularly units with an inherent reconnaissance mission. First aid, and casualty handling, including mass casualty handling, must also be an integrated part of training. NBC contamination, medical, operational, and logistical problems should be evaluated and responded to realistically at all command and staff levels.
>
> Particular emphasis must be placed on the ability of personnel to remove contaminated clothing and equipment while minimizing the transfer of contamination to unprotected skin or to nonprotective underclothing.[218(p31)]

One officer summed up this new way of thinking about chemical training as demonstrated by Solid Shield 87:

> NBC warfare is not a separate, special form of war, but is instead a battlefield condition just like rain,

> snow, darkness, electronic warfare, heat, and so on. Units must train to accomplish their wartime missions under all battlefield conditions. Whenever NBC is separated from other training events, we condition our soldiers to regard operations under NBC conditions as a separate form of warfare.[218(p31)]

To reflect the changes in concept and equipment, the army's field manuals were also rewritten and updated to incorporate chemical warfare readiness into the army's air–land battle doctrine. The five parts of the new doctrine called for contamination avoidance, individual and collection protection, decontamination, chemical weapons employment, and the deliberate use of smoke.

Soviet–United States Agreement

The increase in the United States's retaliatory and defensive capability for chemical and biological warfare, along with internal changes in the Soviet Union, helped convince the Soviets to look closely at a new chemical weapons treaty. In 1987, after admitting for the first time that they possess chemical agents, they announced the halting of chemical weapons production. In September 1989, the *Memorandum of Understanding (MOU) Between the Government of the United States and the Government of the USSR Regarding a Bilateral Verification Experiment and Data Exchange Related to Prohibition of Chemical Weapons*, otherwise known as the Wyoming MOU, started the talks between the two countries.[3]

U.S. Demilitarization Program

While the army was producing the new binary agent weapons, it was also discovering that the destruction of the existing chemical weapons stockpile was proving a far greater challenge than originally expected. In 1982, the army announced that incineration was the best option for disposing of the chemical agents. The construction of the first such disposal system was started on Johnston Atoll in 1985. The following year, congress passed Public Law 99-145, which mandated the destruction of the U.S. stockpile of chemical weapons by 1994. This also required that the army plan for maximum protection for the environment and human health during the destruction. In 1988, congress extended the destruction date to 1997; later, this date was further extended to 2004. In 1989, construction on a second disposal system was started at Tooele, Utah.[3,219]

THE 1990s: THE THREAT MATERIALIZES

The success of the "carrot and stick" strategy with the Soviet Union led to another change in course for the chemical program. On 1 June 1990, with the fall of many of the communist governments in Eastern Europe and improved relations with the Soviet Union, the United States and the Soviet Union signed a bilateral chemical weapons destruction agreement. In support of this agreement, the secretary of defense canceled most of the new chemical retaliatory program, and the army decided to mothball its new binary chemical production facilities in 1990.[220]

Shortly after the signing of the bilateral chemical weapons destruction agreement, the army began Operation Steel Box to remove all U.S. chemical weapons from Germany. The project started in July and finished in November 1990, with all the munitions safely moved to Johnston Atoll. The same year, the Johnston Atoll Chemical Agent Destruction System (JACADS) incinerator on the island became operational. The Tooele demilitarization plant was not operational until 1996.

In 1992, however, Public Law 102-484 instructed the army to restudy incineration as the best process for demilitarization due to continuing opposition by the general public. The army then began researching both neutralization and neutralization followed by biodegradation as alternate disposal options.[3,219]

Persian Gulf War

Despite the ongoing political efforts to abolish chemical warfare, world events dictated that chemical and biological weapons would again be the subject of daily news reports. On 2 August 1990, Saddam Hussein sent Iraqi troops into Kuwait—allegedly in support of Kuwaiti revolutionaries who had overthrown the emirate. By 8 August, however, the pretense was dropped and Iraq announced that Kuwait had simply been annexed and was now a part of their country. In response, President George Bush ordered U.S. forces sent to Saudi Arabia at the request of the Saudi government as part of what became Operation Desert Shield, the buildup phase of the Persian Gulf War.

The United States's response to Iraq's invasion put the army's chemical and biological warfare ex-

perience, training, production program, and lessons learned in the limelight. Not since World War I had U.S. troops been sent to face an enemy that had not only used chemical weapons extensively within the last few years, but also had publicly announced their intentions to use chemical weapons against the United States. William H. Webster, Director of Central Intelligence, estimated that Iraq had 1,000 tons of chemical weapons loaded in bombs, artillery rounds, rockets, and missiles. Much of Iraq's biological weapon program remained unknown until after the war.[221–223]

Iraq had a large biological agent production facility at al-Hakam that produced the agents that cause botulism, anthrax, and others. Started in 1988, the plant had produced about 125,000 gal of agent by 1991. After stating for years that the plant was used to produce animal feed, the Iraqis admitted in 1995 that the plant was a biological warfare production facility. In addition to producing biological warfare agents, they also conducted live-agent tests on animals. The Iraqis also later admitted they had prepared about 200 biological missiles and bombs.[224–227]

The United States's preparation for the military phase of the Persian Gulf War had to consider all these chemical and biological threats. Vaccines for anthrax and botulinum toxin were given to U.S. troops moving into the area.[228] For nerve agent poisoning, troops had the MARK I nerve agent antidote kit, consisting of an atropine autoinjector and a pralidoxime chloride (2-PAM Cl) autoinjector. The atropine blocked the effects of nerve agent poisoning on the muscles, while the 2-PAM Cl reactivated the acetylcholinesterase. Pyridostigmine bromide tablets also were provided as a nerve agent pretreatment.[229] All military units were fully equipped with the latest chemical and biological defensive equipment, and training was continuous.

The actual attack on Iraq on 16 January 1991 as part of the United Nations's mandated effort to free Kuwait, designated Operation Desert Storm by the United States, escalated fears of a new chemical war to levels not seen since World War I. The initial air attack concentrated on Iraqi chemical-production facilities, bunkers, and lines of supply. While the air attacks were ongoing, daily news accounts addressed the potential for chemical and biological warfare. On 28 January, Saddam Hussein told Peter Arnett of CNN News that his Scud missiles, which were already hitting Israel and Saudi Arabia, could be armed with chemical, biological, or nuclear munitions.[230] Vice President Dan Quayle, while visiting the United Kingdom, was reported to have told the prime minister that the United States had not ruled out the use of chemical or nuclear weapons.[230] Likewise, the United States was reported to have threatened to target Hussein personally if he used chemical weapons against Allied troops.[230,231] Iraq, in turn, reportedly threatened to use chemical weapons against Allied troops if they continued the high-level bombings against Iraqi troops.[230]

Thus the stage was set for what many thought was going to be the second major chemical war in this century. When the Allies began the ground war on 23 February 1991, the worst was expected and planned for by chemical and biological defense specialists. Chemical alarms frequently went off across the battlefield, but all were dismissed as false alarms. On 27 February, Allied troops liberated Kuwait City and finished destroying the Iraqi divisions originally in Kuwait. No known chemical and biological attacks were made by the Iraqis.

A number of reasons surfaced after war as to why the Iraqis had not initiated large-scale chemical and biological warfare. Vice Admiral Stanley Arthur, commander of U.S. naval forces, thought that because the wind suddenly changed from blowing south at the start of the land battle, the Iraqis had probably realized that chemical weapons could harm their own troops. Some thought the speed of the campaign was the critical reason. Others reported that the combination of Allied bombing and resulting Iraqi logistical nightmares prevented the chemical weapons from ever reaching the front lines. General H. Norman Schwarzkopf, commander of Allied forces, mentioned that Iraq might have feared nuclear retaliation.[223,230,232]

After the war, however, allegations of chemical and biological exposures began to surface. Initially, the department of defense denied that any chemical and biological exposures had taken place. Veterans of the war claimed the opposite, and their ailments collectively became known as Gulf War Syndrome. By 1996, newspapers reported that almost 60,000 veterans of the Persian Gulf War claimed some sort of medical problems directly related to their war activities. Extensive research by the department of defense failed to find any single cause for the problems.[233,234]

One controversial example of possible exposure occurred on 4 March 1991 at the Kamisiyah arsenal, northwest of Basra, involving the U.S. Army 37th Engineer Battalion. After capturing the site, the engineers blew up the Iraqi storage bunkers. Ac-

cording to newspaper accounts, the engineers claimed that their chemical agent detectors went off during the explosions. Later the same year, a United Nations inspection team reportedly found the remains of chemical rockets and shells in one of the bunkers and found traces of sarin and mustard agent. In 1996, the department of defense acknowledged that one of the bunkers probably contained sarin- and mustard agent–filled munitions, and that as many as 20,000 U.S. soldiers may have been exposed to chemical agents as a result.[235] A Pentagon spokesman summed up the continuing research into the possible exposure: "Our understanding of this episode is still partial."[234(pA-10)]

Additional Allegations of Chemical Warfare

Shortly after the fighting was over between Iraq and Allied forces, reports circulated that Hussein was using chemical agents against rebellious Kurds and Shiite Moslems. The United States intercepted a message ordering the use of chemical weapons against the cities of Najaf and Karbala. President Bush's response was that such use of chemical weapons would result in Allied air strikes against the Iraqi military organization using the chemicals. Thus, despite the end of fighting, Iraqi chemical weapons continued to be a problem for the world.[236,237]

Likewise, U.S. intelligence sources detected increased chemical-development activity in Libya. Libya constructed a chemical weapons plant at Rabta that produced about 100 tons of chemical agents. In 1990, Libya claimed that the plant was destroyed by a fire. New disclosures surfaced in 1996 that Libya was constructing a second chemical production plant at Tarhunah. U.S. intelligence sources claimed that this would be the largest underground chemical weapons plant in the world, covering roughly 6 square miles and situated in a hollowed-out mountain. With Scud missiles having a range of 180 to 300 miles, this created a significant threat to Libya's neighbors. Libya strongly denied the accusation.[238,239]

New Defensive Equipment

During the 1990s, the army standardized several new protective masks. In 1990, the M43 CB AH-64 Aircraft Mask was standardized for use in Apache helicopters. The unique aspect of the mask was its compatibility with AH-64 display sighting system. Within 6 years, the army improved the mask and standardized the new version as the M48 CB Aviator's Mask.[3]

Although the new M40 series was an improvement over the M17 series mask, complaints from soldiers about the M40 masks resulted in the standardization of the M40A1 Field Mask and the M42A1 Combat Vehicle Mask in 1993. The M40A1 Mask added the Quick Doff Hood/Second Skin (QDH/SS), which allowed the hood to be doffed without removing the mask. This feature resulted in faster, more efficient decontamination operations. The M42A1 Mask added the QDH/SS and a canister-interoperability system that allowed the use of NATO canisters in the system. The new masks also included an improved nosecup that provided more comfort than the previous one. These changes increased the likelihood that soldiers would survive on a chemical and biological battlefield.[3,240]

The detection of chemical and biological agents was made much easier in the 1990s. In 1990, the army issued the first XM93 series NBC Reconnaissance Systems (the FOX), a dedicated system of NBC detection, warning, and sampling equipment integrated into a high-speed, high-mobility, armored carrier. A later version, the M93A1, was standardized in 1996. The FOX was capable of performing NBC reconnaissance on primary, secondary, or cross-country routes throughout the battlefield and had the capability to find and mark chemical and biological contamination. While conducting the reconnaissance, the crew was protected by an onboard overpressure system.[3,240,241]

The remote sensing research that started in the 1950s finally resulted in a detector in 1995, when the M21 Remote Sensing Chemical Agent Alarm was standardized. The M21 was an automatic scanning, passive infrared sensor that detected vapor clouds of nerve and blister agents, based on changes in the background's infrared spectra caused by the presence of agent vapor. The detector could "see" agent clouds to 5 km.[242]

After the Persian Gulf War, General Colin Powell testified to congress that the United States was vulnerable to biological warfare. One reason was that the United States had been unable to standardize a good biological agent detector. In 1995, the army standardized the first biological alarm. The M31 Biological Integrated Detection System (BIDS) was a small truck packed with sampling and detection equipment. Each vehicle could provide 24-hour monitoring, with identification of the agent following an alarm in about 30 minutes.[3,243]

The Chemical Weapons Convention

In 1993, the long-sought Chemical Weapons Convention was signed by the United States, Russia, and other countries. This treaty prohibited development, production, stockpiling, and use of chemical weapons. Ratification by the U.S. Senate, however, was delayed for various reasons.[3] One reason was that reports of a Russian chemical-development program surfaced in U.S. newspapers. A Russian scientist claimed that in 1991 Russia had developed a new, highly toxic, binary nerve agent called Novichok. According to the scientist, the nerve agent was undetectable by U.S. chemical detectors and may have been used in the Persian Gulf War by Iraq to produce some of the Gulf War syndrome symptoms. Despite these claims, the negotiations continued and additional agreements were signed with Russia. The United States even agreed to help fund the Russian demilitarization program.[244,245]

Terrorism and Counterterrorism

The use of chemical and biological weapons for terrorism became a key concern of the U.S. Army in the 1990s. In 1994, a Japanese religious cult, Aum Shinrikyo, reportedly released nerve agent in a residential area of Matsumoto, Japan, that killed 7 and injured 500. A second attack on 20 March 1995 spread sarin through a crowded Tokyo subway. This act of terrorism killed 12 and caused more than 5,500 civilians to seek medical attention. After the attacks, news accounts reported that the cult had developed a helicopter to spray toxins, a drone for unmanned chemical and biological attacks, and their own strains of botulism. They had also allegedly attempted to obtain the Ebola virus from Zaire.[246–248]

Chemical and biological terrorism was not limited to foreign countries. The first conviction under the Biological Weapons Anti-Terrorism Act of 1989 occurred in 1995, when a U.S. citizen was sentenced to 33 months in prison for possession of 0.7 g of ricin. The same year, a nonprofit organization shipped plague bacteria, *Yersinia pestis*, to an alleged white supremacist.[249,250]

Some of the items developed by the Chemical Corps were also used as counterterrorism measures, but sometimes with unintended consequences. For example, in 1993 the Federal Bureau of Investigation decided to use a nonlethal riot control agent while attacking the Branch Davidian compound in Waco, Texas. Fires, however, destroyed the complex and killed the 80 occupants.[3,251]

These examples, both good and bad, led many state and local officials to notify congress that they did not have the training or equipment to combat an act of chemical or biological terrorism. Senator Sam Nunn expressed similar concerns:

> I, like many of my colleagues, believe there is a high likelihood that a chemical or biological incident will take place on American soil in the next several years.[252(pA-10)]

In reference to the Tokyo subway incident, he added:

> The activities of the Aum should serve as a warning to us all. This is a lesson that we will ignore at our peril.[251(pA-10)]

A military expert described the dangers of covert biological warfare:

> A terrorist attack using an aerosolized biological agent could occur without warning, and the first sign of the attack might be hundreds or thousands of ill or dying patients, since biological clouds are not visible.[251(pA-10)]

In 1996, the U.S. Congress responded by passing a new antiterrorism training bill to prepare the United States for future chemical and biological terrorism incidents. In addition to using military experts to equip and train local chemical and biological response teams, the bill also provided funding for former Soviet republics to destroy their own chemical and biological weapons to keep them out of the hands of terrorists.[251,253]

SUMMARY

Many lessons can be learned from the past concerning chemical and biological warfare and the U.S. experience combating it. So far, the United States has been extremely lucky and has not experienced a chemical and biological "Pearl Harbor" like some other countries have. To prevent that, the U.S. military forces will have to continue to learn about chemical and biological warfare and how to accomplish their mission—on both a chemical and biological battlefield and at a chemical and biological terrorist site anywhere in the world. In the words of General Pershing, "we can never afford to neglect the question"[43(p77)] of chemical and biological preparedness again.

REFERENCES

1. Department of the Army. *NATO Handbook on the Medical Aspects of NBC Defensive Operations*. Washington, DC: HQ, DA; AMedP-6, Part 3; 1996: 1-1. Field Manual 8-9.

2. Department of the Army. *NATO Handbook on the Medical Aspects of NBC Defensive Operations*. Washington, DC: HQ, DA; AMedP-6(B), Part 2; 1996: 1-1. Field Manual 8-9.

3. Smart JK. *History of Chemical and Biological Warfare Fact Sheets*. Aberdeen Proving Ground, Md: US Army Chemical and Biological Defense Command; 1996. Special Study 50. Not cleared for public release.

4. Browne CA. Early references pertaining to chemical warfare. *Chemical Warfare.* 1922;8(9):22–23.

5. Miles WD. Chemical warfare in the Civil War. *Armed Forces Chemical Journal*. 1958;12(2):27, 33.

6. Haydon F. A proposed gas shell in 1862. *Military Affairs*. 1938;2(2):54.

7. Miles WD. Suffocating smoke at Petersburg. *Armed Forces Chemical Journal*. 1959;13(4):34–35.

8. Pringle L. *Chemical and Biological Warfare*. Hillside, NJ: Enslow Publishers; 1993: 17.

9. Haber LF. *The Poisonous Cloud: Chemical Warfare in the First World War*. Oxford, England: Clarendon Press; 1986: 15–40.

10. MacCurdy E, ed. *The Notebooks of Leonardo da Vinci*. Vol 2. London, England: Jonathan Cape; 1977: 206.

11. US Patent 6529, 12 Jun 1849.

12. US Patent 7476, 2 Jul 1850.

13. Miles WD. The velvet-lined gas mask of John Stenhouse. *Armed Forces Chemical Journal*. 1958;12(3):24–25.

14. Prentiss AM. *Chemicals in War: A Treatise on Chemical Warfare*. New York, NY: McGraw-Hill; 1937: 343–477, 533–566, 574, 685–689.

15. US Senate Committee on Foreign Relations, Subcommittee on Disarmament. *Chemical Biological Radiological (CBR) Warfare and Its Disarmament Aspects*. Washington, DC: Government Printing Office; 29 Aug 1960: 6, 19.

16. Hogg I. Bolimow and the first gas attack. In: Fitzsimons B, ed. *Tanks and Weapons of World War I*. New York, NY: Beckman House; 1973: 17–19.

17. Fries AA, West CJ. *Chemical Warfare*. New York, NY: McGraw-Hill; 1921: 10–11, 14, 31–71, 151.

18. Hanslian R. The gas attack at Ypres: A study in military history, I. *Chemical Warfare Bulletin*. 1936;22(1):5.

19. An account of German cloud gas attacks on British front in France. Unsigned manuscript. Attachment to a letter dated 11 Feb 1922 from Major ON Solbert, Military Attaché, American Embassy, London, England, to Chief, Chemical Warfare Service, Edgewood, Md; Subject: History of gas and development of British respirators from beginning of war to armistice. Original held at US Army Chemical and Biological Defense Command Historical Office in file named Gas Warfare History (British) 1915.

20. Fries AA. Gas in attack. *Chemical Warfare*. 1919;2(2):3, 8.

21. Stockholm International Peace Research Institute. *The Rise of CB Weapons*. Vol 1. In: *The Problem of Chemical and Biological Warfare*. New York, NY: Humanities Press; 1971: 111–124, 141–142, 147, 214–230.

22. Witcover J. *Sabotage at Black Tom*. Chapel Hill, NC: Algonquin Books of Chapel Hill; 1989: 83–101, 134–151.

23. Bancroft WD. *Bancroft's History of the Chemical Warfare Service in the United States*. Washington, DC: Research Division, Chemical Warfare Service, American University Experiment Station; May 1919: 12, 16.

24. Barker ME. Gas mask development. *Chemical Warfare*. 1926;12(7):14–15.

25. Brophy LP, Fisher GJB. *The Chemical Warfare Service: Organizing for War*. Washington, DC: Office of the Chief of Military History; 1959: 3–18, 25–27, 424–471.

26. Brophy LP, Miles WD, Cochrane RC. *The Chemical Warfare Service: From Laboratory to Field.* Washington, DC: Office of the Chief of Military History; 1959: 2–27, 49–76, 85–86, 101–138, 268, 336, 436–453.

27. Spencer EW. An historical lesson. *Chemical Warfare*. 1923;9(3):2–10.

28. Discipline through training or annihilation. *Chemical Warfare*. 1920;5(11):2. Editorial.

29. Hunt R. *Ricin*. Washington, DC: American University Experiment Station; 1918: 107–117. Chemical Warfare Monograph 37.

30. Smart JK. *Preparing for Chemical Warfare: The History of the Infantry Protective Mask*. Edgewood Arsenal, Md: US Army Chemical and Biological Defense Command; 1991. Not cleared for public release.

31. Gilman ED. The evolution of the gas mask. *Chemical Warfare*. 1922;8(8):5–9.

32. Evolution of the gas mask. *Chemical Warfare*. 1920;3(1):3–11.

33. Army War College. *Methods of Defense Against Gas Attacks*. Vol 2. In: *Gas Warfare*. Washington, DC: War Department; 1918: 32–35.

34. Mankowich J, Butcosk AF, Robbins R, Roberts WB, West AL, Love S. *Decontamination of Chemical Agents*. Aberdeen Proving Ground, Md: Technical Support Directorate; 1970: 20, 88–91. Edgewood Arsenal Special Publication 300–5.

35. Falkof MM, Gehauf B. *Detectors and Alarms*. Vol 11. In: *History of Research and Development of the Chemical Warfare Service in World War II*. Army Chemical Center, Md: Chemical and Radiological Laboratories; Oct 1951: 1–3, 102.

36. Nothing equal to the trained nose. *The Catalyst*. 1996;2(2):11.

37. Army War College. *Memorandum on Gas Poisoning in Warfare with Notes on its Pathology and Treatment*. Washington, DC: Government Printing Office; 1917: 18–21, 32.

38. US Army. *Memorandum on Gas Poisoning in Warfare with Notes on its Pathology and Treatment.* Washington, DC: Government Printing Office; 1918: 22, 26–34. Army Expeditionary Force Publication 48.

39. 157th Field Artillery, 82nd Division History Box 23 (282-32.15 157 FA Brig Memos). National Archives Building, Washington, DC.

40. Clark DK. *Effectiveness of Chemical Weapons in WWI*. Bethesda, Md: Johns Hopkins University Operations Research Office. 1959: 99–123. ORO-SP-88 Staff Paper.

41. Fries AA. Chemical warfare inspires peace. *Chemical Warfare*. 1921;6(5):4.

42. Poison gas is indispensable, says German inventor. *Chemical Warfare*. 1921;17(7):10.

43. Pershing JJ. *Final Report of General John J. Pershing*. Washington, DC: US Government Printing Office; 1920: 77.

44. Knappen TM. Chemical warfare and disarmament. *Chemical Warfare*. 1921;7(11):3.

45. Brown FJ. *Chemical Warfare, A Study in Restraints*. Princeton, NJ: Princeton University Press; 1968: 74–75, 98–110, 118, 145, 193–194, 267–269, 279–281.

46. Clark EB. As chemical warfare chieftain. *Chemical Warfare Bulletin*. 1941;27(3):87. Editorial.

47. Fries AA. Sixteen reasons why the Chemical Warfare Service must be a separate department of the Army. *Chemical Warfare*. 1920;2(7):4.

48. Clapp D. Gas. *Chemical Warfare*. 1919;2(1):cover iv. Poem.

49. Barker ME. The work of the Chemical Warfare Service. *Chemical Warfare*. 1933;19(4):1330–1339.

50. Brophy LP. Chemical corps troops and training in the years between the two wars. *Chemical Corps Journal*. 1948;2(3):25–28.

51. War Department. *General Orders No. 26*. Washington, DC: War Department; 17 Jun 1922.

52. Status of chemical warfare preparedness in the US. *Chemical Warfare*. 1924;10(8):13.

53. Edgewood seeking boll weevil poison. *Chemical Warfare*. 1924;10(9):14.

54. Fries AA. Summary of marine piling investigation. *Chemical Warfare*. 1925;11(6):11.

55. Boll weevil investigations. *CWS News Letter*. 1928;1:3.

56. Fries AA. Chemical warfare—Past and future. *Chemical Warfare*. 1920;5(1):4–5.

57. Chemical warfare bombing tests on warship. *Chemical Warfare*. 1921;6(10):6.

58. Fries AA. *Annual Report of Chief, Chemical Warfare Service*. Washington, DC: CWS; 1921: 22–24.

59. Hanslian R. The gas attack at Ypres: A study in military history, II. *Chemical Warfare Bulletin*. 1936;22(3):129.

60. Fries AA. *Annual Report of the Chief of Chemical Warfare Service*. Washington, DC: CWS; 1926: 8.

61. Fair SD. Mussolini's chemical war. *Army*. 1985;35(1):47.

62. Foreign developments in chemical warfare. *Chemical Warfare*. 1923;9(9):19.

63. Smalley VE. *Report of the CW Status of Italy (1926–1948)*. Army Chemical Center, Md: Chemical Corps Technical Command; 1948: 14, 52–53.

64. Williams P, Wallace D. *Unit 731*. New York, NY: The Free Press; 1989: 13–30.

65. Robertson AG, Robertson LJ. From asps to allegations: Biological warfare in history. *Milit Med*. 1995;160(8):369–372.

66. Thomas AVW, Thomas AJ Jr. *Basic Report*. Vol 2. In: *Development of International Legal Limitations on the Use of Chemical and Biological Weapons*. Dallas, Tex: Southern Methodist University School of Law and US Arms Control and Disarmament Agency; 1968: 53–54, 73–102.

67. The present international situation as regards chemical warfare and the impossibility of securing the assured abolition of the use of gas in future wars. *Chemical Warfare*. 1925;11(3):7.

68. Gas warfare not forbidden by any international agreement. *Chemical Warfare*. 1925;11(3):6.

69. The international legal status of chemical warfare. *Chemical Warfare*. 1926;12(10):9–14.

70. Waitt AH. Europe looks at chemical warfare. *Army Ordnance*. 1935;15(89):285.

71. Brigham CE. *Final Report on Status of Chemical Readiness by the Retiring Chief*. Record Group 114; 1937. National Archives, Suitland, Md.

72. Wiseman DJC. *Special Weapons and Types of Warfare*. London, England: The War Office; 1951: 150.

73. Intelligence Division, Chemical Warfare Service. *German Chemical Warfare, World War II*. Washington, DC: CWS; 1945: 28–30, 115–117.

74. Department of the Army. *Chemical Corps Equipment Data Sheets*. Washington, DC: HQ, DA; 1961: 3, 60, 103. Training Manual 3-500.

75. Fox LA. Bacterial warfare: The use of biologic agents in warfare. *Military Surgeon*. 1933;72(3):189–207.

76. Scientific and Technical Advisory Section, US Army Forces, Pacific. *Biological Warfare*. Vol 5. In: *Report on Scientific Intelligence Survey in Japan*. HQ, US Army Forces, Pacific; 1945.

77. West AL, Goldfield J, Mitchell J. Antigas Collective Protection Equipment. Edgewood Arsenal, Md: 1969: 20, 24. Edgewood Arsenal Special Publication 300-4.

78. Duffield M. Ethiopia: The unconquered lion of Africa. *Command Magazine*. 1990;4:10–22.

79. Neil EJ. *Use of Gas in Ethiopia*. Washington, DC: War Department; 2 Sep 1936. War Department Memorandum.

80. Thuillier HF. The use of mustard gas by the Italians in the Abyssinian War. Porton, United Kingdom; 25 Apr 1941. Memorandum CDR5/1793.

81. Volkart W. The Gas Weapon in the Italian–Abyssinian War 1935–1936. Translated from *Allgemeine Schweizerische Militär Zeitschrift*. Typescript prepared for Army Chemical Center, Md; 1951.

82. Murphy P. Gas in the Italo–Abyssinian campaign. *Chemical Warfare Bulletin*. 1937;23(1):1–8.

83. *Time*. Quoted in: Brett HH. Chemicals and aircraft. *Chemical Warfare Bulletin*. 1936;22(4):151–152.

84. Kohn GC. *Dictionary of Wars*. New York, NY: Facts on File Publications; 1986: 226, 433–434, 524.

85. Chemicals in Ethiopia. *Chemical Warfare Bulletin*. 1936;22(3):143.

86. Use of gas in Italo–Abyssinian campaign. *Chemical Warfare Bulletin*. 1937;23(2):81.

87. Hart L. The Abyssinian War. *Ordnance*. 1937;17(102):330.

88. Clark DK. *Effectiveness of Toxic Chemicals in the Italo–Ethiopian War*. Bethesda, Md: Operations Research Office; 1959: 1–21.

89. Baker WC. *Annual Report of the Chief of the Chemical Warfare Service for the Fiscal Year Ending June 30, 1937*. Washington, DC: War Department; 1937.

90. Chemical Warfare School. *Use of Gas in Ethiopia—1936*. Edgewood Arsenal, Md: Chemical Warfare School; 22 Oct 36. Mimeo 1.

91. Brett GH. Chemicals and aircraft. *Chemical Warfare Bulletin*. 1936;22(4):153.

92. 5250th Technical Intelligence Company. *The Use of Poison Gas by Imperial Japanese Army in China, 1937–1945*. Tokyo, Japan: 5250th Technical Intelligence Company; 1946.

93. Watson M. Army is speeding chemical defense. *Baltimore Sun*. 12 Nov 1941. Quoted in: *CWS News Letter*. 1941;5(6):37.

94. Nazis may use gas, General Porter warns. *CWS News Letter*. 1941;5(5):31.

95. General Porter urges America to "Get Tough." *CWS News Letter*. 1941;5(6):36.

96. Chemical warfare goes on maneuvers. *Chemical Warfare Bulletin*. 1942;28(1):4–24.

97. Japs reported using gas. *CWS News Letter*. 1941;5(6):33–34.

98. Miller GA. The development of the 4.2 chemical mortar. *Armed Forces Chemical Journal*. 1948;3(2):33–42; continued in 1949;3(3):35–42.

99. US War Department. *Characteristics and Employment of Ground Chemical Munitions*. Washington, DC: War Department; 1946: 108–119. Field Manual 3-5.

100. US War Department. *Employment and Characteristics of Air Chemical Munitions*. Washington, DC: War Department; 1946: 4–5. Field Manual 3-6.

101. Infield G. *Disaster at Bari.* New York, NY: Bantam Books; 1988: 209, 230–231.

102. Cochrane RC. *Research and Development.* Vol 2. In: *History of the Chemical Warfare Service in World War II.* Aberdeen Proving Ground, Md: Chemical Corps Historical Office; 1947: 245–246, 248–249. Draft.

103. Office of the Chief, Chemical Warfare Service. *Report of Activities of the Technical Division During World War II.* Washington, DC: CWS; 1946: 172–175.

104. Katz SH. *Standard US Army Gas Masks and Components*. Edgewood Arsenal, Md: Chemical Warfare Service Technical Command; 1944. Technical Division Memorandum Report 878-2.

105. Office of the Chief, Chemical Warfare Service. *New Gas Detector Kit*. Washington, DC: CWS; 12 Sep 44. Information.

106. Cochrane RC. *Biological Warfare Research in the United States*. Office of Chief, Chemical Corps: Historical Section, Plans, Training and Intelligence Division; 1947. Draft.

107. Ditto RC. Will Hitler's goose be cooked with gas? *Chemical Warfare Bulletin*. 1943;29(3):6–7.

108. Chemical Warfare Service. *US Chemical Warfare Policy*. Washington, DC: Operations Division, Dar Department General Staff, Strategy and Policy Group; 14 Jun 1945. Draft.

109. Wing HG. *Gas Warfare Planning: History of the Chemical Warfare Service in World War II.* 1953: 43–58.

110. Finlay WW. Why prepare? *Chemical Corps Journal*. 1946;1(1):24.

111. Royall KC. A tribute to the corps. *Chemical Corps Journal*. 1947;2(1):41.

112. King L. Exit gas warfare? *Chemical Corps Journal*. 1948;2(3):3.

113. *The Army Almanac*. Washington, DC: Government Printing Office; 1950: 89.

114. Waitt AH. *Chemical Warfare Organization and Policy in the Post-War Army*. Washington, DC: Chemical Warfare Service. 9 May 46. Memorandum.

115. Office of the Chief of Chemical Corps. *The History of Captured Enemy Toxic Munitions in the American Zone, European Theater, May 1945 to June 1947*. Headquarters: Chemical Corps, European Command; 1947.

116. Department of the Army. *Chemical Agents of the G-Series*. Washington, DC: HQ, DA; 19 Mar 1948. Circular 74.

117. Department of the Army. *Treatment of Poisoning Caused by Chemical Agents of the G-Series*. 19 Mar 1948. Washington, DC: HQ, DA; Technical Bulletin Chemical Warfare 34.

118. Waitt AH. Chief, Chemical Corps, to Director of Plans and Operations, General Staff, US Army. *Gas Warfare Policy*. Washington, DC: Chemical Corps. 2 May 1949. Memorandum.

119. Loucks CS. The "decons" and the air lift. *Armed Forces Chemical Journal*. 1949;3(6):16, 38.

120. McAuliffe AC. Korea and the Chemical Corps. *Ordnance*. 1951;35(184):284.

121. Department of the Army. *Transfer of the Responsibilities for the 4.2-inch Chemical Mortar and Related Equipment to the Ordnance Department*. Washington, DC: HQ, DA; 9 Feb 1948. Memorandum.

122. Rodier HB. Editorial. *Armed Forces Chemical Journal*. 1951;4(3):3.

123. Baker ER. Chemical warfare in Korea. *Armed Forces Chemical Journal*. 1951;4(4):3. Letter.

124. Probe into biological experiments on Korean War POWs reported. *Washington Times*. 15 Aug 1992.

125. Bullene EF. The needs of the army. *Armed Forces Chemical Journal*. 1952;6(1):8.

126. Abolish unit gas officer positions. *Armed Forces Chemical Journal*. 1954;8(5):4.

127. Hylton AR. *The History of Chemical Warfare Plants and Facilities in the United States*. US Arms Control and Disarmament Agency: Midwest Research Institute; 1972;4:59–75. ACDA / ST-197.

128. Fielding GH. *V Agent Information Summary*. Washington, DC: US Naval Research Lab; 1960: 1–2. NRL Report 5421.

129. US Army Chemical Corps. *Summary of Major Events and Problems, FY58*. Army Chemical Center, Md: US Army Chemical Center Historical Center; Mar 1959: 97–101, 108–111, 153–158.

130. US Army Chemical Corps. *Summary of Major Events and Problems, FY59*. Army Chemical Center, Md: US Army Chemical Center Historical Center; Jan 1960: 101–105, 112–114, 117–118, 160–162.

131. US Army Chemical Corps. *Summary of Major Events and Problems, FY57*. Army Chemical Center, Md: US Army Chemical Center Historical Center; Oct 1957: 97–98, 103.

132. Smart JK. Biological Weapons. Aberdeen Proving Ground, Md: US Army Chemical and Biological Defense Command; 1996. Special Study 55. Not cleared for public release.

133. The Inspector General, Department of the Army. *Use of Volunteers in Chemical Agent Research*. Washington, DC: DA, IG; 1976. DAIG-IN 21-75.

134. US Army Chemical Corps. *Summary of Major Events and Problems, FY55*. Army Chemical Center, Md: US Army Chemical Center Historical Center; Dec 1955: 48–49, 61–62, 133.

135. US Army Chemical Corps. *Summary of Major Events and Problems, FY56*. Army Chemical Center, Md: US Army Chemical Center Historical Center; Nov 1956: 128–130, 133–134, 140–141.

136. US Army Chemical Corps. *Summary of Major Events and Problems, FY54*. Army Chemical Center, Md: US Army Chemical Center Historical Center; n.d: 35–36.

137. Chemical Corps Technical Committee. *Standardization of Agent, Decontaminating, STB and Antiset, M1; Reclassification of Bleaching Material, Grade 3*. Army Chemical Center, Md: CCTC; 1950. Memorandum.

138. Creasy WM. The forward look in the Army Chemical Corps. *Armed Forces Chemical Journal*. 1957;11(4):26.

139. Stubbs M. CBR—A power for peace. *Armed Forces Chemical Journal*. 1959;13(3):8–9.

140. Stubbs M. Presentation to Directors, New York State Civil Defense Commission; 9 Feb 1960; Hotel Thayer, West Point, NY. Speech.

141. US Army Chemical Corps. *Summary of Major Events and Problems, FY1961–62.* Army Chemical Center, Md: US Army Chemical Center Historical Center; n.d: 9–20, 124–126, 131–132.

142. Palmer JM. Chemical warfare training. *Armed Forces Chemical Journal*. 1930;14(6):28.

143. Anckaitis WH. Realistic CBR training. *Armed Forces Chemical Journal*. 1964;18(3):16.

144. Harrigan A. The case for gas warfare. *Armed Forces Chemical Journal*. 1963;17(2):12.

145. United Press International. Mustard gas use suggested. *Washington Post*. 18 Oct 1966;A-2.

146. Badeeb SM. *The Saudi–Egyptian Conflict Over North Yemen, 1962–1970*. Boulder, Colo: Westview Press; 1986: 2–41.

147. Meselson M. The Yemen. In: Rose S, ed. *CBW: Chemical and Biological Warfare*. Boston, Mass: Beacon Press; 1968: 99.

148. Pearson D, Anderson J. Egypt's use of gas in Yemen verified. *Washington Post*. 6 Jun 1967.

149. Childs M. Chemical warfare and a death wish. *Washington Post.* 21 Jun 1967;A-20.

150. How Nasser used poison gas. *US News & World Report*. 3 Jul 1967;60.

151. Cromley R. Russians use Yemen as lab for "poison gas." *Washington News*. 24 Jul 1967.

152. Nasser stoops lower. *Chicago Daily News*. 31 Jul 1967.

153. Cromley R. Why Israel stocks up on gas masks. *Detroit News*. 8 Aug 1967.

154. Dupuy TN. *The Encyclopedia of Military History From 3500 BC to the Present*. New York, NY: Harper & Row; 1986: 1279–1280.

155. Hersh SM. *Chemical and Biological Warfare: America's Hidden Arsenal.* New York, NY: Bobbs-Merrill; 1968: 286–287.

156. US Army Chemical Corps. *Summary of Major Events and Problems, FY60*. Army Chemical Center, Md: US Army Chemical Center Historical Center; 1961: 108, 115–117.

157. Department of the Army. *US Army Activity in the US Biological Warfare Programs*. Washington, DC: HQ, DA; 1977. Draft.

158. Edgewood Arsenal. *Consent to Inoculation With Experimental Biological Products*. Edgewood Arsenal, Md: Edgewood Arsenal; 1965.

159. Medical Investigation Division. *Nominees for Special Procedures Program.* Edgewood Arsenal, Md: Medical Investigation Division; 9 Nov 1965. Memorandum.

160. US Army Materiel Command. *Classification of Collective Protection Equipment, Guided Missile Van, NIKE-HERCULES, Trailer-Mounted, M1 (E1R1) as a Standard–B Type & Component of the Related Air Conditioner–Collective Protector (AC–CP)*. Washington, DC: AMC; 23 Dec 1963. Memorandum.

161. Department of the Army. *Chemical Weapons and Defense Equipment.* Washington, DC: HQ, DA; 1972: 147–148, 163, 185–186, 245. Training Manual 750-5-15.

162. Stone WW. *Report of Investigation Concerning Sheep Deaths in Skull Valley, Utah.* Washington, DC: US Army Materiel Command; n.d. A-1.

163. Associated Press. Army speeds removal of Okinawa gas. *Washington Post*; 3 Dec 1969;A-3.

164. Stockholm International Peace Research Institute. *CB Weapons Today*. Vol 2. In: *The Problem of Chemical and Biological Warfare*. New York, NY: Humanities Press; 1973: 193.

165. Ward PF. *A Summary of Ecological Investigations at Edgewood Arsenal, Maryland: Fiscal Year 1970.* Edgewood, Md: Edgewood Arsenal Research Labs; 1971: 15–23. Edgewood Arsenal Special Publication 100-101.

166. Reducing the terror of war. *Commanders Digest*. 20 Dec 1969;4–5.

167. Wagner RL, Gold TS. Why we can't avoid developing chemical weapons. *Defense*. 1982;3.

168. Fair SD. The chemical corps: Alive, well and visible. *Army*. 1972;29–32.

169. "Preferred alternative" would move chemical training to Ft. McClellan. *APG News.* 4 Apr 1979;A-1.

170. Chemical Corps School. *Chemical School*. Fort McClellan, Ala: Chemical Corps School; n.d.

171. Guiler DC Jr. Chemical Corps: A branch in search of an identity. *Army*. 1977;14, 15.

172. Foreign Science and Technology Center. *Foreign Materiel Exploitation Report, Detection Kit, Chemical Agent, Model PKhR-MV (Soviet) (U)*. Washington, DC: Foreign Science and Technology Center; 1975. AST-1640X-174-75.

173. US Army Armament Research and Development Command. *Laboratory Posture Report*. Dover, NJ: ARRADCOM; Fiscal Year 1978: 3–4.

174. Gas antidote. *Washington Star-News.* 18 Jul 1974.

175. Eifried G. Russian CW: Our Achilles' heel, Europe. *Army*. 1979;29(12):24–28.

176. Kastenmayer WW. A rebirth of chemical R&D. *Army Research, Development & Acquisition Magazine*. 1981;22 (4):13–15.

177. Siebert GW, Choi YH. Chemical weapons: Dull swords in the US armory. *Military Review*. 1985;65(3):23–29.

178. Famiglietti G. Army may switch decision, reestablish Chemical School. *Army Times*. 22 Jan 1979.

179. Chemical Corps School. *The Chemical Corps Regimental Activation Ceremony*. Fort McClellan, Ala: Chemical Corps School; 1986. Pamphlet 27.

180. US Army Chemical Corps. *Wizard of Battle*. Fort McClellan, Ala: Army Chemical Corps; n.d. Pamphlet.

181. *Fort McClellan*. Fort McClellan, Ala: National Military Publications; 1983: 3. Pamphlet.

182. Department of the Army. *Binary Chemical Munitions Program*. Aberdeen Proving Ground, Md: Chemical Systems Laboratory; 1981: 1–7. Programmatic Environmental Impact Statement ARCSL-EIS-8101.

183. Ward FP. *Construction and Operation of a 155mm M687 GB2 Binary Production Facility at Pine Buff Arsenal, Jefferson County, Arkansas*. Aberdeen Proving Ground, Md: Chemical Systems Laboratory; 1981: 3–7. Environmental Assessment ARCSL-EA-8101.

184. US Army Materiel Command. *Classification of Paper, Chemical Agent Detector, VGH, ABC-M8 as a Standard-A Type & Reclassification of the M6 as Obsolete & M6A1 as Standard-B Papers; & Completion of Task 1C643606D02202, Nonvolatile Agent Contamination Detector*. Washington, DC: AMC; 1 Nov 1963. Memorandum.

185. NBC nuggets. *NBC Readiness Bulletin.* 1978;4:1, 5.

186. US Army Materiel Command. *Approval of Minutes of Development Acceptance (DEVA) Review and the Reclassification to Standard-A of Shelter System, Collective Protection, Chemical-Biological: Inflatable, 10-man, Trailer-Transported, M51 (XM51).* Washington, DC: AMC; 3 Aug 1971. Memorandum.

187. Department of Defense Appropriation Authorization Act. Public Law 95-79, 30 Jul 1977.

188. Keegan RJ. Definition of policy of the USA and USSR on chemical and biological warfare. *Commander's NU-CH Flash*. 1982;9:6. Bulletin of the US Army Nuclear and Chemical Agency.

189. Haig AM Jr. *Chemical Warfare in Southeast Asia and Afghanistan*. Report to the Congress from Secretary of State Alexander M. Haig, Jr. Washington, DC: US Department of State; 1982. Special Report 98.

190. Hilts PJ. '79 anthrax traced to Soviet military. *New York Times*. 18 Nov 1994.

191. Smith RJ. Yeltsin blames '79 anthrax on germ warfare efforts. *Washington Post*. 16 Jun 1992.

192. DeWeese K. Outbreak tied to microbiology site. *APG News*. 23 Mar 1994.

193. Collins JJ. The Soviet military experience in Afghanistan. *Military Review*. 1985;65(5):27.

194. Hoffman MS, ed. *The World Almanac and Book of Facts, 1990*. New York, NY: Pharos Books; 1990: 44, 46, 49, 721.

195. Spiers EM. *Chemical Weaponry: A Continuing Challenge*. New York, NY: St. Martin's Press; 1989: 121.

196. Dunn P. The chemical war: Journey to Iran. *Nuclear, Biological, and Chemical Defense and Technology International*. 1986;28–35.

197. Associated Press. Iraqi gas attack on Kurds disputed. *Washington Times*. 18 Dec 1990.

198. Rohrbaugh DK, Ward JR, Yang Y. *Comments on the Origin of Mustard in the Gulf War*. Aberdeen Proving Ground, Md: US Army Chemical Research Development and Engineering Center; 1990: 8. Technical Report.

199. Dunn P. *Chemical Aspects of the Gulf War, 1984–1987, Investigations by the United Nations.* Ascot Vale, Australia: Materials Research Laboratories; 1987.

200. United Nations. *Report of the Mission Dispatched by the Secretary-General to Investigate Allegations of the Use of Chemical Weapons in the Conflict Between the Islamic Republic of Iran and Iraq*. New York, NY: United Nations Security Council; 12 Mar 1986: 19.

201. Special to The New York Times. UN Panel says Iraq used gas on civilians. *New York Times*. 24 Aug 1988.

202. Dingeman J, Jupa R. Chemical warfare in the Iran–Iraq conflict. *Strategy & Tactics*. 1987;113:51–52.

203. Morrison J. Angola again tied to use of nerve gas. *Washington Times*. 11 Mar 1988.

204. Lancaster P. Fighting guerrillas with gas. *The Middle East*. 1 Jun 1987;17.

205. Wayne EA. Libya seeks chemical weapons in war against Chad, US charges. *Christian Science Monitor*. 5 Jan 1988;A-1.

206. Satchell M, Blaug E. A plague of "hellish poison." *US News & World Report*. 26 Oct 1987;30.

207. Historical Office, US Army Armament, Munitions and Chemical Command. *US Army Chemical Research, Development and Engineering Center (CRDEC) Annual Historical Review (AHR).* Aberdeen Proving Ground, Md: AMCCOM; Fiscal Year 1987: 195.

208. US Army Materiel Command. *Materiel Status Record Submission 11876009*. Washington, DC: AMC; 23 Sep 1987. Memorandum.

209. New mask replaces M17 and M9A1. *Army Chemical Review*. 1988;44–45.

210. Chemical Systems Laboratory. *Summary History*. Aberdeen Proving Ground, Md: Chemical Systems Laboratory; Fiscal Year 1980: 142–143, 158.

211. Department of the Army. *NBC Protection*. Washington, DC: HQ, DA; 1992. Field Manual 3-4.

212. Historical Office, US Army Armament, Munitions and Chemical Command. *US Army Chemical Research and Development Center (CRDC) Annual Historical Review (AHR)*. Aberdeen Proving Ground, Md: AMCCOM; 1 Jul 1983–30 Sep 1984: 73–76.

213. Chemical Warfare Review Commission. *Report of the Chemical Warfare Review Commission*. Washington DC: Chemical Warfare Review Commission. Washington, DC: Government Printing Office; 1985: 50, 73.

214. The chemical strategy. *Army Chemical Review*. Jan 1988;23.

215. Historical Office, US Army Armament, Munitions and Chemical Command. *US Army Chemical Research, Development and Engineering Center (CRDEC) Annual Historical Review (AHR).* Aberdeen Proving Ground, Md: AMCCOM; Fiscal Year 1988: 8–9, 106–108.

216. Army weaponry and equipment. *Army*. 1990;40(10):326.

217. Parker C. Toxic chemical training. *Army Chemical Review*. Sep 1987;15.

218. Polley W, Dlugopolski M, Hartzell W. 40,000 train in chemical environment. *Army Chemical Review*. Jan 1988;26–31.

219. US Congress, Office of Technology Assessment. *Disposal of Chemical Weapons: Alternative Technologies—Background Paper*. Washington, DC: Government Printing Office; 1992. OTA-BP-O-95.

220. Yockey DJ, Deputy Under Secretary of Defense (Acquisition). *United States Chemical Programs*. Washington, DC: Department of Defense; 12 Jul 1990. Memorandum For Secretaries of the Military Departments, et al.

221. Reid B. Experts debating Saddam's threat to use chemicals. *Baltimore Evening Sun*. 22 Jan 1991.

222. Baker C. Tenacity may be Iraqi ace. *Army Times*. 4 Feb 1991.

223. Atkinson R. No chemical arms found on battlefields. *Washington Post*. 7 Mar 1991.

224. Associated Press. UN arms monitors destroy Iraqi germ-weapons plant. *Baltimore Sun*. 21 Jun 1996;A-22.

225. Iraqi weapons plant destroyed. *Military Newswire*. 1996.

226. Smith RJ. Iraq had program for germ warfare. *Washington Post*. 6 Jul 1995;A-1.

227. Crossette B. Iraq gives UN fuller details on its germ warfare program. *New York Times*. 23 Aug 1995.

228. Barker RB. The future of the DOD chemical/biological defense program. *Defense*. 1992;May–Jun:27.

229. Herbig AT. Nerve agents—their physiological effects. *Army Chemical Review*. 1990;July:9–13. PB 3-90-2.

230. Smart JK. *Desert Storm Diary*. Aberdeen Proving Ground, Md: US Army Chemical and Biological Defense Command; 1991. Not cleared for public release.

231. Johnson SS. Cheney fears chemical attack possible. *USA Today*. 28 Jan 1991.

232. Gertz B. Nerve gas detected by Czechs during Gulf War. *Washington Times*. 7 Sep 1993.

233. Gulf War veterans link ailments to destruction of Iraqi bunker. *Baltimore Sun*. 11 Aug 1996;A-3.

234. American soldiers may have been exposed to Iraqi chemical weapons, Pentagon says. *Baltimore Sun*. 22 Jun 1996;A-10.

235. New York Times News Service. 20,000 troops may have faced gas. *The Sun*. 23 Oct 1996:A-1.

236. Matthews M. US warns Iraq against using chemical arms. *Baltimore Sun.* 10 Mar 1991.

237. Tyler PE. Baghdad reportedly told commanders to use chemicals *Baltimore Sun*. 10 Mar 1991.

238. Wines M. US hints at chemical arms bunker in Libya. *New York Times*. 7 Mar 1991.

239. New York Times News Service. Libya close to finishing huge chemical weapons plant. *Baltimore Sun*. 25 Feb 1996;A-20.

240. US Army Chemical and Biological Defense Command. *AMC Accomplishments During General Ross' Period of Command*. Aberdeen Proving Ground, Md: CBDCOM; n.d.

241. NBCRS headed for production. *The Catalyst*. 1995;1(2):4.

242. Alarming news: M21 alarm approved for production. *The Catalyst*. 1995;1(1):1, 4.

243. Moore A. Putting the "B" back in NBC. *Soldiers*. 1996;51(4):36.

244. Adams JR. Russia's toxic threat. *Wall Street Journal.* 30 Apr 1996.

245. Englund W. Ex-Soviet scientist says Gorbachev's regime created new nerve gas in '91. *Baltimore Sun*. 16 Sep 1992.

246. Lewthwaite GA. Terrorist attacks in US expected. *Baltimore Sun*. 1 Nov 1995;A-1.

247. Associated Press. Japanese guru will hear litany of nerve-gas victims. *Baltimore Sun*. 21 Apr 1996;A-22.

248. Congress probes Japanese cult. *Military Newswire*. 1996.

249. Birch D. Bubonic plague sample delivered to white racist. *Baltimore Sun*. 18 May 1995;A-4.

250. Wire Reports. Bio-terrorism sentence. *Baltimore Sun*. 19 May 1995;A-3.

251. Associated Press. ATF officials say they've instituted reforms since Waco. *Baltimore Sun*. 1 Nov 1995;A-10.

252. Wire Reports. Anti-terrorism training bill clears senate on 96–0 vote. *Baltimore Sun*. 28 Jun 1996;A-10.

253. *Defense Against Weapons of Mass Destruction*. House Bill HR 3730; 27 Jun 1996.