Chapter 1

OCCUPATIONAL HEALTH IN THE U.S. ARMY, 1775–1990

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INTRODUCTION

Occupational health applies the disciplines of medicine, biology, epidemiology, engineering, economics, education, politics, and the law to protect workers from hazards in the workplace.[1] The army's occupational health effort, the U.S. Army Occupational Health Program, has a set of defined goals and objectives and is accompanied by a plan and the resources necessary to achieve success.

Diseases and the injuries associated with productive labor accompany human history. Pliny the Elder (AD 23–70), a Roman scholar, recommended that workers wear masks to prevent inhaling dust and fumes. Georgius Agricola (1494–1553), a German physician, wrote a classic volume describing the diseases and accidents that befall miners and ways to prevent those diseases. The father of occupational medicine, Bernardino Ramazzini (1633–1714), studied and practiced in Italy. His treatise on working conditions and occupational diseases included diseases of military service (*De Morbis Castrensibus*) and *cautions,* or preventive measures. Ramazzini is credited with formulating the question that must be asked about every patient: "What occupation does he follow?"[2–4]

The long-standing interest in Europe in workers' health had no parallel in the United States. Massachusetts created this country's first factory-inspection office in 1867, and the Knights of Labor, a labor group formed later during the 19th century, fought for health and safety measures in mining and other industries. Noteworthy achievements, however, were few.[2,5] Alice Hamilton, M.D. (1869–1970), the pioneer who established occupational health as a specialty in medicine, described early 20th-century conditions (Figure 1-1):

> American medical authorities had never taken industrial diseases seriously, the American Medical Association has never held a meeting on the subject, and while European journals were full of articles on industrial poisoning, the number published in American medical journals up to 1910 could be counted on one's fingers.
>
> For a surgeon or physician to accept a position with a manufacturing company was to earn the contempt of his colleagues as a "contract doctor"; as for factory inspection and control, we never discovered a trace of it.
>
> This ignorance and indifference was not confined to the medical profession—employers and workers both shared it. The employers could, if they wished, shut their eyes to the dangers their workmen faced, for nobody held them responsible, while the workers accepted the risks with fatalistic submissiveness as part of the price one must pay for being poor.[6(pp3–4)]

The development of the U.S. Army Occupational Health Program and the civilian occupational health movement were closely related. Military program efforts were directed primarily at (*a*) the army's civilian worker in the industrial setting, (*b*) the soldier in the industrial setting, and (*c*) the soldier with militarily unique exposures.

THE CIVILIAN WORKER IN WORLD WAR I

U.S. Army Medical Department (AMEDD) involvement with civilian-employee health programs began during World War I because poisonous military chemicals were being produced and used on the battlefield.[7,8] After the German army launched an effective chlorine gas attack against French and Canadian troops in 1915, army medical officers were assigned to the British and French armies as gas warfare observers and reported their observations on gas defense. As a result of the army's concern about gas defense, and possibly related to the observers' reports, AMEDD was assigned the mission to furnish gas masks and other gas-defense equipment to the army. Later, this mission was transferred to the Chemical Warfare Service.[9,10]

Gas Production and Gas Protection Plants

Gas-defense equipment was procured under contract, but the U.S. Army's Office of The Surgeon General (OTSG) had to build and supervise its own plant to manufacture items that were not available commercially. To develop and test procedures for gas defense, some AMEDD personnel participated in experiments and training exercises that dealt with the use of poisonous gases in warfare. The OTSG quickly became convinced that all soldiers and civilian workers who might be exposed to poisonous gas in any setting, including gas factories, must be provided protection and medical care. Lacking expertise in providing

Fig. 1-1. Dr. Alice Hamilton was so impressed by the morbidity and mortality associated with occupational exposures that she devoted her professional life to the practice of occupational medicine. This occurred at a time when American physicians knew nothing about this field or showed little interest in it. Dr. Hamilton was also a pioneer in other respects. After she received her M.D. degree in 1893 from the University of Michigan, she studied in Europe and at The Johns Hopkins University in Maryland; taught pathology at the Woman's Medical School, Northwestern University, in Chicago; and in 1919 became the first woman faculty member at Harvard University. Photograph: Reprinted from United States Public Health Service. *Man, Medicine, and Work*. Washington, DC: USPHS; 1964. Publication 1044.

protection against war gases, the OTSG obtained assistance from the U.S. Bureau of Mines (Department of the Interior), several major universities, and the Marine Biological Laboratory at Woods Hole, Massachusetts. A collaborative program with the Bureau of Mines for supervising the *sanitary supervision* (health and safety evaluations) of government- and contractor-operated gas factories resulted from this effort.[10,11]

Munitions Industries

Because American manufacturers had previously relied heavily on the German chemical industry, they lacked experience in producing (and protecting their workers against) not only chemical warfare agents but also many of the other chemicals needed for wartime use. Additionally, even though American manufacturers were concerned about preventing explosions in their plants, they had no interest in the toxicity of industrial chemicals, particularly unfamiliar ones like picric acid and trinitrotoluene (TNT).

The first beehive coke ovens in the United States were built in southwestern Pennsylvania in 1841 to produce coke from coal for iron and steel production (Figure 1-2).[12] During the early years of World War I, American industries, especially those dealing with coke by-products, had to reconfigure to produce dyes, aniline (needed to make dyes and rubber), and nitric acid (needed to make munitions). Dr. Hamilton, working for the Department of Labor, conducted inspections of these factories.[6] Sometimes *canaries* (workers stained yellow with picric acid) led her to the plants; at other times she located the industrial sites

> by the great clouds of yellow and orange fumes, nitrous gases, which in those days of crude procedure rose to the sky from picric-acid and nitrocellulose plants. It was like the pillar of cloud by day that guided the children of Israel.[6(p184)]

Both Dr. Hamilton and army sources document occupational exposures in the munitions industry as causes of morbidity and mortality.[6,13] In a 1917 report,

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Fig. 1-2. The first beehive ovens in the United States were built in southwestern Pennsylvania in 1841 to produce coke from coal for iron and steel production. Near the turn of the century, spurred by the loss of products from the German chemical industry during World War I, American industrialists began to seek better ways to make coke and to capture the chemicals necessary for manufacturing explosives and other synthetic materials. However, the severe air pollution associated with beehive coke ovens continued into the second half of the 20th century. Source: Hamilton A. *Exploring the Dangerous Trades, the Autobiography of Alice Hamilton, M.D.* Boston: Little, Brown and Co; 1943. Photograph: Reprinted with permission from Gates JK. *The Beehive Coke Years: A Pictorial History of Those Times.* Uniontown, Pa: John K. Gates; 1990.

Dr. Hamilton identified 2,432 instances of occupational poisoning. Oxides of nitrogen accounted for 1,389 cases, and 28 of 53 deaths. TNT exposure was considered to be the cause of 660 illnesses and 13 deaths.[6] Similarly, army sources reported a total of 475 fatalities—all or nearly all civilians, presumably due to occupational diseases—from exposure to TNT and related compounds during World War I.[13] According to the chief of ordnance, factories in the United States, which produced 40% of the military explosives used by the allies during World War I, reported a ratio of 230 fatalities (presumably due to occupational diseases) per billion pounds of explosives manufactured.[13]

Dr. Hamilton considered poisoning from oxides of nitrogen to be an engineering problem, which the manufacturers addressed effectively over time, but preventing TNT poisoning was more difficult because this hazard either was not recognized or simply was neglected. In England, medical scientists determined that TNT was absorbed through the skin and manufacturers addressed the need for plant cleanliness and personal cleanliness, including showers at the worksite and washable work clothing, to reduce the potential for skin contact and accidental ingestion. Unfortunately, American manufacturers did not. Furthermore, a wealth of clinical information concerning TNT poisoning had been accumulated in England, but American physicians did not know what to look for, were indifferent, or were secretive.[6]

Dr. Hamilton's attacks on the explosives industry resulted in (*a*) the National Research Council's (NRC's) appointing an expert committee to act as a consultative body and (*b*) her working to establish a code to protect TNT workers. Eventually, the expert committee made it possible for medical students to visit TNT plants to study exposures and poisonings. In April 1919, 5 months after the armistice, a code was published. However, not only was it weaker than the English code, it was also voluntary.[6]

Although Dr. Hamilton was a pacifist, she acknowledged that occupational health in America advanced as a result of World War I:

Fig. 1-3. This April 1942 photograph from the U.S. Army Ordnance Department shows workers measuring smokeless powder, which contains a nitrate or nitroglycerin compound, and pouring the powder into bags, which will later be used to propel projectiles from guns or cannons. Although the dangers of skin absorption in the munitions industry and the need for washable work clothing were recognized in the World War I era, these early–World War II workers labored in street clothes without any evidence of concern about skin contact with the powder. Source: Hamilton A. *Exploring the Dangerous Trades, the Autobiography of Alice Hamilton, M.D.* Boston: Little, Brown and Co; 1943. Photograph: U.S. Army Ordnance Department, 1942.

> The war did have a beneficial influence on industrial hygiene. If it increased the dangers in American industry, it also aroused the interest of physicians in industrial poisons. And that interest has never died down, on the contrary it has increased with the increasing complexity of methods of manufacture. A change took place also in the attitude of employers, for a large labor turnover was found to be not only wasteful but an unsatisfactory method of dealing with dangerous processes in industry. The Public Health Service had entered this field during the war and the medical journals had published articles discussing the action of the new poisons and various methods of preventing danger from the old ones. Industrial medicine had at last become respectable.[6(p198)]

When World War I ended, the medical division of the Chemical Warfare Service continued to do toxicological research and to develop treatments for chemical casualties.[11] However, the army's interest in the health of its civilian employees all but disappeared (Figure 1-3), and when war recurred, the army would again turn to the civilian community to meet its occupational health requirements.[8,13–18]

THE CIVILIAN WORKER IN WORLD WAR II

During the 1930s, first aid was the only occupational health service available to civilian employees of government-owned industrial plants. Part-time contract surgeons, nurses, and enlisted personnel provided this care whenever the War Department (which would later become the Department of the Army [DA]) recognized that a need existed. This changed on 10 August 1938, when the chief of ordnance requested that additional medical services be made available to employees of the army who were engaged in potentially hazardous jobs—particularly those handling TNT. He recognized that the army had a legal responsibility to provide diagnostic and preventive measures for occupational illnesses. The surgeon general knew of no requirement for AMEDD to furnish these services, but recommended that the matter be referred to higher authority. As a result, the adjutant general arranged for additional pay for contract surgeons to perform periodic physical examinations on civilian employees with potentially hazardous exposures.[13] It is interesting to note that it was the chief of ordnance, and not AMEDD, who led the effort to initiate prevent-ive medical services for the army's civilian employees.

The Army's Responsibility for Employee Health

Between 1939 and 1940, the Ordnance Department expanded its activities and continued to place pressure on the surgeon general to confront occupational health issues. The questions: Who should receive occupational health services?; How should the services be implemented?; and How should the needed professional expertise be obtained? were discussed repeatedly. On 18 November 1940, the surgeon general assumed responsibility for the medical care of civilian employees, but only for those who worked at Ordnance Department arsenals. However, he realized that other technical services, like the Quartermaster Corps, also were expanding and had similar needs. (The identification and definition of these occupational health needs were accomplished, at least in part, through site visits and inspections in which the U.S. Public Health Service [USPHS] played a major role.) In September 1941, the army surgeon general requested authority to establish an armywide industrial medical program. The adjutant general responded in January 1942 by directing AMEDD to provide emergency treatment for military and civilian workers and to supervise industrial hygiene practices, but only in army-operated industrial plants (Figure 1-4). Provisions were made for space, equipment, money, and personnel to support the effort.[13]

The participants in an industrial medical conference in August 1942 estimated that the army owned and operated more than 160 industrial plants that employed approximately 400,000 civilians. The army's stated responsibility to this work force was to determine that (*a*) employees are physically fit for their work, (*b*) the conditions under which employees work are safe and sanitary, (*c*) adequate industrial medical service is provided, and (*d*) injuries that occur to employees while they are on duty are reported to the U.S. Employees' Compensation Commission, when indicated.[13]

Expanding the Industrial Medical Program

The surgeon general was under constant pressure to expand the industrial medical program to encompass *all* War Department employees, not just those at industrial installations. He resisted due to a lack of funds and trained personnel. In December 1942, he established a medical program for the approximately 40,000 civilian employees—whose duties were primarily clerical—at the Pentagon. (This reduced the absences from work that occurred when employees needed to visit their personal physicians.) Eventually,

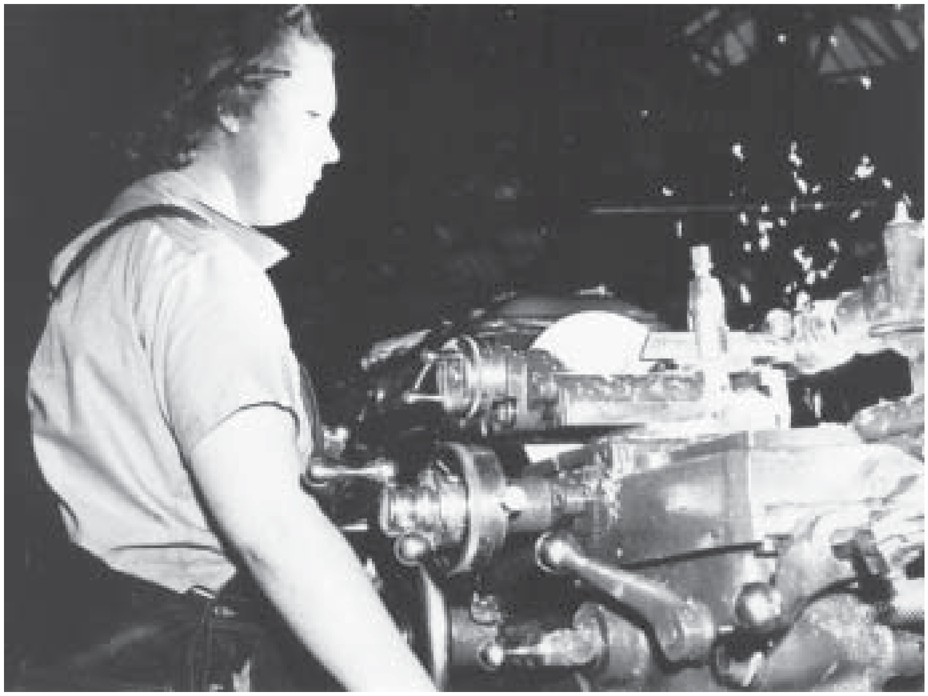

Fig. 1-4. This photograph of an 18-year-old woman operating a lathe, with a caption stating that the "chips are flying," was proudly released by the U.S. Army Ordnance Department in May 1942 as an example of a woman operating a machine that had previously been operated by a man. The photograph itself, its original caption, and the fact that they were released demonstrate that recognition of the need for industrial hygiene controls such as eye protection was lacking. In January 1942, the adjutant general directed the Army Medical Department (AMEDD) to supervise industrial hygiene practices in army-operated industrial plants. Source: Anderson RS, ed. Special fields. In: *Preventive Medicine in World War II.* Vol 9. Washington, DC: DA Office of The Surgeon General; 1969. Photograph: US Army Signal Corps, 1942.

in June 1945, emergency medical treatment services were expanded and made available to all civilian employees of all U.S. Army Service Forces installations. (This was one of the three major commands; the other two were the U.S. Army Air Force and the U.S. Army Ground Forces, and included corps areas and technical supply services.)[13]

Special Considerations for Pregnancy

By 1944, women constituted 40% to 70% of the employees in many army industrial plants. The number of women in the work force had not only increased during the war years but their job assignments also included most types of work. Women were soon given special consideration for medical services. In July 1944, a War Department policy statement on pregnancy was issued and was considered to be the first of its kind in American industry. This policy, which commanders considered a major advance in employee relations, (*a*) limited the work period relative to weeks of pregnancy and the postpartum period, (*b*) required that the job assignment not endanger the employee's health, and (*c*) ensured that job seniority would not be lost as a result of pregnancy.[13]

Special Considerations for Infectious Diseases

In addition to medical services involving women, infectious diseases were also given special consideration. Tuberculosis and venereal diseases in civilian employees were matters of concern. At no cost to the army, the USPHS conducted tuberculosis surveys and case finding among workers of army-owned and army-operated industrial plants.

Workers exposed to TNT or other chemicals that might cause systemic illnesses received routine serological tests. However, these were required only for employees who had been hired for jobs that might jeopardize their health if they had, or were being treated for, syphilis.[13] (Because syphilis was treated with arsenicals that could injure multiple organs, the concern was that the patient would sustain multiple toxicities.)

Special Considerations for Occupational Health Overseas

Interest in and debate regarding American and foreign-national civilians working for the U.S. Army overseas centered on the army's need to do preemployment and preassignment medical screening and the rights of these employees to receive emergency medical care and compensation for job-related injuries and illnesses. There was particular concern about hiring large numbers of foreign nationals without evaluating their health status, especially if they might have communicable diseases. Although overseas civilian-employee medical programs received considerable discussion, better programs should and could have been established. The Occupational Health Division of the OTSG, in evaluating the World War II–overseas programs, recommended that

> the basic plan for future operations in foreign areas ought to include more competent means of medical and engineering control of industrial operations wherever troops are so engaged and civilian employees assist them.[13(p130)]

Ironically, however, the first U.S. Army Occupational Medicine Consultant in Europe (discussed later in this chapter) was not assigned until 1983.

Organizational Advances in Providing Occupational Health Services

The army made significant advances in occupational health in several other areas during World War II: (*a*) occupational health representation in the OTSG was firmly established, (*b*) the U.S. Army Environmental Hygiene Agency (USAEHA) was founded, and (*c*) progress was made in the effort to protect the health of workers in munitions and other wartime industries.

Representation in the U.S. Army Surgeon General's Office

Recognition that occupational health needed to be represented in the OTSG resulted in the 1941 establishment of the Industrial Hygiene Section of the Preventive Medicine Division. In 1942, a separate Occupational Health Division was formed and headed by Lieutenant Colonel Anthony J. Lanza, who developed a 15-point plan for implementing the army's Occupational Health Program. Many of his original points remain appropriate today:

- Worksites with potentially hazardous exposures should be evaluated, and a continuing program of inspection and control should be inaugurated.
- Records should be standardized and should include physical examinations, morbidity reports, and reports of absenteeism.
- Records of mortality and absenteeism should be compiled and compared for all plants.
- Surveys and inspections should be conducted, not only to determine performance and compliance but also to educate civilian and military plant medical officers, plant officials, and workers.
- Health-education programs for employees should be encouraged.[13]

Although his plan eventually succeeded, Dr. Lanza faced inadequate resources including a shortage of doctors and the lack of a policy regarding the practice of occupational health in the army. As its number of industrial employees rapidly increased, the army commissioned physicians with experience in industrial medicine in private life. However, establishing an occupational medicine training program for regular AMEDD officers was considered too time consuming. Those available physicians who had training in general public health were given duty as industrial medical officers, but a shortage of physicians still necessitated that contract surgeons be used.[13] Because trained physicians were few and policy was undeveloped, numerous questions were directed to the Occupational Health Division, U.S. Army Surgeon General's Office. At times, these inquiries showed that some army industrial medical officers simply were not familiar with the standard practice of occupational medicine. In other instances, where the physicians were adequately trained and competent, the questions indicated their difficulty in dealing with the army system. Dr. Lanza realized that both a carefully developed occupational health directive and the guidance necessary to implement the directive were needed. He knew that a document from the OTSG could possibly be more harmful than helpful. Policy that is not developed on the basis of current, accurate data may create unnecessary work, not achieve needed goals, or result in misclassification of priorities. Therefore, staff visits to installations became important vehicles for acquiring data upon which to base policy, establish priorities, and market the army's Occupational Health Program.

By February 1943, sufficient data and experience had been accumulated to warrant issuing War Department Circular Number 59, *Industrial Medical Program of the United States Army*. This document established that industrial medical services would be provided to all employees at installations that were predominantly industrial in nature, regardless of whether or not the job exposures were hazardous. Specifically, the circular stated:

> As an employer, the Army is obligated to furnish safe and hygienic working conditions and to maintain an adequate industrial medical service. The Surgeon General will make all necessary provisions for the supervision of industrial hygiene and for the emergency treatment of military personnel and civilian employees at Army-operated industrial plants.[13(p117)]

Although Circular Number 59 encompassed numerous employees, War Department workers other than those employed in industrial facilities were excluded. By June 1943, War Department civilians not receiving medical services numbered approximately 600,000.[13] However, 730,000 employees were provided medical services under War Department Circular Number 59 at industrial installations that included depots, manufacturing plants, and repair shops of the Quartermaster Corps; arsenals and depots of the Ordnance Department; arsenals of the Chemical Warfare Service; depots and laboratories of the Signal Corps; depots of the Corps of Engineers; and ports of embarkation. In June 1945, medical services were expanded to include emergency treatment for all civilians working at U.S. Army Service Forces installations.[13]

The U.S. Army Industrial Hygiene Laboratory

The U.S. Army Industrial Hygiene Laboratory was established in October 1942 at The Johns Hopkins University School of Hygiene and Public Health in Baltimore, Maryland. Largely through the efforts of Dr. Anna Baetjer, who played a major role in the laboratory, The Johns Hopkins University fostered the development of the field of industrial hygiene before World War II. The laboratory's mission was to

> conduct surveys and investigations concerning occupational health hazards in U.S. Army–owned and U.S. Army–operated industrial plants, arsenals, and depots.[13(pp169–170)]

Of the two phases of the army's occupational health effort—the supervision of workers and the control of the working environment—the latter was centered largely at this laboratory.[8,13,18,19]

Its initial staff—five officers, one enlisted man, and three civilians—accomplished the laboratory's diverse activities. The officers belonged to the first group of civilian professionals, trained or experienced or both in industrial health, and were commissioned specifically to carry out the army's Occupational Health Program.

The laboratory's activities included both periodic and special surveys and special investigations; these industrial hygiene surveys were conducted at 98 installations. The laboratory developed new methods of industrial hygiene sample collection and analysis (eg, the charcoal-tube method, which is used in many chemical analyses). Special studies investigated the combustion products of solid fuels, the lead hazard associated with field stoves and lanterns, and the fungicides used in the manufacture of various military materials. In conjunction with the USPHS, the laboratory also participated in numerous toxicity evaluations with extensive patch testing.[8,13,18] Other services were provided in the areas of engineering design, chemistry, medicine, statistics, education and training, and toxicology.

The Industrial Hygiene Laboratory played an extremely important role throughout World War II. At the end of the hostilities, the army recognized its future value, relocated it to Edgewood Arsenal, Maryland, and renamed it the U.S. Army Environmental Hygiene Agency.[8,13,18]

Occupational Health in Munitions and Other War Industries

Early in the war, ordnance plants were identified as needing effective accident- and occupational disease–prevention programs. As a result, the Industrial Hygiene Branch in the Office of the Chief of Ordnance was established to oversee preventive-medicine efforts in ordnance plants, regardless of who owned or operated the plant. An army physician and two USPHS officers staffed this branch. The USPHS conducted periodic surveys in contractor-operated plants, and the U.S. Army Industrial Hygiene Laboratory conducted the same type of surveys in government-operated plants. The USPHS also provided further assistance by offering the services of the National Institutes of Health (NIH), and the Water and Sanitation Investigations Station. Specifically, the NIH conducted studies of explosives and gasoline additives, and the Water and Sanitation Investigations Station conducted field studies of water pollution. The USPHS and the Bureau of Mines also collaborated with the army in providing occupational health–education programs.[13] The types of plants that received assistance included (*a*) explosives manufacturing works, (*b*) miscellaneous chemical works (that manufactured basic chemicals for explosives), (*c*) small-arms ammunition plants, (*d*) bag-loading plants (that loaded artillery ammunition), (*e*) arsenals, and (*f*) proving grounds.

One hundred one government-owned explosives plants compiled quarterly occupational disease reports. Ten reporting periods, extending from 1 June 1941 through 31 July 1945, encompassed an average of more than 37 months of operation, with an average workforce of 309,000 employees. These reports demonstrated that the greatest hazards were (*a*) poisoning from TNT; (*b*) exposure to lethal concentrations of oxides of nitrogen (generated through the nitration of organic compounds in explosives manufacturing); and (*c*) contact dermatitis from exposure to compounds like *tetryl* (trinitrophenylmethylnitrosamine), a powerful sensitizer that was used as a booster charge in large-caliber ammunition.[13]

In 968,000 *man-years* of operations during World War II (a man-year is defined as the number of workers multiplied by the number of years each worked), 28 occupational disease fatalities occurred, of which 22 were attributed to TNT, 3 to oxides of nitrogen, 2 to carbon tetrachloride, and 1 to ethyl ether—fewer than three fatalities per 100,000 workers per year. Occupational illnesses that resulted in time lost from work amounted to 2.4 cases per 1,000 man-years of production. Dermatitis caused two-thirds of these, with more serious, systemic illnesses causing 0.8 cases per 1,000 man-years of production.[13]

Compared with data acquired during World War I, the army's efforts to establish a vigorous, large-scale occupational health program during World War II were effective. During World War I, American plants experienced 230 fatalities per billion pounds of explosives manufactured. During World War II, however, government-owned, contractor-operated plants (which produced 95% of all military explosives manufactured in the United States) experienced only five disease-related fatalities per billion pounds of explosives manufactured. Moreover, mortality and morbidity rates decreased as World War II progressed, despite the significantly increased production. These results were attributed to

- a coordinated effort by several governmental agencies that provided occupational health services;
- effective industrial-plant surveys that addressed actual and potential problem areas;
- follow-up and enforcement of survey recommendations through operational channels;
- the availability of technical consultation and studies;
- the fulfillment of research requirements; and
- education programs for healthcare providers, management, and workers.[13]

THE OCCUPATIONAL SAFETY AND HEALTH ACT AND THE U.S. ARMY

From the end of World War II until 1970, there were no significant developments in army occupational health. The Occupational Safety and Health Act (OSHAct) of 1970 made employers responsible for providing safe and healthful workplaces, and ensured that federal and state officials developed and enforced meaningful workplace standards. The OSHAct required record keeping and reporting procedures to monitor job-related morbidity and mortality and strongly encouraged employers to improve old programs or develop new programs to reduce, control, or eliminate workplace hazards and associated injuries and illnesses.[3]

The original OSHAct did not include federal workers, civilians employed by the Department of Defense (DoD), or the military. Title 29, Code of Federal Regulations (CFR), Parts 1910 and 1960, subsequently stated that each federal agency shall comply with the standards issued under the OSHAct.[20] The DA's responsibilities were defined clearly in (*a*) Department of Defense Instruction (DoDI) Number 6055, the *DoD Occupational Safety and Health Program*; (*b*) U.S. Army Regulation 40-5, *Medical Services*, *Preventive Medicine*; and (*c*) U.S. Army Regulation 385-10, *The Army Safety Program*. These documents required that the DA

- utilize and comply with the standards promulgated under the OSHAct in all operations and workplaces that are not unique to the military, regardless of whether the work is performed by military or civilian personnel;
- apply safety and health standards promulgated under the OSHAct to militarily unique equipment, systems, operations, and workplaces, in whole or in part, insofar as practicable; and
- develop and publish special military standards when compliance under the OSHAct is not feasible in militarily unique situations, or when no applicable standard exists.[21–23]

The applicability of the OSHAct to DoD and DA civilians was only mildly controversial; however, the question of its applicability in certain instances involving uniformed service members, particularly in training and research settings, generated heated controversy. If the U.S. Army Safety Office determined a certain situation to be militarily unique, the OSHAct provisions did *not* apply to the soldiers involved. However, as specified in DoDI 6055.1 and U.S. Army regulations, such a determination in no way relieved the army of its responsibility to its soldiers in the areas of occupational health and safety.[20–23]

The OSHAct has changed the army's official attitude towards occupational health over the last 20 years, reflected in its leadership's greater recognition of the need for

- effective occupational health services that would reduce or eliminate the threat that the army would be cited for serious noncompliance;
- more comprehensive occupational health services at the installation level, particularly with regard to more responsibility for control of the workplace with less reliance on the USAEHA; and
- effective record keeping and reporting procedures, including current, accurate inventories of hazards.[24]

During the early 1980s, the army's leadership became aware of questions in two areas regarding the adequacy of the army's occupational health services. First, at DoD periodic briefings and in response to congressional and other inquiries, it became apparent to the OTSG, the office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), and the office of the Assistant Secretary of the U.S. Army (Installations, Logistics, and Financial Management) that the army did not maintain current workplace-hazard inventories; furthermore, if applicable standards emanating from the OSHAct, or elsewhere, were being met, no documentation existed. And second, Office of Workers Compensation Programs (OWCP) claims for DA employees were increasing toward $100 million per year.[24] These concerns prompted army leadership to take action to improve compliance with the OSHAct and to reduce workers' compensation claims.

Occupational Health Programs at Army Installations

The offices of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), and the Assistant Secretary of the U.S. Army (Installations, Logistics, and Financial Management) responded to these problems by authorizing 185 civilian occupational health positions and making $19.5 million available to the Occupational Health Program in fiscal year 1984. Additionally, $7.5 million per year was identified for distribution in fiscal years 1985 through 1988. Later, the annual disbursement of significant amounts of money to the army's occupational health effort was extended into the 1990s.

The new civilian positions allowed for stronger occupational health programs at army installations, particularly in the areas of developing and maintaining workplace-hazard inventories. The money purchased contract assistance, new equipment (such as industrial hygiene sampling instruments and mobile occupational health clinics), and a new, comprehensive U.S. Army Occupational Health Management Information System (OHMIS). These new resources were intended primarily to benefit civilian employees working in the United States and overseas, but they also benefited soldiers.[24,25]

The Occupational Health Management Information System

The army developed the OHMIS specifically to meet AMEDD requirements for data collection, management, and analysis. OHMIS is a three-module, integrated system consisting of (*a*) the Hearing Evaluation Automated Registry System (HEARS), which addresses audiometric testing and workplace noise data; (*b*) the Health Hazard Information Management (HHIM) system, which maintains workplace-hazard inventory data and information on control of hazards; and (*c*) the Medical Information Module (MIM), which provides assistance in the management of clinical services including medical surveillance. OHMIS was a major step toward modernizing and standardizing occupational health data collection, storage, retrieval, and use.[24,26]

Overseas Programs

The recommendation that plans for future military or industrial operations in foreign areas that include soldiers and civilians ought also to include an occupational health program emanated from World War II.[13] But by 1980, still no defined, comprehensive occupational health program existed in any army overseas command. Occupational health needs overseas had not been totally neglected, however. Both the Tenth Medical Laboratory in Germany and the U.S. Army Pacific Environmental Health Engineering Agency in the Far East provided workplace evaluations, consultations, and environmental services. Additionally, the USAEHA performed routine and special studies outside the United States.[8] However, a defined program combining medicine, nursing, and industrial hygiene, with strong installation programs supported by the USAEHA and other laboratories, did not exist. A policy that addressed overseas occupational health programs was also weak or absent.[24] Even though the OSHAct in itself did not apply outside the United States, its applicability to overseas DA civilians and soldiers was covered in regulations and in a DoDI.[20–23]

In 1983, the OTSG initiated overseas army occupational health programs. The army's first occupational health consultant in Europe was assigned to establish the policy and framework needed to support a commandwide program.[27] A major reason that establishing the position of European occupational health consultant was so long delayed was that fully trained occupational medicine physicians were in short supply in the army. During the early 1980s, however, the numbers of highly qualified applicants to the army's occupational medicine residency program at the USAEHA increased greatly, indicating that new positions in occupational medicine could be developed and staffed.[24] The fledgling program in Europe was allocated 40 civilian-position authorizations for fiscal year 1984, and $2.2 million in fiscal year 1985 as its share of the newly received occupational health resources. In 1984, the first occupational health nursing consultant in Europe was hired.[24,27–29] Similarly, but on a smaller scale, an occupational health program was launched in Korea in fiscal year 1987.[30]

Both these overseas ventures represented new approaches to providing services, since distinct occupational health clinics were not created. Instead, the new resources were integrated with existing health services, and missions were expanded to include industrial hygiene and occupational medicine. In most cases, the installation's preventive medicine service and outpatient clinics absorbed the expanded mission requirements.[24]

THE INDUSTRIAL SOLDIER

During the early 1980s, in an attempt to improve occupational health services for soldiers, AMEDD began to sponsor one physician's assistant each year to obtain a master's degree in occupational health at the University of Oklahoma. In 1984, a graduate of this program initiated a model test program for soldiers at Fort Campbell, Kentucky.[31]

Many people assume that all soldiers are combatants. As a result, soldiers engaged in garrison industrial operations, and their need for occupational health services, are overlooked. The test model began by defining all industrial operations at Fort Campbell that were not militarily unique. Of 769 industrial operations—including acid cleaning, battery charging, degreasing, spray painting, and welding—soldiers exclusively performed 530.

A survey of healthcare providers was conducted in an attempt to assess morbidity. Eye injuries were selected as an indicator because safety glasses were noticeably absent among the troops. This survey showed that (*a*) an estimated 95 eye injuries occurred each week among soldiers and (*b*) appropriate eye protection would have prevented 48% of them. The yearly time lost from work associated with preventable eye injuries was over 89,000 man-hours.[31] When the survey findings were presented to the military command, the occupational health specialists were able to demonstrate that preventable eye injuries were detrimental to combat readiness. As a result, funds were allocated not only for safety glasses but also for other items of personal protection, such as respiratory-protective devices. New procedures for procuring these items still needed to be established because the sources of funding and the responsibility for procurement were different from the existing procedures used to purchase personal protective equipment (PPE) for civilian workers.[31]

The Fort Campbell experiment stimulated other studies of occupational morbidity in troops and served as a model for army garrisons worldwide.[31,32] Aspects of the Fort Campbell model that were implemented at many installations included occupational health education efforts for troop medical-care providers, development of new data-gathering systems and forms to support epidemiological surveillance and studies, and efforts to increase command emphasis on occupational safety and health.

MILITARILY UNIQUE EXPOSURES

Soldiers should not be placed at unnecessary risk—in training or in combat—because of either their machines' shortcomings or their own ignorance of the health hazards associated with their equipment. For example, a soldier who fails to wear hearing-protective devices on the firing range today will be a deaf and ineffective leader on the battlefield tomorrow. The tank commander who uses his vehicle's ventilation system improperly while firing his weapons will put his crew at risk of carbon monoxide poisoning.[17,33] Thus, applying the principles of occupational health to the fighting soldier's unique environment is crucial to military readiness.

The Early Years

Dr. Benjamin Rush (1745–1813), a signer of the Declaration of Independence and the surgeon general of the Middle Department, Continental Army, during the American Revolutionary War, recorded his observations on diseases in military camps and hospitals, including hearing loss from artillery fire.[7] However, for the most part, military men simply accepted hearing loss, exploding cannons, and other risks of their profession.

This acceptance changed during the Civil War (1861–1865), with the introduction of a new generation of weapons—the revolving gun turret, armored railroad artillery, and an early version of the machine gun—that significantly threatened the health of the soldiers who manned them.[34]

The union repeating gun, the early version of the machine gun, was mounted on artillery wheels with a large hopper on top of its single barrel. As the weapon's crank was turned, cartridge cases in the hopper were dropped one by one into a revolving cylinder. A firing pin struck each cartridge, which was then ejected. President Abraham Lincoln liked the weapon, but Colonel John Geary, a hero of the Mexican-American War, returned those that had been sent to him. One reason for his rejection was the danger the weapon posed to its operators. Pieces of soft metal had apparently sheared off—when the cartridges were forced against misaligned parts of the weapon—during firing and had endangered Colonel Geary's own troops. The weapon's most famous casualty was General William Tecumseh Sherman, who was wounded when a piece of metal penetrated his leg while he watched a test-firing.[34]

World War I

Several aspects of war presented unique hazards to soldiers in World War I, including tanks, highly effective machine guns, and trench warfare. Except for its response to the threat posed by gas warfare, no evidence exists to show that the United States paid any attention to the militarily unique occupational health needs of its soldiers. Our European allies, however, did.[7,9,17]

The first major use of tanks was by the British in 1917 in France (Figure 1-5). One of the first British soldiers to go into battle in a tank described his experience:

> The whole crew are at various guns, which break forth in a devastating fire.…By this time, the fumes from the hundreds of rounds which we have fired, with the heat from the engines and the waste petrol and oil, have made the air quite oppressive and uncomfortable to breathe in. However, those who go down to the land in tanks are accustomed to many strange sensations, which would make an ordinary mortal shudder.[35(p40)]

British and French medical officers identified and attempted to manage threats to the health of their soldiers who used military machines during World War I. The dangers of heat stress in armored vehicles, and of carbon monoxide poisoning that occurred when machine guns were fired in tanks and in enclosed gun emplacements, were well known. (Accidents that caused carbon monoxide casualties had occurred before, and during, the war.)[9,17]

Carbon monoxide was produced by incomplete combustion of the propellant in the machine gun cartridges. Machine gun emplacements, which gun crews had attempted to seal to protect themselves against the enemy's poisonous gases like chlorine, were not well ventilated and were extremely dangerous; carbon monoxide reached toxic levels inside.

Ventilation inside tanks was also poor, and carbon monoxide accumulated when the tanks' weapons were fired. In April 1918, a series of tests performed in France on a Renault tank with a Hotchkiss machine gun showed that soldiers could reduce the level of carbon monoxide inside by opening the tank's doors or running its engine (Figure 1-6).[17] Tests and observations by the French army concluded that machine gun emplacements must never be hermetically sealed, and that soldiers must be protected with adequate ventilation against carbon monoxide poisoning. The French attempted to develop an effective filtering system for carbon monoxide, although their efforts were unsuccessful.[17]

The tunnels that laced the trenches of World War I battlefields created extremely hazardous conditions underground. Defensive mining operations, consisting of digging tunnels and planting explosives, were initially used only when necessary to protect important trenches, salients, or sectors. Later, offensive mining, using large quantities of explosives, resulted in intensive crater warfare. Thousands of soldiers, many of them skilled miners in civilian life, worked underground daily. The use of compressor engines

Fig.1-5. The first major tank battle, the Battle of Cambrai, took place on 20 November 1917 in northern France. From behind the British front, 378 ironclads (an early name for tanks) similar to the British Mark IV shown above moved toward the Hindenburg Line. The Mark IV had five .303-caliber Lewis machine guns and armor only thick enough to protect against small-arms fire. The inside of the tank was one large compartment in which the crew were exposed to combustion products from the weapons and exhaust from the petrol engine. Sources: (1) Gaydos JC. A historical view of occupational health for the soldier. *Medical Bulletin of the US Army Medical Department.* 1988;2:4–6. PB 8-88.(2) Cooper B. *The Ironclads of Cambrai.* London: Souvenir Press; 1967. Photograph: Courtesy of Colonel Joel C. Gaydos, Bethesda, Md.

and explosives inside the tunnels created oxygen-deficient areas that had high concentrations of carbon monoxide, nitrogen oxides, hydrogen, and methane. Gas poisonings and explosions caused large numbers of casualties. The British army evaluated existing mine-rescue equipment that was used in the civilian mining industry and adopted an apparatus containing compressed oxygen for the rescuers and an oxygen-resuscitating apparatus for treating the casualties. They also started mine-rescue schools and published an official manual, *Memorandum on Gas Poisoning in Mines*.[9]

Between the Wars

Although the AMEDD made no attempt to develop the field of occupational health and its related areas after World War I, those initiatives were made elsewhere.[8] Fortunately, governmental agencies and private industry recognized the value of such skills. Civilian programs in occupational medicine and industrial hygiene received emphasis in graduate schools of public health and were able to provide the occupational health experts that AMEDD required during World War II.

Special Laboratories During World War II

Several laboratories played a major role in militarily unique occupational exposures during World War II, including (*a*) the Harvard Fatigue Laboratory, (*b*) the Armored Medical Research Laboratory, (*c*) the Climatic Research Laboratory (CRL), and (*d*) the U.S.

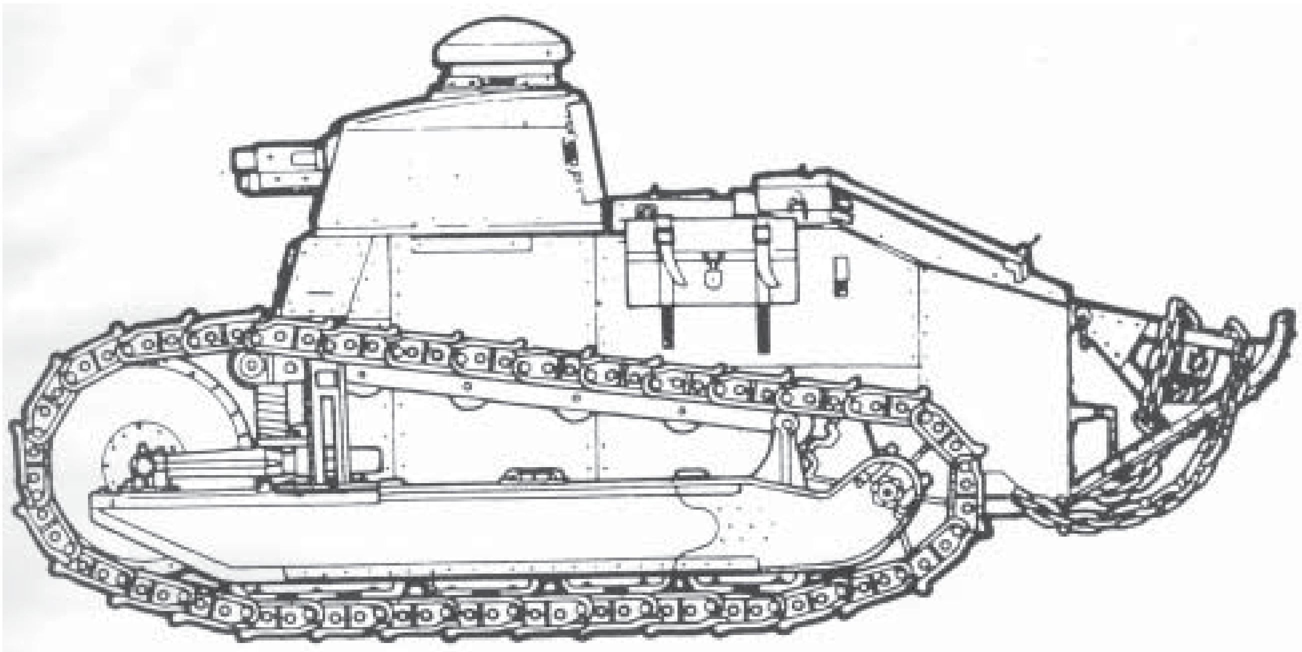

Fig. 1-6. The basic configuration of the modern tank first appeared in 1917 with the French Renault LT. Earlier tanks resembled large, armored boxes but the Renault had the driver in the front, a fully traversable turret containing the main gun in the center, and the engine in the rear. The first Renaults were armed with either an 8-mm Hotchkiss machine gun or a 37-mm gun (above). From the time they had first examined a wooden mockup in December 1916, French military leaders expressed concern that the crew space was too small and that ventilation would be inadequate to prevent asphyxiation of the crew after the gun was fired. Results from a series of tests done in April 1918, in a Renault tank with a Hotchkiss machine gun, showed that the level of carbon monoxide inside the crew compartment could be reduced by firing the weapon with the tank doors opened or with the engine running. Sources: (1) Gaydos JC. A historical view of occupational health for the soldier. *Medical Bulletin of the US Army Medical Department.* 1988;2:4–6. PB 8-88.(2) Zaloga, SJ. *The Renault FT Light Tank.* London: Osprey Publishing; 1988. Original drawing by Leon Conjour, USAEHA Illustration Shop.

Army Research Institute of Environmental Medicine (USARIEM).

The Harvard Fatigue Laboratory

The Harvard Fatigue Laboratory was established in 1927, and its distinguished faculty, students, and graduates had compiled an impressive research record by the time the United States entered World War II. Some staff members remained at the laboratory during the war to do collaborative work with the military; others left for military service elsewhere, either as civilians or as officers. From June 1940 to March 1947, the laboratory submitted 180 research reports to different U.S. governmental agencies and to the British and Canadian armed forces. Those reports addressed clothing and equipment, primarily for use in cold weather; nutrition; physical fitness, including methods of evaluation; high-altitude problems, including anoxia, oxygen masks, heated suits, and physiological response to cold; physiological adaptation to excessive heat; and blood-chemistry derangements, particularly carbon monoxide poisoning.[14,36]

The Harvard Fatigue Laboratory closed in 1947, but it left an indelible mark on the scientific community.[14,36] Several military research facilities were associated with the Harvard Fatigue Laboratory during its existence because staff members who entered the military initiated collaborative efforts with their former colleagues. These facilities, which continued their efforts after the laboratory closed, included the Armored Medical Research Laboratory, Fort Knox, Ken-

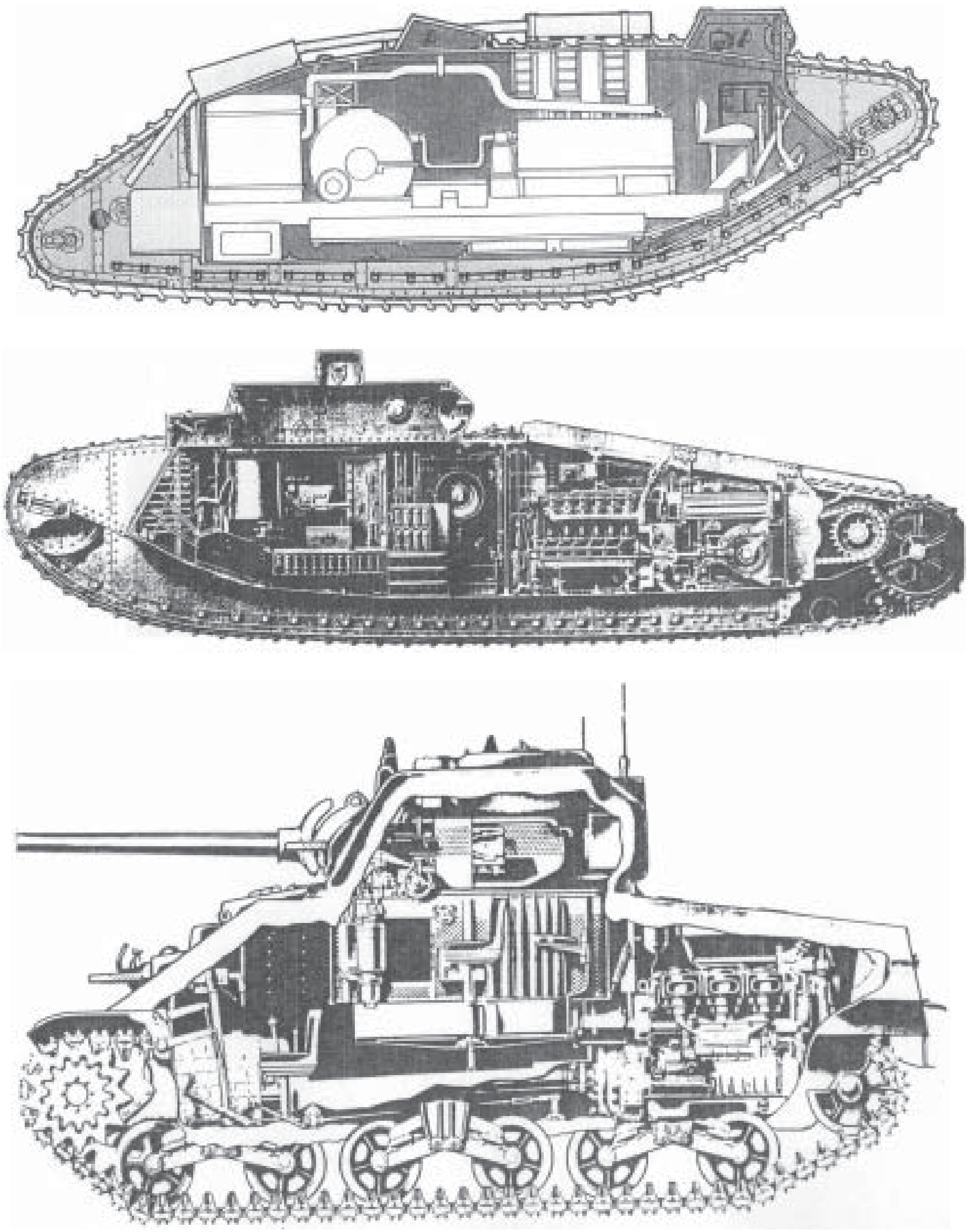

Fig. 1-7. Cutaway drawings of the British Mark IV combat tank of World War I (upper), the British Mark VIII (center), which appeared around the end of World War I, and the Sherman M4 (lower), which was used extensively during World War II. The light areas represent the crew compartments. After only a few years' experience, designers of the Mark VIII placed a bulkhead between the engine and the remainder of the tank interior that, at least theoretically, would reduce crew exposure to engine exhaust products, petrol vapors, engine heat, and engine fires. The concept of a separate engine compartment was incorporated into World War II tanks, but crew exposure to combustion products of weapons continues even to the present. Original drawings by Leon Conjour, USAEHA Illustration Shop.

tucky; the U.S. Army Climatic Research Laboratory (CRL), Lawrence, Massachusetts, and later Natick, Massachusetts; the Naval Medical Research Institute, Bethesda, Maryland; the Navy School Aeromedical Laboratory, Pensacola, Florida; and the Aeromedical Laboratory, Wright Field, Ohio.[14,36]

The Armored Medical Research Laboratory

As the threat of World War II approached and the role of armor in modern warfare unfolded, no U.S. Army organization had been assigned the responsibility for studying the soldier in this environment, particularly the exposures inside tanks (Figure 1-7).[36] The concern that crews of armored vehicles would be unable to perform and endure in hot climates was so great that achieving the technology needed for air-conditioning tanks was considered to be a major breakthrough in modern warfare. The British feared that the Germans had begun to produce air-conditioned tanks.[37] The Germans had not mastered the required technology, however, and there was no rational basis for the British fear.

Even though the initial basic tank design, exemplified by the British Mark IV, had changed considerably, U.S. Army tank commanders and medical officers still feared that limited ventilation in a confined space could result in very high internal temperatures and accumulation of toxic levels of weapons combustion products. Control of the internal temperature of a tank and control of air contaminants through filtration or dilution could be expected to greatly improve the endurance and performance of tank crews, particularly in hot climates and under other conditions that required that hatches be closed. Unfortunately, space and power were so limited in tanks that our own AMEDD officers could not convince tank developers to install even a small fan in the Sherman tank to improve ventilation.[15]

The tank environment posed several potential problems to the soldiers of all forces, including heat stress, toxic gases created by weapons fire, postural injuries, and fires in the crew compartment. With the assistance and support of the NRC, the Armored Medical Research Laboratory was established in 1942 at Fort Knox, Kentucky, to deal with the medical problems of armored-vehicle crews.[13,15] Staffed by physicians, medical and physical scientists, and engineers, the laboratory's mission was to

- identify and evaluate the stressful demands placed on operators of tanks and other weapons;
- determine the limits and the capabilities of soldiers; and
- find the proper balance between operating demand and human capabilities, to avoid breakdown or failure of the man–weapon system.

In April 1942, the OTSG began to recruit teachers and researchers from civilian sources to staff the Armored Medical Research Laboratory.[13-16,36] During its more than 3 years of wartime service, the laboratory staff produced approximately 130 reports dealing with 19 different categories of problems, including temperature extremes; rations; physical and mental standards for tank crewmen; protection against fire, dust, noise, and blast in tanks; defense against chemical warfare agents; fatigue; and toxic gases.[15,16,38] In one demonstration, general officers became the tank crew in order to experience the irritating effect of ammonia produced by main gun fire in an M4 tank with all its hatches closed (Figure 1-8).[15]

After World War II, the Armored Medical Research Laboratory was involved in reorganizations and name changes; eventually, responsibility for many of its research areas was transferred to USARIEM.[36]

The Climatic Research Laboratory

The CRL, established in 1943 in Lawrence, Massachusetts, was a Quartermaster command with some staffing from the OTSG. The Harvard Fatigue Laboratory supplemented the facilities and staff and provided a senior scientist as the first director and commander.[36] The laboratory was designed to simulate all climatic conditions to which soldiers might be exposed and to test clothing and equipment under those conditions. Between 1943 and 1954, the staff published 359 technical reports on topics including the effects of environmental temperature and physical activity on the variables related to the insulating properties of materials used in clothing, sweat production under varying conditions, cold-induced diuresis, and rewarming.

In 1954, the laboratory was reorganized and eventually became the Environmental Protection Research Division (EPRD) at Natick, Massachusetts. In 1961, sections of the EPRD became part of USARIEM.[36]

The U.S. Army Research Institute of Environmental Medicine

The army established USARIEM in Natick, Massachusetts, by consolidating research elements that had been initiated in the Armored Medical Research Labo-

Fig. 1-8. Sherman medium tank (M4A4, 1942 vintage). The M4 tank had no ventilation designed specifically for the crew. While the engine was running, air that was needed to cool the engine was drawn through the turret, allowing some air exchange to occur in the crew compartment. During World War II, a test was conducted at the Armored Medical Research Laboratory, Fort Knox, Kentucky, in which two general officers and an Army Medical Department (AMEDD) officer attempted to fire 10 rounds of 75-mm ammunition from an M4, similar to the one above, with all the hatches closed. After firing only four rounds, ammonia levels reached about 400 ppm and the "crew" were weeping copiously and ready to quit the test. During World War II, morbidity and mortality from toxic combustion products of weapons were probably averted because tank crews tended to leave the hatches open whenever possible. Source: Hatch, TF. Some reminiscences, the armored force medical research laboratory in WW II. *Medical Bulletin of the US Army (Europe).* 1985;42:22–26. Photograph: Courtesy of Colonel Joel C. Gaydos, Bethesda, Md.

ratory and the EPRD. The laboratory's main effort always was directed at the health and effectiveness of soldiers who functioned at extremes of temperature or at high altitude. More recently, USARIEM assumed research roles in physical fitness and nutrition.[36]

Data and information were acquired at Natick; the Arctic Medical Research Laboratory at Fairbanks, Alaska; the John T. Maher Laboratory at Pikes Peak, Colorado; and from numerous field studies. Using these data, USARIEM assisted military commanders and medical officers by consulting on and teaching about a wide range of topics, including tolerance times for soldiers working in the heat; coagulopathies associated with heat stroke, frostbite, and hypothermia; and injuries associated with physical-fitness training.[36]

Weapons Modernization During the 1980s

Allegations of adverse health effects in operators of new army weapons systems began to surface during the late 1970s. Early in the 1980s, the DoD launched a major weapons modernization program, which brought more allegations and criticism that the army had forgotten the soldier in the man–machine inter-

Fig. 1-9. The OH-58D Advanced Scout Helicopter was designed for enhanced aerial reconnaissance; intelligence gathering; and target detection, acquisition, and designation. It serves as an excellent example of the many different, potentially adverse exposures that may be inherent in new materiel. Under the Health Hazard Assessment Program, the OH-58D was evaluated for the following potential hazards to human health: lasers contained in the ball on top of the main rotor; heat stress resulting from the large number of electronic items carried in board; engine-exhaust products that could enter the cockpit; whole-body vibration; and the crash worthiness of the seats, which had been used on other aircraft and were reported to have been associated with excessive spinal injuries during crash landings. Source: Rowden SE, McIntosh RM. The health hazard assessment program: Occupational health for the soldier in the field. *Medical Bulletin of the US Army Medical Department.* 1988;2:7–13. PB 8-88. Photograph: USAEHA file.

face. Critics also attacked the army for failing to adequately address crew and vehicle survivability on the battlefield in the design and testing of armored combat vehicles.[17,39,40]

The Health Hazard Assessment Program

Weapons and equipment development continued after World War II, as new technologies (such as radar and lasers) produced potential threats to the health of soldiers who operated and maintained them. Although AMEDD continued to develop its expertise in occupational health, this expertise was not integrated into the U.S. Army Materiel Acquisition Decision Process (MADP), a multiyear cycle in which new military items are systematically conceived, developed, tested, reviewed, and accepted, rejected, or modified, before being fielded. Therefore, no systematic medical review occurred to identify and control, or eliminate, hazards to the soldiers who used and maintained the new tanks, guns, and other equipment.[17,39]

Problems resulting from the absence of expert medical opinion in the MADP became obvious by the late 1970s and early 1980s. Questions arose regarding the potential harmful effects from blast overpressure with the M198 howitzer and carbon monoxide poisoning in the Bradley Fighting Vehicle (BFV), when both were nearing the end of a multiyear MADP cycle. These questions should have been addressed earlier in the conceptual stages of materiel development to preclude the possibility that costly—and even unacceptable—changes would have to be made. To prevent similar problems in the future, U.S. Army Regulation 40-10 established the U.S. Army Health Hazard Assessment (HHA) Program, which was published in October 1983.[41] This regulation required medical review of items in the MADP at critical points in the multiyear cycle. The HHA process has evaluated a long list of potential hazards, including noise and vibration in helicopters, toxic gases in armored vehicles, blast overpressure from mortars, and skin irritation and sensitization caused by chemical protective masks, clothing, and other items of PPE (Figure 1-9).[39]

After the army's HHA program was initiated, the U.S. Deputy Chief of Staff for Personnel undertook the Manpower and Personnel Integration (MANPRINT) initiative. This effort's objective was to ensure that the human component was considered first in the design and development of army systems such as weapons systems, field water-treatment systems, and communication systems. By regulation, key personnel in the MADP were required to attend MANPRINT education programs (which included orientation on medical topics) and to ensure that the human aspect of the soldier– machine interface not only was not forgotten, but was given the highest priority.[42]

Testing for Survivability and Vulnerability

Whether or not a military vehicle, particularly an armored combat vehicle (ACV), survives combat is directly related to both the vehicle's and the crew's vulnerability. Until the 1980s, vehicle vulnerability was assessed by simply evaluating the ability of the armor to withstand penetration by a specified antiarmor threat (eg, a particular rocket or artillery shell). Selective components of the vehicle were tested and data were extrapolated, using computer modeling, to determine the vulnerability and survivability of the ACV. This approach—particularly the testing of the BFV—was criticized, and as a result, the Office of the Secretary of Defense initiated the *Joint Live Fire Program* in 1984. In a closely related action in 1987, the U.S. Congress passed legislation requiring live-fire testing of all weapons platforms, like an ACV, ship, or airplane, that perform as a combat machine against realistic combat threats. The objectives of the testing were to (*a*) assess the vulnerability of both vehicle and crew, (*b*) identify design changes to improve both vehicle and crew survivability, (*c*) produce a database in order to improve computer modeling of vulnerability, and (*d*) assess the lethality of American weapons systems against foreign systems.[40,43] Because the first three of these objectives addressed the protection and survivability of American troops, AMEDD had a role in identifying and defining the potential hazards and making recommendations for improving survivability. However, AMEDD's involvement with the last objective was precluded for ethical reasons. The lead medical organization in this new undertaking was the Walter Reed Army Institute of Research (WRAIR), Washington, D.C., with support from USAEHA and the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama.[43] The Armed Forces Epidemiological Board also provided assistance.[44,45]

Using current technology and developing new, the army's vehicles, containing a variety of sophisticated instruments, were subjected to antiarmor threats. Fragments, thermal effects, blast overpressure, flash, acceleration and deceleration, and toxic gases were studied. The results of this effort have been directed toward improving soldier survivability in battle and AMEDD's ability to predict, diagnose, and treat battle casualties. After considerable research and study, health risks within an ACV (including a scenario in which the crew remained in the vehicle after its armor was penetrated) and criteria for predicting injuries were defined and reviewed.[40,44]

CHEMICAL WARFARE

Just as Germany's use of poisonous gas during World War I had stimulated the U.S. Army to initiate its first occupational health program,[7,8] poisonous gas again became a center of interest in both occupational health and environmental fields as the decade of the 1980s drew to a close.

Demilitarization

In 1969, President Richard M. Nixon unilaterally halted American production of warfare chemicals, thereby eliminating the routine replacement of chemical weapons affected by aging.[46] By the late 1980s, a deteriorating American chemical-warfare stockpile was described as "90% useless for military purposes, and costing approximately $65 million per year to safeguard."[47] The 1986 Defense Authorization Act attempted to correct this situation by requiring the destruction (demilitarization) of aging munitions and chemical agents stored at eight locations in the continental United States (CONUS), Johnston Island in the Pacific Ocean, and West Germany.[47] The initial target date of 30 September 1994 for completion of the mandated destruction was later extended to 1997.[47,48] Public concern, congressional interest, and strict requirements for environmental evaluations focused considerable attention on the army's plan to incinerate the agents at the eight CONUS locations and Johnston Island.[48] The involvement of the army's occupational health community in conjunction with the USPHS and the Committee on Toxicology of the NRC included

- documenting and verifying occupational and environmental exposure standards (to include those for the general population);
- reviewing workplace and destruction procedures for compliance with standards;

- assisting with the preparation of environmental assessment and impact documents; and
- addressing inquiries and concerns of citizens, legislators, and the U.S. Environmental Protection Agency (EPA).

Production of Binary Chemical Weapons

In support of the United States government's position that a chemical weapons capability deters an enemy poisonous gas attack, the 1986 Defense Authorization Act also approved production of binary chemical weapons,[48] which began at Pine Bluff, Arkansas, in December 1987.[46] In the binary system, two toxic but sublethal component chemicals are manufactured and stored separately. When the fuze is installed in the weapon (eg, an artillery shell), separate containers of each chemical component are also installed. When the weapon is fired, the separate containers rupture and the components mix to form a new, lethal compound.[47] This weapons system produced a number of new chemicals, such as ethyl 2-[di-isopropylamino]-ethylmethylphosphonite (known as QL). To protect civilians and soldiers who might be exposed to the new chemicals, the army's occupational health community defined requirements for toxicity studies, interpreted toxicity data, developed exposure standards, and evaluated worksite procedures.

Contemporary Threats

The threat of exposure to poisonous chemicals has been considered a possibility with (*a*) armed conflict, (*b*) terrorist activities, (*c*) the destruction of our aging chemical stockpile, or (*d*) the accidental unearthing of old, forgotten underground disposal sites.

In a 1919 report to Congress, General of the Armies John J. Pershing stated:

> 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.[49(p1)]

Chlorine, mustard, and phosgene had been used in World War I and caused more than 1 million casualties and almost 100,000 deaths.[49] The possibility of an enemy gas attack was considered to be remote during World War II, but American military personnel received chemical-warfare training nevertheless. Few, however, took either the training or the threat seriously. The opposing sides maintained significant stockpiles, but there was no confirmed combat use of chemical weapons by major belligerents.[49]

An unfortunate incident in 1943 demonstrated that when medical personnel do not suspect and are unprepared to handle chemical casualties, the consequences can be grave.[50,51] At dusk on 2 December 1943, the Germans bombed the allied-occupied harbor of Bari, Italy. The merchant ship SS *John Harvey* was in port loaded with a large quantity of high-explosive munitions and a secret cargo of approximately 100 tons of American-made mustard bombs. The ship and her cargo exploded, and any crew members who might have known of the secret cargo were killed. Many casualties were exposed to mustard vapor and were covered with mustard mixed with oil (Figure 1-10).

The medical personnel who received the casualties had no reason to suspect chemical agents. They made no attempt to protect themselves or to decontaminate their patients; the mixture of mustard and oil remained on their skin for many hours, perhaps even days. The patients' undiagnosed clinical states aroused suspicion among the medical personnel that something unusual had happened, and some kind of chemical exposure was suspected. Eye injuries, skin erythema, and blisters were noted 12 to 14 hours after the bombing. Several days later, an investigating medical officer who had been flown in from England used clinical, epidemiological, and pathological data to show that exposure to mustard had occurred. Of the 617 known mustard casualties among military and merchant marine personnel, 83 (13.6%) died. An unknown number of civilian casualties also occurred. Of the military personnel and merchant seamen, the significant casualties—and all the deaths—occurred among those who had been completely covered with the mustard-and-oil mixture.[50,51]

Fifteen nations were thought to possess chemical weapons in 1989 and eight more were suspected of possessing them.[49] Even though the risk that a superpower might be the first to use chemical weapons was thought to be remote, some nations, like Iraq, had demonstrated a willingness to employ them. Furthermore, the ease of concealment of chemical grenades or canisters, and the psychological impact if they were used, made the possibility of a terrorist chemical attack worthy of consideration.[49]

Also, with the legally mandated destruction of the United States' old chemical stockpile, the likelihood that an accident could occur increased whenever the agents were moved, manipulated, and incinerated.[46–48] Chemical agents have been manufactured, stored, and used in anger, research, and training since World War I, both in the United States and abroad. Many times disposal was by burial in unmarked and unrecorded sites; there have been anecdotal and documented reports of unearthing containers of chemical agents at CONUS

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Fig. 1-10. The harbor of Bari, Italy, on 3 December 1943. A German air raid late in the day on 2 December damaged or sank a large number of ships in the allied-occupied harbor, including the SS *John Harvey*, which carried about 100 tons of mustard bombs. Mustard vapor in the smoke, mustard agent mixed with oil from the damaged ships, and lack of preparedness for dealing with mustard casualties resulted in hundreds, or even thousands, of casualties; 13.6% of the 617 military and merchant marine casualties died. Sources: (1) Infield GB. *Disaster at Bari.* New York: Macmillan; 1971. (2) Alexander SF. Medical report of the Bari Harbor mustard casualties. *Military Surgeon.* 1947;101:1–7. Photograph: Reprinted with permission from Infield GB. *Disaster at Bari.* New York: Macmillan; 1971.

installations and American installations overseas. Recently, hundreds of vials of chemical agents, dating back to the early 1950s or earlier, were found at Fort Polk, Louisiana, when a firing range was excavated.[52]

Medical Education

Enhanced respect for the chemical threat and interest in the adequacy of training in the medical management of chemical casualties increased dramatically in the late 1980s. The American program to demilitarize outdated chemical stocks began as an increasing number of countries became able to wage a chemical war.[47–49] In February 1987, the Technical Inspections Division, U.S. Army Inspector General Agency, published the report of an evaluation of medical support at chemical storage sites. The report identified a lack of doctrine and lack of institutionalized training, which extended beyond the storage and demilitarization mission.[53] In response, The Surgeon General of the army authorized a full-time position for a medical consultant for *surety programs*, and tasked the consultant to address all the identified deficiencies and to develop and coordinate all the needed corrective actions with the various commands involved.[53] Emphasis was immediately placed on developing doctrine and improving the level of medical readiness through training.

Work on doctrine and official guidance for battlefield and nonbattlefield exposures to chemical threats was invigorated and The Surgeon General launched and financed a consolidated program of training for medical personnel.[53] The U.S. Army Medical Research Institute of Chemical Defense at Edgewood, Maryland, had offered an outstanding training course in the medical management of chemical casualties for many years. The course's impact was limited because it was not funded and staffed separately, but was taught as an additional mission on a time-available basis by people who had other primary duties. As a result, the numbers of students trained were too small to meet the army's needs. However, using this course as a nucleus, training at Edgewood was expanded and plans were initiated for a high-quality, exportable course; training of certified instructors; special-application training packages to meet special needs (such as the demilitarization mission); and augmentation blocks of instruction to be used in other existing AMEDD courses (such as the Officer Basic Course).[53]

Ethics

Why are army occupational health professionals involved with chemical warfare agents? The question has been asked repeatedly. Occupational health addresses the protection of workers and the prevention of morbidity and mortality from all hazardous exposures, including chemicals. The principles are the same, regardless of *why* an individual is exposed. Defense against chemical weapons—including physical protection, exposure standards, prophylaxis, and treatment—have been the impetus for, and a continuing part of, army occupational health.

From World War I to the present, the offensive and defensive aspects of chemical production and warfare have never been clearly distinct.[7] At times, this has created a moral dilemma. For example, a medical professional's assessments of chemical exposures are required to determine the need for, or the adequacy of, physical protection, prophylaxis, and treatment. But unfortunately, weapons developers may also use such assessments for destructive purposes. AMEDD has maintained two positions:

- First, identification and definition of potential human health hazards and development of recommendations for promoting health and preventing morbidity and mortality are AMEDD responsibilities.
- And second, assessments accomplished for the purpose of promoting health and preventing morbidity and mortality are a part of the AMEDD mission.

We may argue that medical assessments should be classified or controlled so that access is restricted. However, except in cases involving national security, restricting access can cause and has caused difficulties. For example, the right to know about actual or potential exposures may be violated, and acceptable peer review of the assessment may not occur. An individual's right to know the nature and extent of any exposure has been well established, both in our workplaces and in our communities. After the 1986 Defense Authorization Act was passed, interest in potential exposures from the production, storage, transport, and destruction of chemical agents increased dramatically among scientists and the lay public.[48] The army was criticized because much of the data relating to health had neither been published in the open scientific literature nor been made available to the public through established information channels. The institution of an expert-panel review process by the Centers for Disease Control in Atlanta, Georgia, blunted this criticism.[54] Additionally, all unclassified reports were submitted to the Defense Technical Information Center and the National Technical Information System to facilitate public access.

ENVIRONMENTAL HEALTH

The definition of occupational health, slightly modified, also includes *environmental health*: the application of medicine, other scientific disciplines, and the law to protect all people from environmental hazards and to preserve the environment.[1] Occupational health usually deals with workers and workplace exposures, while environmental health concerns the total population and their exposures in the environment. These two closely related fields differ regarding

- the demographic features and the health status of their populations of interest,
- the knowledge of the exposures and the related risks in those potentially exposed,
- the acceptance of the risks associated with exposure, and
- the application of control measures.

Mission and Organization

In general, AMEDD's role in environmental health, as with occupational health, has been to (*a*) identify and define hazards and to assess the risk to human health; (*b*) use medical means (such as medical screening, diagnostic evaluations, and risk assessment) to help prevent injury and illness and to treat and rehabilitate those already afflicted; and (*c*) assist commanders and managers in communicating risk information, eliminating hazards, and reducing morbidity. Industrial hygienists and safety personnel identify and define hazards inside the traditional workplace and develop recommendations for their control; environmental scientists and engineers accomplish these tasks outside. Often, occupational health professionals in the army have been expected to make the transition from occupational to environmental health whenever the need occurred. Even though this expectation may seem to be reasonable, the transition is usually difficult. Medical surveillance and evaluation measures for worker populations are unlikely to be directly applicable to a general population in whom not only the dose, duration, and route of exposure, but also the demographic features are quite different. Additionally, even though risk assessment and risk communication have long been considered an important part of employee health programs, they took on different perspectives and greater meaning in the 1980s, as concerned citizens and legislators demanded more precise information on environmental pollutants and their associated disease risks. Army physicians, toxicologists, and other occupational health professionals recognized and accepted their environmental health roles much earlier than their civilian counterparts did, and acquired their expertise through on-the-job and formal training. For example, environmental health has been an important component of residency training programs for physicians at the USAEHA for decades.

AMEDD's role in occupational—and particularly environmental—health were questioned during organizational realignments during the 1980s. Proposals were made to remove industrial hygienists and environmental engineers from AMEDD and place them in the U.S. Army Safety Community and the Corps of Engineers. In every instance, the final decision was to maintain AMEDD's team intact, since an improvement could not be identified.

Environmental Program Initiatives

The army's interest in protecting the environment, paralleling the similar interest in the civilian sector, has increased greatly during the past 20 years. This interest—due to legislation, initiatives by army leadership, public pressure, and special events such as the demilitarization of our aging chemical stockpile and Pershing missiles under the Intermediate-Range Nuclear Forces (INF) Treaty—resulted in the following programs: (*a*) the U.S. Army Environmental Program, (*b*) the Installation Restoration Program (IRP), and (*c*) the Defense Environmental Restoration Program (DERP).[47,48,55,56]

The U.S. Army Environmental Program was initiated during the early 1970s to protect natural resources (air, water, and land) while the army performed its missions. The scope of the program increased, with some shifts in emphasis, to encompass hazardous waste (including toxic and medical waste), noise, radioactive waste, radon control, and asbestos control.[55]

The IRP was developed in 1974 to deal with environmental contamination from toxic and hazardous materials where these were known to exist and where environmental control efforts of some type already existed.[55] The IRP was linked closely to the Resource Conservation and Recovery Act (RCRA) and was primarily the responsibility of the Office of the Chief of Engineers (OCE).[57] The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980,[58] also known as the *Superfund Act*, and the Superfund Amendments and Reauthorization Act (SARA) of 1986[59] prompted efforts to clean up much older, hazardous-waste sites on active army installations. With the passage of these two acts, the IRP's mission was greatly expanded and the army's environmental effort became part of DERP. The funding that was available through the Defense Environmental Restoration Account (DERA) facilitated this effort.

Army sites identified for major environmental cleanup were required to have a Health Risk Assessment (HRA) Report.[60] The OTSG, with support from the USAEHA and the U.S. Army Medical Research and Development Command (USAMRDC), was involved in the preparation of selected HRA reports and reviewed OCE contractor-generated reports. The USAEHA also provided help and conducted on-site studies to deal with special problems.[60] During the period November 1988 through January 1990, the army documented savings of $19.6 million as a result of AMEDD's involvement in the environmental effort; the potential savings may reach $128.4 million.[60,61] Approximately 200 OCE contractor-generated HRA reports were reviewed; nearly one-half of them were unsatisfactory, containing errors that would have been extremely costly because unnecessary or inappropriate work would have been performed in cleaning up the environment. Additionally, quick responses to potential problems (eg, workers' complaints regarding illnesses) averted serious outbreaks of diseases and consequent adverse publicity.[60,61]

The INF Treaty, an agreement between the USSR and the United States, became effective on 1 June 1988. This treaty required that Pershing missiles be eliminated and specified that solid-fuel rocket motors be destroyed by demolition, burning, or launching. *Static firing* (ie, firing the rocket motors while they are bolted horizontally to a fixed firing stand on the ground) was selected as the primary means of destruction. The air emissions from the perchlorate-based propellant were primarily hydrogen chloride, aluminum oxide, nitrogen, carbon monoxide, and carbon dioxide.[56]

Coordination of and discussions regarding preliminary testing and eventual destruction of the Pershing missiles involved several groups. AMEDD participated in the early testing to ensure that the data collected would be adequate for making health assessments. With assistance from the Committee on Toxicology of the National Academy of Sciences, guidelines for exposure of the general population to rocket-motor combustion products were established, and inquiries from governmental agencies and concerned citizens about the basis for and acceptability of the guidelines were answered.[61,62] Since the INF Treaty required verifiable destruction, both sides exchanged observers. The AMEDD was also involved with the INF Treaty by providing health-risk information, education, and prophylaxis, when indicated, to American observers stationed on Soviet soil.

SUMMARY

Occupational health in the army evolved with America's interest in occupational health. Before World War I, American disinterest in employee health in civilian industries was mirrored in the military, but the threats posed by the manufacture and enemy use of chemical warfare forced AMEDD to become involved with the health and safety of workers in gas-producing and gas-defense plants. The war effort stimulated the development of the American chemical industry, with a concomitant increase in attention to the workers' health.[63]

Between World Wars I and II, army leadership lost sight of the value of employee health programs. As World War II approached, however, they quickly recognized that industrial medical services were needed in the wartime industries and that new equipment like the modern tank exposed soldiers to unusual and militarily unique hazards. The civilian sector furnished trained experts and facilities to the ill-prepared army.

Aided by the USPHS, AMEDD implemented and monitored many successful programs that supported both soldiers and civilian employees, produced pioneering contributions to both military and civilian occupational health, and documented the effectiveness of the wartime industrial medical services. Fortunately, the army did not forget about occupational health after World War II.[64]

More workplace services became available after the 1970 OSHAct was passed. The massive equipment-modernization program during the 1980s called new attention to soldiers' militarily unique exposures, and as antiquated chemical weapons were demilitarized and new chemical warfare agents were produced, AMEDD was required to identify and describe environmental hazards and to protect soldiers and civilians with potential exposures to poisonous military chemicals.

The army directed critical resources and great effort to occupational health programs because the need for them was significant and often related to national defense. History has demonstrated that the army's occupational and environmental health programs must be able both to meet the needs of the time and to serve as the framework for rapid expansion during mobilization. Relying on nonmilitary experts in future national crises requires that AMEDD develop and maintain strong ties with the civilian occupational and environmental health communities and foster those experts' professional growth and development.

Equally important, AMEDD's peacetime occupational and environmental health programs must never be weakened to the degree that they no longer provide a framework for mobilization.

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