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U.S. Army Public Health Center

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Military Medicine: "That body of knowledge peculiar to diseases and injuries incurred as a consequence of military occupations." Dr. Llewellyn J. Legters and Colonel Thomas A. Lamson, Uniformed Services University of the Health Sciences School of Medicine.

This special edition was made possible through the exceptional efforts of Col Joel C. Gaydos, MC, who compiled the articles, and through the assistance of Mrs. Barbara Donovan, Ms. Janice Ginger, and Mrs. Michele Jewett, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md. Their diligent and persistent efforts in collecting and editing the articles are sincerely appreciated.

Preface

Col Monmohan V. Ranadive, MC*

The motto of the Army Medical Department: CONSERVE THE FIGHTING STRENGTH.

What does occupational medicine have to do with soldiers? Soldiers will die of carbon monoxide poisoning if a main battle tank is not operated properly; they will die from training in HC-Smoke if it is not used with caution; and soldiers can and do loose their eye sight when laser target designators are misused. A less dramatic but more well known and, unfortunately, still quite common occurrence is permanent hearing loss in soldiers because of occupational noise exposure.

For the soldier, sailor and airman the workplace may be a tank, a submarine, a missile silo or a garrison motor pool garage. In the more traditional industrial setting, like the garage, the principles and practice of occupational health are the same for both civilian workers and soldiers. In the militarily-unique settings, the unusual nature and complexity of multiple exposure offer new and difficult challenges. For example, the tanker and aviator may face the adverse effects of noise, toxic gases, heat stress, and whole body vibration simultaneously. As soldiers come into contact with more sophisticated military machines and complex hazards, military occupational health must face a critical challenge. We must ensure that our soldiers do not suffer serious adverse effects as a result of their military service and that they are afforded the opportunity to perform at maximum efficiency. This means, that we must effectively deal with both the hazards of the installation industrial setting and the hazards of the militarily-unique setting.

The military occupational health program has grown tremendously in the Army over the past ten years. This growth occurred to better serve our civilian workers and to provide urgently needed but long neglected services to our soldiers. The purpose of this special edition is to highlight some of the interesting things that have happened in military occupational health, to alert the readers to some hazardous situations of concern, and to challenge the occupational health workers to provide more effective occupational health services to the soldiers and civilian workers. (For anyone who would like more information about career opportunities in Army Occupational Health, the following address is provided: Office of The Surgeon General, ATTN: DASG-PSP, 5109 Leesburg Pike, Falls Church, VA 22041-3258.)

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A Historical View of Occupational Health for the Soldier

Col Joel C. Gaydos, MC*

The effectiveness of the practice of Army Occupational Health today may be measured by our soldiers' ability to survive, to continue to fight and to win on the battlefields of the future.

The profession of arms is a dangerous and deadly occupation and can be expected to always remain so. However, soldiers need not be exposed unnecessarily to hazards during training. Equally as important, soldiers going into combat should not be disadvantaged or placed at unusual risk because of shortcomings in their machines or a lack of knowledge about the health hazards of their equipment. Today's young soldiers who fail to wear hearing protective devices on the firing range will be deaf and ineffective sergeants on tomorrow's battlefields. Poorly designed crew seats and excessively vibrating vehicles will produce troops who are impaired by fatigue or back pain before they ever reach the battlefield. The modern tank commander, who does not properly use his vehicle ventilation system during weapons fire, will see his crew become casualties from carbon monoxide without ever having received an enemy hit.

Some of our military medical colleagues view the need for occupational health for the soldier as a recent requirement related to intense mechanization and weapons modernization. Recent developments in military equipment and warfare have reawakened us to the need, but the need has been long-standing and usually neglected.

The 18th and 19th Centuries

Soldiers in the late 18th and early 19th centuries faced injury or death from exploding cannons and accidents with horses and moving artillery. However, these risks had been accepted by military men for hundreds of years. It was the Civil War (1861-1865) that changed things significantly. This conflict ushered in an entirely new generation of weapons that would significantly threaten the health of the soldiers who would man them. Innovations included the revolving gun turret, armored railroad artillery (the precursor of the tank and the self-propelled gun), and the machine gun.[1]

The quest for the machine gun was described by Burke Davis and is summarized here. President Lincoln first saw the weapon officially called "The Union Repeating Gun," in June 1861. Mounted on artillery wheels, a large hopper was placed on top of its single barrel. Cartridge cases in the hopper were dropped one by one into a revolving cylinder as the gun crank was turned. Each cartridge was struck by a firing pin and ejected.[1]

Mr. Lincoln liked the weapon and dubbed it a "coffee-mill gun," but his officers disagreed on its value. Colonel John Geary, a Mexican War hero, returned the guns sent to him. One reason for his rejection was the danger posed to the operators. He had apparently experienced problems with pieces of metal shearing off during firing and endangering his own troops. The shearing occurred when soft metal cartridges were forced against misaligned gun parts. The most famous casualty of a "coffee-mill gun" was General William Tecumseh Sherman who received a piece of metal in the leg while watching the weapon being tested. This early automatic gun was finally put to rest in 1866 when the United States Army adopted the Gatling Gun, a six-barrel machine gun which used a new, improved steel-jacketed cartridge.[1]

Pre-World War I

Knights of old attempted to encase themselves and their mounts in protective armor so it was no surprise when military planners viewed the horseless carriage as a moving, armored fortress. A heavy, low-powered, wheeled armored car with a periscope was developed at least as early as 1902.[2] Some versions of early armored vehicles, shown in figures 1 and 2, were used by the United States Army in 1916 along the Mexican border.

In 1903, H. G. Wells published a short story entitled "The Land Ironclads" in *Strand Magazine.* He described a turtle-back weapon, 100 feet long, which could climb ditches and cross trenches. However, the birth of the tank had to await two major technological developments: an internal combustion engine to provide a reasonable source of power and tracks to allow the vehicle to cross rough country.[2] High interest in this unique fighting machine and realization of the needed technology came together in time to field the tank on the battlefields of World War I.

World War I

The tank, along with a highly effective machine gun and poisonous gases, brought fear and presented unique hazards to the soldiers who were called upon to use the sophisticated weapons of the Great War.

The first significant tank battle, The Battle of Cambrai, occurred on November 20, 1917 in Northern France. From behind the British front, 378 tanks, similar to the one shown in figure 3, moved toward the Hindenburg Line. Bryan Cooper chronicled the events surrounding the development of the tank and the Battle of Cambrai.[2] Included were descriptions of the plight of early tankers:

"Inside the tanks, the crews worked manfully to steer and control their lumbering charges. There was very little room to move about in, most of the space being taken

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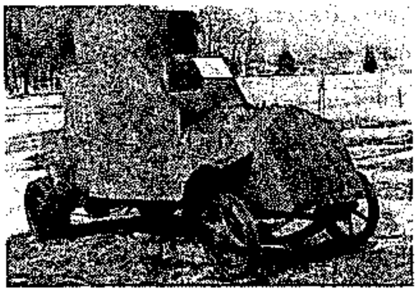

Figure 1. White armored car (M1913-1914) at the US Army Ordnance Museum, Aberdeen Proving Ground, Md. Built by the White Motor Company, this vehicle weighed about 2 tons and was a built-up, armored truck. Sporting dual rear wheels, pneumatic tires, and a caliber .30 Vickers-Maxim machine gun in the rounded turret, it was used by General Pershing's troops along the Mexican border in pursuit of Pancho Villa in 1916.

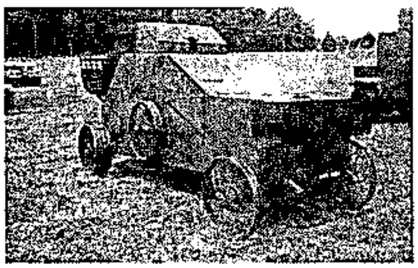

Figure 2. King armored car (M1916) at the US Army Ordnance Museum, Aberdeen Proving Ground, Md. The main armament of this vehicle was a Benet-Mercier machine rifle. It also was used in the 1916 Mexican border dispute.

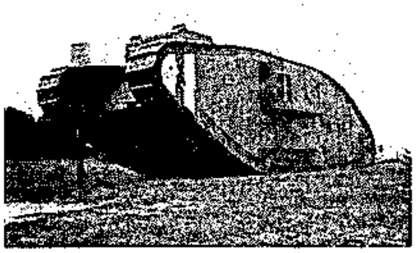

Figure 3. British Mark IV at the US Army Ordnance Museum, Aberdeen Proving Ground, Md. This 1917 vintage tank had five caliber .303 Lewis machine guns. The armor was only thick enough to protect against small arms.

Figure 4. Sherman medium tank (M4A4) of 1942 vintage at the US Army Ordnance Museum, Aberdeen Proving Ground, Md.

up by the large petrol engine in the centre. The interior was dimly lit by a naked electric light bulb, fed from the batteries. Vision to the outside was provided through narrow glass prisms, which had a habit of splintering into a driver's eyes when hit by a bullet. While riding across rough country, the crew were thrown from side to side as if weathering a stormy sea, and the noise was so intense that it was not unknown for a man's eardrums to split. Another hazard was that of the choking fumes of the petrol engine, and if an exhaust pipe became damaged, a crew could easily be asphyxiated."

One of the first men to go into battle in a tank, William Divall, described the experience in a letter to his sister:

"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."[2]

The noise and the vibration of the World War I tanks were so intense that the wireless transmitters of the day could not be used. As a less than ideal alternative, semaphores were adopted, with metal arms protruding from the sides of the tanks. Morse-code flag signalling was done through a trap door in the roof.[2]

The first evidence of military medical officers attempting to identify and correct health threats to the users of military machines appeared in the French Army during the World War I period. The danger of carbon monoxide poisoning from firing machine guns in tanks and enclosed or partially enclosed shelters was well known. The carbon monoxide came from the incomplete combustion of propellant in the machine-gun shells. Accidents producing carbon monoxide casualties had occurred prior to and during the war. Gun emplacements which had been hermetically sealed to protect gun crews against enemy poisonous gases, like chlorine, were identified as being extremely dangerous because these allowed the carbon monoxide to accumulate and reach high levels.[3] There was very little ventilation inside a tank and this situation also resulted in the accumulation of carbon monoxide. Observations made at the Tank Training Center at Marly and at Bourges on the Schneider tank resulted in a formal report on casualties from carbon monoxide poisoning in tanks.[3]

In a series of tests done in April 1918, in a Renault tank with a Hotchkiss machine gun, an attempt was made to identify the circumstances producing the maximum carbon monoxide level. This was found to be an average of 5.7 parts per 1000 parts of air (by volume) with the firing of 490 rounds. The internal vehicle atmosphere was described as filled with considerable smoke and causing tearing. The circumstantial cause of this level was firing with all doors closed and the engine stopped. Opening the doors or running the tank engine reduced the level considerably.[3]

The conclusions that the French drew from their fairly extensive work were that machine-gun emplacements must never be enclosed by completely air-tight sealing and soldiers must be protected against carbon monoxide by adequate ventilation. They were unsuccessful in filtering-out carbon monoxide but obtained some encouraging data to show that modifications to the machine-guns of the period might be feasible and effective in reducing carbon monoxide levels.[3]

Between the Great Wars

During World War I, the US Army Surgeon General had been in-

volved in poisonous gas defense. However, following the war, the Army Medical Department (AMEDD) failed to develop and maintain the skills in occupational health and related areas which were needed to prevent soldiers from being exposed to unnecessary risks.[4] Fortunately, federal, state and local governments, and private industry recognized the value of such skills. As a result, programs in occupational medicine and industrial hygiene received emphasis in civilian graduate schools of public health. These civilian sources provided the expertise and citizen soldiers of the AMEDD to deal with the problems of the military machines of World War II.[4,5]

World War II

As new generations of sophisticated weapons were being displayed and the involvement of the United States in World War II became a reality, the AMEDD began evaluating the medical consequences to the soldier who operated weapon systems. The Armored Force Medical Research Laboratory was formed at Fort Knox, Ky, in early 1942. Staffed by physicians, medical and physical scientists and engineers, the mission of the laboratory was to:

(1) Identify and evaluate the stressful demands placed on operators of tanks and other weapons.

(2) Determine the limits in the capabilities of soldiers.

(3) Find the proper balance between operating demand and human capabilities to avoid breakdown or failure of the man-weapon system.[6]

During its more than three years of service, people in the laboratory produced approximately 130 reports dealing with 19 different categories of problems, including fatigue, heat stress and toxic gases. Theodore F. Hatch, ScD, and William B. Bean, MD, have summarized some of the most interesting work.[6,7] For example, Dr. Hatch chronicled one demonstration in which general officers became tank crewmen in order to experience the irritating effect of ammonia produced by main gun fire in a buttoned-up M4 tank (similar to the one in figure 4).[6]

Post World War II

Weapons and equipment development continued following World War II and new agents, like radar and laser energy, became potential threats to the soldiers who would operate and maintain the new items. The AMEDD did not lose its expertise in occupational medicine and industrial hygiene but continued to provide service and to do research. However, the Medical Department was not integrated into the Army Materiel Acquisition Decision Process (MADP) through which new items are developed and fielded. Therefore, there was no systematic medical review of new tanks, guns, and equipment in order to identify and control or eliminate hazards to the users and the maintainers.

In the late 1970s the shortcomings resulting from the absence of medical expertise in the MADP became apparent. Questions arose about the potential harmful effects from blast overpressure with the M198 Howitzer and carbon monoxide levels in the Bradley Fighting Vehicle when both these items were in the homestretch of a multiyear MADP cycle. These questions should have been addressed early in the conceptual stages to preclude possible costly and even unacceptable changes. To prevent similiar problems in the future, Army Regulation 40-10 which established the Army Health Hazard Assessment (HHA) program, was published in October 1983.[8] This regulation requires medical review of items in the MADP at critical points in the multiyear cycle. The HHA process has been involved with the evaluation of a long list of potential hazards, to include noise and vibration in helicopters, toxic gases in armored vehicles, blast overpressure from mortars and possible skin irritation and sensitization from items of personal issue.

More recently, the Army Deputy Chief of Staff for Personnel has undertaken the Manpower Integration, or MANPRINT, initiative. The primary objective of this effort is to ensure that the human component is considered first in the design and development of Army systems. By regulation, key personnel in the MADP are required to attend MANPRINT educational programs (which include orientation to medical topics) and to ensure that the human aspect of the soldier-machine interface is not forgotten but that is given the highest priority.[9]

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The Health Hazard Assessment Program: Occupational Health for the Soldier in the Field

Maj (Ret.) Scott E. Rowden*
Maj Roger M. McIntosh, MC**

The purpose of the Army Health Hazard Assessment (HHA) Program is to identify potential chemical, physical, and ergonomic hazards associated with the use of military vehicles and equipment. The goal of this effort is to eliminate or control these hazards, and reduce the likelihood of injury, illness and performance decrements in soldiers. This is accomplished through design modification, providing personal protective equipment for the soldier, and/or training in the proper use of equipment. This article discusses the evolution of the HHA Program and provides an overview of selected health hazards associated with several Army systems and items.

The Department of Defense has recently undertaken one of the greatest modernization efforts in recent history. Advances in technology will ensure the development of increasingly sophisticated weapon systems for use in future conflicts. However, these new systems will generate greater noise and blast overpressure, more shock and vibration, higher concentrations of toxic fumes and gases, as well as new hazards from ionizing and nonionizing radiation.

In the mid-1970s, the AMEDD and Army materiel developers became aware that soldier performance decrements and adverse health effects associated with the use of field equipment were beginning to define the limits of technology for new systems. To address these concerns, the basic Army materiel acquisition regulation[1] was revised to give the Army Surgeon General responsibility for evaluating health concerns during the materiel acquisition process. The Surgeon General accepted responsibility for identifying the health hazards associated with new materiel and estimating the expected decrement in soldier performance associated with these hazards. However, no formal program for addressing health hazards was initiated.

In the late 1970s, the M198 (155mm) Howitzer was undergoing development and evaluation. During field testing, there were reports from soldiers of chest wall pain and blood-tinged sputum. Impulsive noise measurements indicated that existing hearing conservation standards were exceeded even when double hearing protection was worn. The initial AMEDD recommendation was to position crew members outside a 25-foot circle behind the breech. Since this was unacceptable to the field artillery school, the AMEDD investigated further. After completing animal and carefully controlled human studies, the maximum number of rounds were calculated that could be fired safely each day by crew personnel without adverse health effects.

Following this incident, The Army Surgeon General initiated actions which ultimately resulted in the publication of Army Regulation 40-10, the formal authority for the HHA Program.[2]

The Materiel Acquisition Decision Process

The procedure by which new Army items are developed, tested and eventually accepted into the inventory is called the Materiel Acquisition Decision Process (MADP). As a system or item progresses through this developmental process, medical data are gathered and used to prepare HHA reports which are then provided to the decision makers. These written reports contain recommendations which address system redesign, personal protective equipment, and administrative controls. Recommendations are also made to incorporate specific procedures or protective equipment requirements into user manuals. Through this process, the potential health concerns associated with a system are addressed prior to their incorporation into the Army inventory.

Understanding the Diversity

The preparation of an HHA report requires input from health professionals in a variety of occupational health-related disciplines such as occupational medicine, industrial hygiene, acoustical engineering, laser and microwave technology, toxicology, and environmental engineering. Discerning and characterizing the nature of a system's health hazards is a unique challenge, requiring detailed information about how the system will be deployed, maintained, and disposed of. An intricate knowledge of the health effects associated with a wide variety of chemical, physical, and ergonomic hazards is required as well. The following example is instructive.

The OH-58D is a superb example of the diversified exposure of soldiers, which can be associated with one system (Fig 1). This advanced scout helicopter has a two-person crew and is designed for enhanced aerial reconnaissance, intelligence gathering, and target detection, acquisition, and designation. Five major categories of health hazards have been identified:

(1) The ball on top of the main rotor contains a laser for target ranging and designation. The laser's potential for retinal or skin damage had to be evaluated.

(2) Due to the great amount of electronic equipment on-board and

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Figure 1.

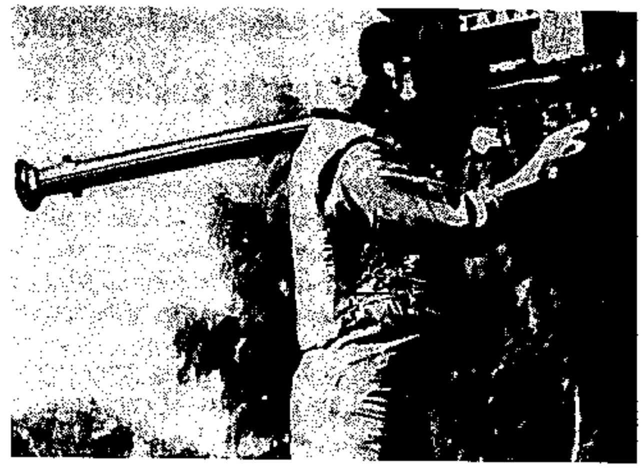

Figure 2.

the need for the crew to wear chemical protective clothing, heat stress was identified as a potential concern and assessed through psychometric measurements and computer modelling.

(3) Because of the potential for engine combustion products to enter the cockpit through the ventilation system, the presence of potentially harmful exhaust products in the cockpit was evaluated.

(4) The airframe and main rotor were modified, and a new engine was added. These modifications altered the steady-state noise and whole-body vibration signature, necessitating an evaluation of these physical hazards.

(5) Finally, the seats used with the OH58D airframe had been associated with an increased incidence of spinal injuries during crash landings. Therefore, the crash worthiness of the seats was raised as an issue to be readdressed by the aviation safety community.

Overview of Specific Health Hazards

An overview of several selected health hazards associated with other systems which have been studied further highlights the diversity of the HHA Program.

Hydrogen Chloride

Hydrogen chloride is a severe irritant of the respiratory tract, skin, and eyes. When inhaled in high concentrations, it can cause necrosis of the tracheal and bronchial epithelium, and produce burning, coughing, or shortness of breath.[3] Any perchlorate-based rocket motor will generate significant concentrations of hydrogen chloride gas during combustion.

The Stinger is a shoulder-fired, surface-to-air, guided missile (Fig 2). Unfortunately, this weapon system was designed to be fired by soldiers who are not wearing protective masks. Wearing a mask makes it impossible for a soldier to use the Stinger. During test firings in an open environment, concentrations of hydrogen chloride in the breathing zone of the user exceeded established ceiling limits and an emergency exposure limit proposed by the National Academy of Science. At concentrations of 150 mg/m,[3] soldiers firing the weapon complained of coughing, eye watering, and difficulty in breathing. These adverse effects, while short-lived, could result in significant performance decrements in soldiers required to fire the Stinger. Recommendations have been made to redesign the Stinger to accommodate a protective mask.

The multiple launch rocket system, another perchlorate-based rocket system, is used for fire support and suppression of enemy air defenses (Fig 3). Soldiers inside the crew compartment were exposed to high concentrations of both *hydrogen chloride* and *ammonia* during testing. This resulted in complaints of eye and throat irritation, coughing, and difficulty in breathing. Recommendations were made to overpressure the crew compartment and to improve the seals of the crew compartment to prevent hydrogen chloride exposures.

Hydrogen Cyanide

Hydrogen cyanide is a potent chemical asphyxiant which acts within seconds to minutes by inhibiting oxidative phosphorylation at the cellular level.[4] A request was received to evaluate the medical aspects of three candidate fuel bars to be used as heating rations in the field. These were trioxane, Delrin®, and hexamine. All of these fuel bars liberate carbon monoxide, formaldehyde, and ammonia during combustion. Unfortunately, hexamine, when burned inside a field tent, may also generate greater than 50 parts per million hydrogen cyanide. While this concentration is not lethal, exposure to such levels will cause headache, nausea, fatigue, and confusion after prolonged exposure.[5]

Because the burning of fuel bars inside tents cannot be precluded, and since there are other acceptable alternatives to hexamine for use in heating field rations, hexamine was identified as a medically unacceptable fuel bar.

®Delrin is a registered trademark of E.I. du Pont de Nemours and Co., Wilmington, Del.

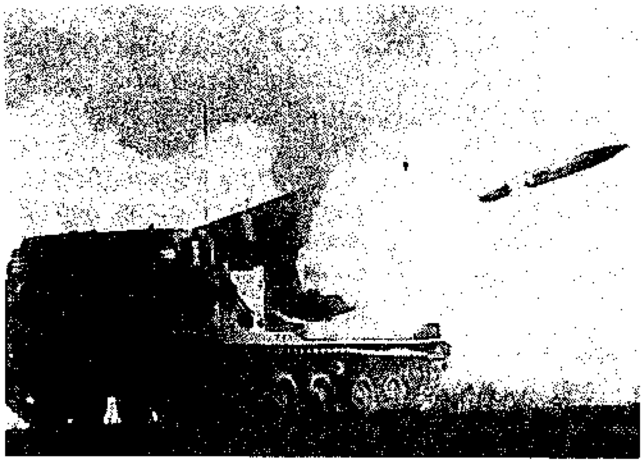

Figure 3.

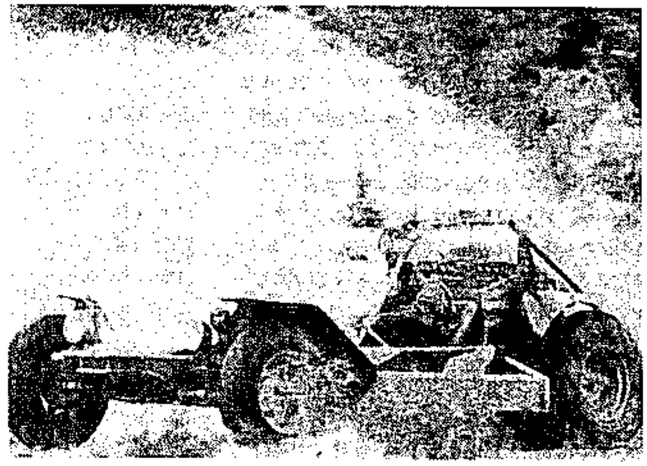

Figure 4.

Hexavalent Chromium

Exposure to certain insoluble hexavalent chromium compounds has been linked with an increased incidence of lung cancer in occupational mortality studies.[6,7] In 1982, it was discovered that certain lots of the M11 canister (worn with the M9 protective mask) were leaking charcoal fines onto the face of the mask wearer. The AMEDD became concerned because these charcoal fines contained basic copper dichromate and copper dichromate dihydrate —both of which are insoluble hexavalent chromium compounds. Further investigation revealed that the charcoal fines had particle sizes of 1 to 50 microns, with a substantial fraction within the respirable range. Following extensive studies, a filter pad was inserted downstream from the charcoal container to collect the escaping charcoal fines and thereby limit potential hexavalent chromium exposure. In addition, recommendations have been made to substitute less toxic, noncarcinogenic molybdenum or vanadium compounds in place of chromium in the charcoal.

Whole Body Vibration

Whole body vibration is a hazard generic to any vehicle moving rapidly over rough terrain. It may be exacerbated or mitigated by the vehicle suspension system and seat design. The human health effects from prolonged occupational exposures to whole body vibration are unclear. Short-term animal studies and human epidemiologic studies suggest that whole body vibration acts as a nonspecific generalized stressor in aggravating existing health impairment. More severe levels of whole body vibration may cause sprains and strains, low back pain, and damage to the urinary tract.[8,9]

An HHA was performed on the Fast Attack Vehicle—a modified dune buggy capable of high speed cross-country travel (Fig 4). This vehicle had an extremely stiff suspension system and essentially no seat cushioning. Measurements of whole body vibration with seat-pad-accelerometers demonstrated that the predominant vibration accelerations occurred over a frequency range at which the human body visceral organs actually resonate —that is, they amplify the absorbed vibration energy. Under these testing conditions, there were reports of gross hematuria and back-related injuries in a significant number of soldiers. Recommendations were made to alter the suspension system so that the predominant vibration accelerations are outside the human body resonant frequencies. It was anticipated that this modification, along with improving the shock absorbency of the seats, would improve driver performance and reduce the likelihood of health impairment.

Microwave Radiation

The HAWK Air Defense Missile System has two radar systems. The high power illuminator radar (HPIR) can irradiate in a narrow pencil beam mode or as a wide beam in a fixed direction. The continuous wave acquisition radar revolves continuously on its pedestal, and generates much lower power density levels at any fixed point in the field. Both of these radar units emit microwave radiation in the 10-20 Gigahertz (Ghz) frequency range. The current Army standard for radiofrequency radiation allows exposure to power density levels of 10mW/cm (in the 10-20Ghz frequency range) for an indefinite period of time.[10] However, it was found that field maintenance personnel may be exposed to power density levels of 250mW/cm^3 when operating the HPIR in the wide beam mode or 800mW/cm^3 in the narrow beam mode. These exposures would only occur if the individual were standing directly in front of the unit while it was transmitting. Nevertheless, considerable heating of the lens or surface body tissues could occur under these conditions. Following identification of the problem, adequate emission control features were built into the system to preclude such exposures.

Heat Stress

Almost all the new systems have the requirement that they be capa-

ble of operating in a chemical environment. Often times, this means the wearing of protective clothing or mission oriented protective posture (MOPP) gear by the operators. The OH58D advanced scout helicopter was projected for use in training scenarios with crew members flying up to 4-hour missions while wearing MOPP gear. However, since this helicopter contains a laser, it can only be used in training on laser safe ranges. Unfortunately, all these ranges are located in the desert. Computer modelling of flight conditions at Yuma Proving Ground, Arizona predicted that within two hours aviators would begin to develop performance decrements and within three hours, heat illnesses would occur. This prediction was based upon psychrometric data obtained with the doors of the aircraft open and the crew in flight suits only. In a tropical environment, with crew members wearing MOPP gear and having the doors closed, it was predicted that crew members would suffer performance decrements within 90 minutes and heat illnesses shortly thereafter. It was therefore recommended that a microclimatic cooling system be incorporated into the helicopter for use when MOPP gear is required.

Lifting

A chief ergonomic concern is lifting. The XM17 Sanator is a portable, gasoline-driven decontamination system designed to draw water from any source to spray it over the exterior surfaces of contaminated vehicles and equipment at high temperatures. The main advantages of this unit over the Army's present system were supposed to be its lightweight and portability features. The new unit weighed 330 pounds and was designed to be lifted and carried by four individuals—one at each corner of the apparatus. Potential users envisioned transporting this unit in trucks having tailgates in excess of 52 inches high. The use scenario required that each individual perform a one-handed lift of 83 pounds to a height of 52 inches. Only 8% of US Army male soldiers would be expected to have the capability to perform this lift, and less than 1% of female soldiers could accomplish the task. Recommendations were made to employ some type of material-handling-equipment when transporting this equipment.

CONCLUSION

These examples illustrate that not anticipated health hazards may limit the effectiveness of new Army systems if adequate design modifications or controls are not recommended prior to fielding the system. Recognition of this fact has led to the development of a highly successful HHA program by the AMEDD. This program has demonstrated its value numerous times during its short history.

The practice of Army occupational health offers unique and difficult challenges. Nowhere is this demonstrated more than in the support provided the HHA program. In many of the unusual and combined exposures evaluated, civilian industry and academic institutions have developed little in the way of relevant data. Therefore, the Army has found it necessary to begin significant research programs in occupational health. Examples of these are in the areas of whole body vibration and toxic gases, particularly where short duration, high exposure levels occur.

Implementing changes in major systems can be costly in terms of time and money. The HHA Program requires a continuing dialogue between the AMEDD and system program managers to identify requirements and priorities. Trade-offs are considered, and effectiveness as well as cost of design changes, use of personal protective equipment, and training are weighted. The HHA process has placed a critical and long neglected requirement for ongoing medical evaluation and input in the material acquisition and decision process.

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Carbon Monoxide in US Army Tactical Vehicles

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The potential hazards of carbon monoxide (CO) in automobile exhaust and improperly used heaters have long been recognized. In confined areas CO buildup from incomplete propellant combustion poses an additional hazard to the soldier. Carbon monoxide is a serious threat to modern combat vehicle crewmen when vehicle systems are improperly used or malfunction.

Tactical Setting

"After standing silent watch for almost 7 hours, the crew moved their tank into a firing position. Targets were engaged, first with great precision and later with increasing inaccuracy. After firing 13 main gun and approximately 100 coaxial machine-gun rounds over a period of 32 minutes, the tank broke off the engagement. The loader was slumped forward in his seat, unconscious. The tank commander was dizzy and having visual difficulties. Hostile fire could not be returned."

Fortunately, this scenario had an acceptable ending. The crew recovered and the vehicle was not lost to enemy action. This would certainly not be the case had it occurred on an European battlefield. The commander and loader of this M1E1 tank undergoing operational testing at Fort Hood, Texas, had been overcome by one of the oldest known anthropogenic toxic substances, CO. Several hours after exposure ceased, their blood carboxyhemoglobin (COHb) levels were 27.8 and 33% respectively—well above levels where degradation of performance occurs.

At the time of this incident the tank's hatches were closed, the engine was off, and the main nuclear-biological-chemical (NBC) system was inoperable. The tank's back-up breathing system was being used. The breathing air supplied to the crewmen's protective masks had been circulated through the gas particulate filter (GPF) unit designed to protect the crew in a chemical environment. The GPF system recirculated air in the vehicle crew compartment. It removed combustion products which trigger olfactory warning sensations, thus eliminating cues of a build-up of noxious and irritating products. Neither the GFP system nor the tank's NBC system remove CO from inspired air. All four crewmembers were astonished that they were affected by CO without any of the expected odors or mucous membrane irritation.

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Crewspace Environments

The danger of CO exposure in tactical vehicles has long been recognized. One of the earliest attempts to study CO exposure hazards in military weapon systems was conducted in 1943.[1] This study provided the following:

(1) Insight into the nature and potential severity of toxic gases in armored vehicles.

(2) Stated that the atmospheric conditions inside the M4 series medium tanks were completely unsatisfactory.

(3) Noted a direct association between levels of COHb in the blood and the workload of the crewmen.

Following World War II, little attention was directed toward resolving the CO hazard in confined crew spaces. However, in the mid 1970s, the US Army Test and Evaluation Command began to report the occurrence of extremely high CO concentrations in newly developed enclosed weapons systems. The low profile, compact, air-tight tactical vehicle design requirements for survival on the modern, chemical battlefield, coupled with a need for additional firepower and increased maneuverability, had exacerbated the crew space CO problem.

Crew space CO exposure profiles in modern combat vehicles are characterized by short, high-level, transient CO concentrations with rapid rises and falls. Concentrations in excess of 6,000 parts per million are routinely measured for brief periods. Fortunately, these high concentrations decay in less than a minute if vehicular ventilation and breech gas scavenging systems are operative. Unfortunately, these systems are extremely vulnerable to enemy fire and malfunction. Failure of any component of the ventilation or breech gas scavenging system results in rapid accumulation of CO in the crew space. The M1E1 scenario described above clearly illustrates the significance of this limitation.

CO Poisoning

CO is a colorless, odorless, tasteless, and nonirritating gas, slightly less dense than air. It is formed by the incomplete combustion of carbonaceous materials. It is introduced into the crew spaces of tactical vehicles as an emission of weapons fire and engine exhaust. It is not significantly altered metabolically in the body. The main physiologic effect is tissue hypoxia which occurs when CO binds reversibly with heme pigments, principally hemoglobin, to form COHb.

CO competes with oxygen for binding sites on the hemoglobin molecule. Hemoglobin affinity for CO is approximately 220 times greater than oxygen. Once formed, COHb is slowly reduced. In addition to decreasing the oxygen-carrying capacity of the blood, COHb also shifts the oxyhemoglobin dissociation curve to the left. This reduces the oxygen tension in both the capillaries and cells increasing tissue hypoxia. CO can seriously impair the transport of oxygen even when present at very low partial pressures.

The COHb formation rate is influenced by many variables. Uptake is limited by the rate of diffusion from the alveoli and the rate of combination with the hemoglobin in the blood. Diffusion across the pulmonary membrane varies with the concentration of inspired CO, exercise (alveolar ventilation), body size (diffusion capacity), and the barometric pressure (pulmonary capillary oxygen pressure). Formation of COHb exacerbates the effects of oxygen deficiency associated with anemia and present at high altitude. When CO and high altitude are combined, the effects appear to be additive.

Excretion or elimination of CO from the blood conforms to a "half-life" phenomenon with an average of 320 minutes.[2] COHb reduction occurs rapidly at first, becoming slower with time and decreasing COHb concentrations. Excretion can be accelerated by increasing alveolar ventilation rates and the partial pressure of inspired oxygen. Breathing oxygen at one atmosphere reduces the COHb half-life to 25% of the ambient-condition of CO excretion. Inhalation of oxygen at hyperbaric pressures produces incremental decreases in the COHb half-life reduction.

Performance Degradation

The threshold concentration of COHb for demonstration of adverse effects on performance is still under investigation. Visual brightness discrimination and effects on vigilance have been reported at concentrations as low as 4% saturation.[3] The ability to perform complex intellectual tasks, such as remembering number sequences, appears to be reduced at COHb concentrations above 7%. Operational significance of these subtle alternations remains to be defined. When COHb saturation is 20% or greater, objective evidence of CO intoxication is observed. The first consistent symptom, appearing with concentrations between 15 and 20%, is the onset of a frontal headache relieved by breathing 100% oxygen. Dramatic impairment of manual dexterity occurs when COHb concentration approaches 30%.[4] The capacity for exercise is greatly reduced above 30% and the ability to perform work is negligible above 40% COHb concentration. Unconsciousness, coma, convulsions, and death are expected when concentrations begin to exceed 50%.

The cardio-vascular effects of COHb deserve special consideration. Sudden exertion in an individual with carboxyhemoglobinemia requires a substantial increase in coronary blood flow in order to overcome the effects of increased myocardial oxygen requirements, decreased oxygen carrying capacity of hemoglobin, and the leftward shift of the oxyhemoglobin dissociation curve. In the presence of existing compromised coronary blood flow, myocardial hypoxia may occur. Ectopic electrical activity, decline in contractile forces, and ventricular fibrillation have been reported with COHb concentrations as low as 5%.[5] Individuals with atherosclerotic heart disease, chronic obstructive pulmonary disease, or anemia are hypersensitive to the effects of CO and should be excluded from exposure.

Evaluation of CO Exposure

Blood COHb determination is the only means of direct measurement of the physiological effects of CO exposure. Venous blood COHb concentrations in samples collected in evacuated tubes containing heparin or ethylenediaminetetraacetic acid are stable for at least ten days at ambient temperatures.[6] Blood COHb concentrations can be directly measured by spectophotometric or gas chromatographic elution methods. Unfortunately, only major laboratories are usually equipped with the necessary instrumentation. This leaves the majority of clinicians with only exposure history and physical assessment on which to base differential diagnoses and direct patient management. Fortunately, a means of estimating blood COHb values from expired air has been described by several authors.[4,7,8] A predictable relationship exists between the concentration of COHb in the blood and

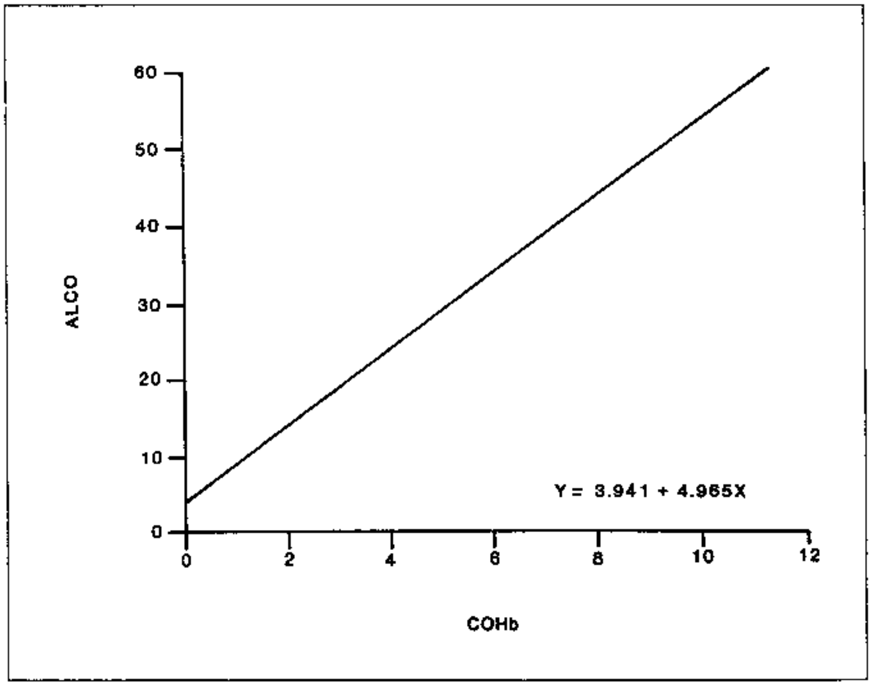

Figure 1. COHb estimation from expired air.

the CO concentration in aveolar air of the functional residual lung volume collected during forced expiration. This relationship appears to be best expressed in terms of the linear equation: ALCO = a + bx, where ALCO is the alveolar CO concentration in ppm volume and x is the percent saturation of COHb in the blood. The constant 'a' equals 3 and the constant 'b' equals 5 (Fig 1). This relationship only holds true when ambient CO concentrations are negligible and subjects are capable of assisting in the collection technique. All COHb estimates above 10% should be confirmed by blood analysis. This technique is especially suited to the operational and emergency room environment where laboratory support is limited. Instruments to measure CO in expired air may be found in Army Preventive Medicine organizations.

SUMMARY

Recent Army materiel development programs involving tactical vehicles have stressed the need for smaller, low-profile vehicles with additional firepower and increased maneuverability. Current doctrine requires that tactical vehicles be capable of sustained operations in a chemical environment. These specifications and conditions place maximum demands on all vehicular environmental systems including ventilation. Failure of any system component through malfunction, combat damage, or inappropriate use by crewmen, could lead to a dangerous accumulation of CO in the crew space. Inhalation of CO results in the decreased ability of the blood to transport oxygen due to the formation of COHb. Levels of COHb above 5% have been associated with performance degradation of vigilance skills and above 20% with crew incapacitation.

Direct measurement of blood COHb is frequently not available to physicians assigned to health facilities supporting operational units. However, blood COHb concentration can be accurately estimated from the end forced expiratory breath alveolar concentration of CO. The accuracy and simplicity of this technique support its adoption as a practical field method for the rapid estimation of blood COHb levels in crewmen exposed to CO in confined crew spaces of tactical weapons systems.

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COW POCK. *Colored etching by James Gillray (English, 1757-1815), London, 1802. "Cow Pock" is outright caricature that pulls no punches. Vaccination was a very controversial issue at the beginning of the nineteenth century, and was violently attacked by word and picture. The scene is probably the Smallpox and Inoculation Hospital at St. Pancras. The administering physician is unmistakably Jenner himself. It seems strange to us today that a rational technique such as vaccination should have generated such virulent opposition when it was first proposed.*

Hazards of Fielded Lasers

David H. Sliney*

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Laser use in the Army has increased dramatically. Used improperly, many lasers can cause serious injury, especially to the eyes. With proper precautions, soldiers may train with currently fielded Army lasers without a substantial risk of injury. The risk of overexposure to laser radiation is relatively high for laser maintenance technicians and the developers of new lasers. In wartime, the possibility of laser injury increases for all soldiers because of the use of lasers by the enemy.

Soldiers commonly use lasers for fire control and training. Fire control lasers have two purposes: *range-finding* (measuring target distance) and *target designation* (irradiating a target with an "optical signature" that can be used as a homing beacon for laser-guided munitions). Training lasers are used to simulate the firing of conventional weapons, eg, the familiar Multiple Integrated Laser Engagement System (MILES) family of training devices simulates firing the M16 rifle and other direct-fire weapons.

Although fire control lasers are relatively low powered, given the proper circumstances most can injure the eyes and in some cases the skin. Training lasers are safe but some approach power levels that can cause eye injuries if viewed through unfiltered telescopic sights at distances less than 300 meters. Despite the potential for laser eye injuries, very few have actually occurred. This is because of built-in safety features (engineering controls) and the enforcement of strict safety control measures on laser ranges (administrative controls).

Laser Eye Injuries

Cases of suspected laser eye injuries that prove to be false alarms are far more common than confirmed injuries. As a result, clinicians should be skeptical about alleged laser injuries and should avoid a hasty diagnosis that states or even implies that one has occurred. It is usually difficult to establish with certainty that a particular ocular lesion was caused by a laser because of the similarity in appearance between laser-induced lesions and those caused by other means. For example, clinical findings associated with sun gazing could cause confusion. Usually, the best that a clinician can do is to determine whether the patient's signs and symptoms are consistent with an exposure from the type of laser implicated in the incident.

Different types of lasers produce lesions in different parts of the eye. The wavelength of the laser determines which ocular structure(s) will be damaged. Each type of presently-fielded Army laser emits radiation at only a single wavelength, and fortunately there are only four types of lasers (with respect to wavelength) that are used often enough to merit concern. They are summarized in Table I.

Table I. Wavelengths of Common Laser Types.

Laser Type	Wavelength (nm)	Band
Helium-neon	632.8	Visible (red)
Ruby	694.3	Visible (red)
Gallium-arsenide	905.0	Infrared
Neodymium-YAG	1064.0	Infrared

None of the wavelengths in Table I are absorbed to any great extent by the ocular media (cornea, aqueous, lens, and vitreous); therefore, at these wavelengths virtually all of the energy reaches the retina. Clinicians should be careful to avoid attributing a nonretinal lesion to one of the lasers listed in Table I, unless it is accompanied by massive retinal damage.

Table II provides information on fielded lasers and differentiates between the lesions caused by the different types of lasers. A spectrum of retinal lesions may be produced by the same laser, depending on the exposure level and duration. In addition, Table II describes the symptoms typical of each type of exposure. Visible lasers produce a brilliant flash of light and an afterimage, while infrared lasers do not. Pulsed lasers, both visible and infrared, frequently will elicit an audible snap. The symptom common to all laser-induced retinal lesions is scotoma (blind spot) situated at the visual field locus that corresponds to the site of the injury on the retina, eg, the scotoma will be in the temporal visual field if the lesion is on the nasal retina.

If the signs and symptoms are consistent with an exposure from the relevant laser type, the clinician should consider two additional factors before making a diagnosis: circumstances of exposure, and preexisting lesions. Circumstances of exposure include whether the angle of exposure (eg, position of the laser) is consistent with the location of the lesion, whether the laser was turned on, and whether laser-protective eyewear was being worn. Laser beams may be reflected. Therefore, in some cases unravelling the circumstances of exposure may require a trained health physicist. Finally, the clinician should

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Table II. Laser Types and Army Classifications with Associated Clinical Signs and Symptoms of Laser Eye Injuries.

Laser Type	Signs	Symptoms	Army Application
Helium-neon	None (with currently fielded devices)	Brilliant flash of light; afterimage	M55 tank gunnery trainer
Ruby	Vary from well-defined area of retinal edema, to subretinal hemorrhage, to vitreous hemorrhage	Brilliant flash: audible snap (if pulsed laser); afterimage; scotoma; pain	AN/VVS-1, AN/VVG-2; examples of use: tank rangefinders.
Gallium-arsenide	None (with currently fielded devices)	Dull red glow	TASO, MILES, MAGLAD; examples of use: Direct-fire simulators and training devices.
Neodymium-YAG	Vary from well-defined area of retinal edema, to subretinal hemorrhage, to vitreous hemorrhage	Scotoma without flash or after-image; audible snap (if pulsed); pain	AN/PAQ-1, AN/PAQ-3, AN/GVS-5, AN/TVQ-2, LAAT; examples of use: ground laser designators and tank rangefinding.

look for evidence in the medical record of a pre-existing lesion, eg, a fundus photograph or ophthalmoscopic examination, a visual field loss, or a history of reduced visual acuity.

Medical Surveillance for Laser Exposure

Army policy on medical surveillance for laser exposure is based on the Department of Defense Occupational Health Surveillance Manual[1] and is described in detail in an Army regulation, a technical bulletin, and an Office of The Surgeon General Policy Letter.[2-4] A useful reference on laser surveillance is the *Proceedings of the Symposium on Ophthalmic Surveillance of Personnel Potentially Exposed to Laser Radiation.*[5]

Since the eye is much more vulnerable to the effects of laser radiation than other parts of the body, laser surveillance is limited to ocular and visual examinations. The extent of the examination depends on whether individuals are "laser workers" or "incidental workers."

Laser Workers

A laser worker is one who routinely works in a laser environment and who has a significant risk of accidental overexposure. Fortunately, there are relatively few Army personnel in this category. Examples of laser workers include those individuals who regularly work in research, development, test, and evaluation (RDTE) of lasers or those who do maintenance on lasers. Laser workers require complete medical surveillance to include preplacement, periodic, and termination examinations.

The preplacement and termination examinations for laser workers must be done by a health care professional who has been specifically credentialled to perform laser surveillance, generally an optometrist or ophthalmologist. The examination protocol consists of:

(1) A case history with emphasis on previous eye injury or disease.

(2) Distance visual acuity (with correction) in each eye. If the acuity is poorer than 20/20 in either eye, a refraction must be done to obtain the best corrected acuity.

(3) A slitlamp examination of the lense and cornea and an ophthalmoscopic evaluation of the fundus, both with the rapidly acting, short-duration mydriatic (unless the use of a dilating agent is contraindicated by medical history and/or professional judgment). Photographic documentation is encouraged, but in its absence the following must be recorded in writing:

1. Presence or absence of opacities of the media.
2. Sharpness of the outline of the optic nerve head.
3. Cup to disk ratio.
4. Ratio of the caliber of the retinal arteries to the retinal veins.
5. Presence or absence of a well-defined macula.
6. Presence or absence of a foveal reflex.
7. Any retinal pathology, even if only a small deviation.

Any abnormality found must be documented with a photograph or a sketch.

Laser workers are required to have periodic examinations every two years. These may be administered by a nurse or a technician, and consist of the screening protocol appropriate to that individual's job.[6] If the distance acuity (with correction) on the periodic examination is less than that found on the preplacement examination, the worker should be referred to an optometrist or ophthalmologist to determine whether there was an actual loss of acuity and, if so, to ascertain its cause.

Incidental Workers

An incidental worker is one whose work makes it possible, but unlikely, that he or she will be exposed to laser energy sufficient to damage the eyes. Examples of this category include operators of fielded laser equipment, individuals involved in laser use on approved laser ranges, and soldiers who participate in "force-on-force" laser training exercises.

Incidental workers require only a preplacement and termination exami-

nation. The examination protocol consists only of testing distance visual acuity (with correction) in each eye. If the distance acuity is found to be less than 20/20 in either eye, referral to an optometrist or ophthalmologist for a determination of the best corrected acuity and (if applicable) the cause of the reduced acuity is indicated. The visual portion of the entrance/pre-employment or separation/retirement physical may be used to satisfy this requirement (provided that the appropriate referral is made when 20/20 vision is not found).

Immediate Examination for Known or Suspected Overexposure

Any individual who is known or suspected to have been overexposed to laser radiation needs an examination by an optometrist or ophthalmologist within 24 hours. The examination protocol should include, as a minimum, all the tests required for a preplacement or termination examination of a laser worker. In addition, use of the Amsler grid is recommended. The US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, should be notified by telephone as soon as possible after the incident or accident (AUTOVON 584-2331/3534).

Eye-Protective Filters

Eye-protective filters are used on the optical sights of some fire control lasers. Although this type of filter protects laser operators, it fails to protect the individuals who are most likely to be exposed to direct laser radiation, the soldiers down range. To protect soldiers down range, "eye-safe" filters are available which are placed over the laser output port to cut down the beam's power. However, the "eye-safe" filters are intended for use only during training.

Laser eye protection for soldiers in combat must take into account other battlefield protective devices. For instance, future generations of chemical/biological masks will be equipped with laser filters. In addition, ballistic protective eyewear, which will safeguard against high-velocity, low-mass projectiles, will also provide laser eye protection.

Regardless of whether laser eye protection is issued as a stand-alone device or whether it is incorporated into other protective equipment, the challenge is to protect against hazardous forms of radiation without removing beneficial ones, eg, visible light. The degree to which visible light is eliminated depends on the method of filtration used. Glass filter lenses, which work on the principle of absorption, remove a significant amount of visible light. Examples of these are the BG-18 which protects against ruby (visible) and neodymium-YAG (infrared) lasers, and the KG-3 (or KG-5) which protects against neodymium-YAG lasers. The use of dyes with polymers, an approach more likely to be compatible with the protective mask and ballistic eye protection, causes even more visible light to be filtered out for the same degree of laser protection as the BG-18. To provide laser eye protection with minimal loss of visible light, the Army is developing "notch filters" which filter only the wavelengths of concern. While currently not available, notch filters may one day provide the optimum mix of safety and performance on the battlefield.

SUMMARY

With the use of proper protective equipment and procedures, currently fielded Army lasers are relatively safe. Therefore, only minimal medical surveillance is required except in those few cases in which ordinary administrative and engineering controls are not in effect (workers in RDTE and maintenance operations).

In combat, the unprotected eyes of friendly troops will be vulnerable to both hostile and friendly lasers. To defend against the battlefield laser hazard, the Army is developing filters which will provide eye protection.

We have had thousands of laser systems in the field over the last 15 years. These have been associated with only two documented eye injuries. Administrative and engineering controls do work but informed vigilance on the part of the medical community is absolutely necessary to ensure that injuries are identified and to validate the effectiveness of controls.

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Protection Against Noise and Blast

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J.H. Patterson, PhD**

Military service, in peacetime or war, is an inherently noisy occupation. Exposure to intense noise can pose a serious risk to hearing. Noise is broadly categorized as either continuous or impulsive. Continuous noise from engines, machinery, helicopter blades and tracked vehicles is almost ubiquitous in the military. Because of its importance as an environmental hazard in the civilian community, a great deal of research and regulatory interest has been focused on continuous noise. This paper deals only with the impulse noise which is generated by the firing of small arms, mortars, artillery and rockets. Intense impulse noise, though present at lower energy in industrial settings, is principally a military occupational health hazard. In addition to posing a serious risk to hearing, impulse noise may, in extreme circumstances, affect nonauditory structures. Hearing loss data from the Falklands conflict, a research effort to identify critical military auditory tasks, the disagreement among national standards, and an Army study to provide valid hazard criteria for mortars and towed artillery are all discussed.

Noise induced hearing loss (NIHL) is a major occupational hazard of military service. It is the single largest category of medical disability compensation for the US military with $166,517,208 being paid in benefits in 1985. In that year, it was listed as the primary disability diagnosis for 63,009 individuals and as a secondary diagnosis for another 211,344. These numbers are cumulative and do not represent the incidence of NIHL. However, as large as they are, they probably greatly underestimate the true prevalence of NIHL.

Surveys have shown that approximately one half of US Army combat arms soldiers will incur some NIHL over the course of a 20-year career. Tables I and II show that soldiers in the combat arms experience a steady decline in hearing acuity throughout their careers. There is no significant difference in hearing loss between soldiers in the infantry, armor or artillery. This survey was done in 1975 and thus contains large numbers of soldiers exposed to impulse noise during the Vietnam conflict. Unfortunately, there are no comparable data obtained since then.

Wartime service is associated with a great deal of hearing loss. The British have unique data from the Falklands conflict wherein soldiers had audiometric hearing surveys on record before combat. The soldiers were interviewed and examined upon their return from the war zone. As detailed in Table III, substantial numbers of soldiers were left with marked changes in hearing as the result of that brief, intense exposure. Mortarmen showed the greatest loss. A few individuals incurred such a severe NIHL that they had to be reassigned or discharged from the service.

Operational Liability of NIHL

Hearing loss is important not only for its social cost but because it may degrade military effectiveness. The handicap of deafness is obvious but can, to a degree, be ameliorated by amplifying appliances. Of more immediate concern to the military is the potential loss in combat performance which may accompany a hearing loss. The modern soldier is required to process a great deal of aural information and to make critical decisions

Table I. Percentages of soldiers falling into the categories of hearing function[30] for combat arms branches in the US Army.[9]

	US Army Hearing Loss Profile*		
Branch	H-1	H-2	H-3 or 4
Infantry	77.4	10.8	11.8
Armor	78.3	10.8	10.9
Artillery	75.8	9.5	14.7

*H-4 is the most severe (this equates to disqualification from service—even with the use of a hearing aid).

Table II. Percentages of combat arms soldiers (infantry, armor, and artillery) falling into the categories of hearing function[30] by length of service.[9]

	US Army Hearing Loss Profile*		
Years in Service	H-1	H-2	H-3 or 4
1.5 - 2.4	88.5	5.9	5.6
2.5 - 7.4	79.3	12.1	8.6
7.5 - 12.4	59.6	16.9	23.5
12.5 - 17.4	52.2	15.4	32.4
17.5 - 22.4	45.8	18.2	34.0

*H-4 is the most severe (this equates to disqualification from service—even with the use of a hearing aid).

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on that input. Accurate hearing is essential for spoken and radio communication as well as for surveillance functions. There are a number of factors inherent to military operations which compound the problem.

A high noise background (eg, vehicles, generators, and gun fire) makes it difficult to accurately interpret aural input. An everyday example is the difficulty experienced in hearing a telephone conversation when in a noisy room with typewriters or television.

Military communication may also contain much information of novel content. A higher signal-to-noise ratio is required to accurately interpret unexpected information. Multinational operations pose a problem as speech interpretation in a second language also requires a high signal-to-noise ratio. Imagine the difficulty of a North Atlantic Treaty Organization (NATO) operation with a German pilot speaking over a noisy radio in English to a French air traffic controller.

The operational liability of hearing loss has not been quantified but should be a matter of great concern to both the medical and combat services. A major research effort in this area is needed. Not only will such research identify critical military auditory tasks but it will serve as an effective means for obtaining and sustaining command emphasis on hearing conservation.

Table III. *British experience with hearing loss during the Falklands conflict.[18,26] (Hearing categories are by United Kingdom definitions with 4 being the most severe.)*

Test Group	Hearing Category	Pre	Post	%-Dropping Below H-1 + 2
All Infantry	1+2	316	271	13.3
	3	21	52	
	4	1	15	
Infantry—Small Arms	1+2	105	97	7.3
	3	4	9	
	4	0	3	
81mm Mortarmen	1+2	73	55	23.7
	3	2	17	
	4	1	4	
105mm Light Gun Crew	1+2	78	68	11.9
	3	6	14	
	4	0	2	

Prevention of Hearing Loss

There is no cure for NIHL; it must be prevented. Prevention is based upon providing some form of hearing protection and then limiting noise exposure to that which can be safely tolerated. This implies that exposure standards incorporate an understanding of the biophysical mechanisms of NIHL and the practical efficacy of hearing protection. This is not entirely true for present standards.

The US Army standard, MIL-STD-1474B, is based primarily on experiments conducted in the 1950s and early 1960s with unprotected exposure to small arms fire.[8] MIL-STD-1474B makes a uniform reduction in effective peak level for the use of any type of single hearing protection (SHP) (eg, ear plugs *or* muffs) and another for ALL types of double hearing protection (DHP) (eg, ear plugs *and* muffs). No allowance is made for the wide variation in inherent effectiveness of protectors or the differences in user application.[1,12] MIL-STD-1474B rates impulse noise hazard in terms of peak pressure, an arbitrary duration term (B-duration, the total time that the pressure signal fluctuates above ± 10 percent of the peak), and number of exposures.

Somewhat similar standards are used in the United Kingdom, the Netherlands and West Germany with slightly different duration terms being used by the latter two.[3,14,28] Use of peak and duration terms to describe hazards reflects the state of instrumentation available to researchers two or three decades ago when the original work was done in impulse noise. Recent studies by Patterson et al have shown that the energy in an impulse is a better indicator of hazard than its peak pressure.[11] Now it is possible to derive complex frequency dependent energy measures from pressure signals.

A new French standard for noise protection does incorporate an A-weighted energy function and an equal energy hypothesis.[22] (Note: The A-weighting network is frequency dependent and closely approximates the human ear's response to sound at low levels.) Since A-weighted sound pressure level is used in the assessment of steady noise hazard,[7] it would be convenient if an A-weighted level for impulse noise were an adequate indicator of hazard. Unfortunately, there is evidence to the contrary.[20,31] In fact, none of the existing national standards are in complete agreement with experimental data.[31]

Animal studies in the US and Europe and two US volunteer trials have indicated that all of the NATO standards mentioned above may be conservative for the lower frequency, high energy blast overpressure (BOP) of heavy weapons.[31] The spectral tuning of the ear may make it much more tolerant to low frequency impulses (cannons) than to high frequency impulses (rifle fire).[20] Despite conditions substantially above the limits of MIL-STD-1474B, no change in hearing sensitivity was found in 38 volunteers firing two rounds of a light, shoulder-fired antitank rocket (181.3 dB peak and 16.7 msec B-duration).[10] In another study, 59 soldier volunteers were exposed without ill effect to the BOP of 12 rounds of the top zone

charge of the M198 155mm Howitzer (180.7 dB peak and 43.4msec B-duration). In both trials only SHP with E.A.R.® ear plugs was used. Subjects inserted their own plugs, but they were closely monitored by Army investigators. Forrest, Forshaw, and Crabtree monitored hearing loss resulting from a field training exercise where the primary exposure was to the 81 mm mortar.[18] They noted no additional hearing loss after exposure to several hundred rounds with hearing protection. This is in contrast to the Falkland's experience noted above where the use of hearing protection was admittedly poor.[16]

There is evidence from a military environment, Army aviation, where the use of hearing protection is nearly 100%, that the hearing loss is less than that noted by Walden, et al.[13,19] After an average of eight years of service, aviators had hearing levels only slightly worse than the non-noise exposed civilian population. This is a prime example of applying good hearing protection and reasonable noise limits to achieve the goal of conserving the hearing of our soldiers.

Another important factor in any exposure standard is the decision as to the acceptable level of risk. No standard can protect everyone exposed from all risk. MIL-STD-1474B has as its premise the protection of 95% of the exposed population from incurring a significant permanent NIHL over a career of exposures.[8] The United Kingdom standard uses essentially the same data base as the US standard but allows significantly greater exposures because it is intended to protect only 75% of those exposed.[14] Decisions on acceptable incidences and severities of injury are more administrative than medical but are essential for converting a scientifically derived damage risk criteria into a usable safety standard.

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In 1980, a NATO Research Study Group of Panel VIII (RSG-6; "Effects of Impulse Noise") was assembled to address the differences in national impulse noise exposure standards. RSG-6 has served as a forum for exchange of data and coordination of research. Although no common standard has been formulated, it is clear that one must deal with some form of frequency—weighing of impulse noise, the nonlinear growth of hazard with increasing level, intersubject variability, and the practical efficacy of hearing protectors.[31]

A consideration in establishing the limits of MIL-STD-1474B was the possibility of "nonauditory physiologic injury."[8] It is well known that strong blast waves may injure gas containing organs.[24] While the unprotected ear is most sensitive, injury can occur in the respiratory and gastrointestinal tracts. Protection against the nonauditory effects of blast has proven to be either impractical (rigid armor) or ineffective (cloth ballistic vest). In one study, volunteers had pressure measurements made in the esophagus during exposure to blast waves of the same strength as are routinely experienced by artillerymen. Esophageal pressures were significantly higher when the standard issue Kevlar ballistic vest was worn.[29]

Extensive work with animals has defined the important parameters of BOP for nonauditory injury. Peak pressure and the pressure impulse of the initial positive phase (the A-impulse of Figure 1) as well as the total number of exposures interact to determine injury.[21,23] Based on extensive work with animal models, the estimated threshold of even the most trivial of these effects is significantly above the present NATO limits.[31]

In light of the findings above, the US Army is preparing to conduct a large scale volunteer study to directly determine the safe exposure limits for freefield heavy weapon noise. It will address the use of single hearing protection with either ear muffs or E.A.R. ear plugs and DHP with both. Maximum exposures will be determined by the estimated threshold of trivial nonauditory effects, the occurrence of laryngeal petechiae. An individual's exposures will be determined by his or her own response and not by group results. After each exposure, a hearing test and throat examination will be performed. If there are no effects, the next exposure can occur the following day with either the same number of more intense impulses or up to twice the number of impulses of the same intensity. Up to 100 exposures will take place within a two-hour period. Impulses will be generated by the detonation of a bare explosive charge and intensity will be controlled by varying the distance between subject and explosive. Short distances (0.5 to 2 meters) will give impulses of high peak pressure and low A-impulse which are characteristic of mortars. Greater distances (up to 10 meters) will give signals like large caliber artillery. This study has been endorsed by NATO RSG-6 and should provide valid noise hazard criteria for mortars and towed artillery.[31] Complex pressure signals (such as in the cab of self-propelled Howitzers or in firing from within enclosures) will still have to be dealt with using existing standards or on a case-by-case basis.

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Clinical Manifestations of Exposure to Nitrogen Tetroxide and Hydrazine Propellants

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Properties and effects of exposure to propellants used by the US Air Force and the National Aeronautics and Space Administration are discussed. The nitrogen tetroxide and hydrazine propellants have undergone decreased use in the Air Force with the phase-out of the Titan missile. However, these are still used extensively in attitude rockets for in-flight adjustment of trajectory and orientation in more modern missiles and are the propellants for the attitude adjustment rockets of the space shuttle. They have distinct advantages, but because of both acute and chronic toxicity, they require very strict handling procedures and protective measures.

Nitrogen Tetroxide Propellant

The nitrogen tetroxide (N_2O_4) propellant is a heavy, red-brown liquid which is 30% nitrogen and 70% oxygen by weight. It exists largely (70%) as N_2O_4 in equilibrium with NO_2. It reacts with water to form nitric and nitrous acid. Some alcohols and unsaturated compounds are hypergolic with N_2O_4. Most parafins and aromatics can be dissolved up to 3000 parts per million (ppm) before becoming detonable. N_2O_4 can cause spontaneous combustion in contact with paper, cloth, and other flammable debris of a similar nature. Nitration of plant and organic matter may produce explosives.[1]

N_2O_4 and hydrazine (N_2H_4) can be stored as liquids without refrigeration. The reaction between N_2O_4 and N_2H_4 is limited to the interface between the two liquids because they are kept apart by the gases formed in the reaction. N_2O_4 itself is not combustible and fires resulting from contact with combustible materials can be fought with ordinary firefighting methods. This is also true for combustion caused by contact of N_2O_4 with hydrazine.[1]

Clinical Findings

The clinical picture resulting from exposure to N_2O_4 will vary depending on concentration and length of exposure. At very low atmospheric concentrations, tissue reaction in the lung probably results from direct nitration of lung tissue. At more concentrated atmospheric levels, nitric and nitrous acid formation with secondary oxidation of tissue is the likely mechanism of tissue damage.[5]

Odor is detectable by some people at 0.11 ppm and by most at 0.22 ppm. The odor is similar to that of chlorine and has been described by some as smelling like battery acid. Levels of 3-6 ppm may result in increased airway resistance in sensitive people with decreased O_2 diffusion and decreased compliance due to interstitial edema. There is some evidence for increased respiratory infection rates even at 1 ppm. This is probably due to damage to the alveolar macrophages. Cilia are suppressed at 5 ppm. At 25 ppm there is respiratory irritation with cough and chest pain. At 50 ppm there may be development of acute pulmonary edema. At 100 ppm there is acute pulmonary edema and death. Pulmonary edema may be delayed from eight to 30 hours.[2]

NO_2 is relatively insoluble in water. This results in very little initial reaction to the presence of NO_2 in the inspired air and this allows respiration to proceed for considerable periods of time before any significant discomfort occurs. One unlucky individual found himself totally immersed in the gas at such concentration and with such suddenness that he thought the lights had failed. He told of groping in the dark for the ladder which led to the exit and fully mounting the 10-foot ladder before he began to experience discomfort. He estimated the time from exposure to symptoms as one minute. He then developed severe bronchial and laryngeal spasms but ultimately survived.

Clinical manifestations can be subdivided into categories of increasing severity:

(1) Mild disease, usually with complete recovery, may be categorized as no development of pulmonary edema and some or all of the following symptoms, some of which may last as long as three weeks: (a) ocular and upper airway irritation with fatigue: (b) cough, dyspnea and cyanosis; (c) vomiting, vertigo, and somnolence, loss of blood pressure due to the direct vaso-dilating effect of NO and NO_2; (d) loss of consciousness.

(2) Moderate injury may be characterized as any of the symptoms of mild injury plus the development of pulmonary edema in the first 30 hours. The majority of these individuals will recover without sequella but a number will die from the onset of the pulmonary edema.

(3) Severe disease may be categorized as the development of bronchiolitis fibrosa obliterans. Onset of this phase may occur anywhere from 10 to 30 days following exposure and may even occur, though rarely, in individuals minimally affected at the time of exposure. This is a disease in which the alveoli fill with a consolidated material and the brochioles become surrounded by fibrous tisssue. The victim develops dyspnea, cyanosis and fever which is often mistaken for miliary tuberculosis on a chest x-ray. Similar x-ray pictures can occur after pertussis and influenza infections. Individuals who develop bronchiolitis obliterans frequently

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have rounded nodules scattered throughout their chest following recovery from the initial insult. These abnormalities are usually seen only in retrospect and do not serve as good predictors of the development of disease.

In all forms of this disease, varying degrees of oxygen desaturation may occur. Desaturation results from ventilation-perfusion inequalities. Systemic acidosis due to lactic acid production stemming from hypoxia may require active treatment.

Treatment

Persons exposed at 50ppm and above should be hospitalized and observed for 48-72 hours. Steroids should be started at the first sign of pulmonary difficulty and should be continued for eight weeks with gradual reduction in the second month. Broncho-dilators, oxygen, and assisted ventilation may be used as necessary. Diuretics are not useful. Broad spectrum antibiotics are not useful in preventing infection. Antibiotic use should depend on the development of infection and sensitivity testing.

In spite of the seriousness of this response the majority of those affected will survive. However, one-third of all the NO_2 exposed will not survive either the initial pulmonary edema or the bronchiolitis obliterans.[3,4]

Hydrazine Propellants

The hydrazine propellants are hydrazine (HZ), monomethylhydrazine (MMH) and 1,1, dimethylhydrazine (unsymmetrical dimethylhydrazine) (UDMH). These propellants are used individually or as mixtures in rockets, thrusters, and emergency electrical systems in some military aircraft.[6] Aerozine 50, a 50/50 blend of HZ and UDMH is the primary propellant used in the Titan III missile. Both HZ and MMH are used in the National Aeronautics and Space Aministration and US Air Force space shuttle systems.[6]

HZ, MMH and UDMH generally have similiar physical characteristics. Both MMH and UDMH are more volatile than HZ, resulting in potentially significant hazards during handling and storage.[7]

HZ and MMH fuels are clear, oily, water-white liquids with ammoniacal odor. Both are strong reducing agents, weakly alkaline and very hygroscopic. Exposure to air from large surface areas, such as saturated rags, may result in spontaneous ignition due to heat evolved from oxidation with atmospheric oxygen. HZ and MMH mix with water and low molecular weight alcohols. HZ is insoluble in hydrocarbons, while MMH is soluble.

UDMH is a clear colorless liquid having an ammonia or "fishy" odor. It is hygroscopic and mildy alkaline. Carbon dioxide will react with UDMH to form a salt. Exposure of UDMH to air will cause a partial oxidation of the chemical to form nitrosodimethylamine (NDMA). UDMH completely mixes with water, HZ, diethylenetriamine, ethanol and most petroleum fuels.[7]

Clinical Findings

The adverse health effects resulting from exposure to hydrazine fuels are well recognized and of considerable concern. Since only a few reports exist on symptoms observed in humans, most of the data were obtained from animal studies. The symptoms observed in hydrazine poisoning are varied, but are usually more severe with the methylhydrazines than hydrazine itself. The prime target organ is the liver. Routes of entry include inhalation, skin absorption and ingestion.

Hydrazine

The vapor is highly irritating to eyes, upper respiratory tract and skin. Liquid coming in contact with the eye may cause permanent corneal lesions and severe exposure may result in temporary blindness. The liquid is corrosive. Clinical effects range from severe dermatitis to marked skin edema and penetrating burns. Repeated exposures may result in sensitization dermatitis. Systemic exposure may result in dizziness, nausea and anorexia. Animal studies indicate that the liver is more susceptible to damage from hydrazine than MMH and UDMH. Clinical studies show fatty degeneration of liver tissue, depletion of liver glycogen and loss of mitochondrial activity.[8] In animal studies, hydrazine causes a decrease in glomerular filtration and maximal rate of fall in tubular resorption of glucose. Inhibition of glutamic acid decarboxylase (GAD) by hydrazine is believed to be the cause for convulsive seizures. Studies are still being conducted to determine its carcinogenic potential.

Monomethylhydrazine (MMH)

These vapors are also irritating to the eyes and nose. Volunteer subjects exposed to 50 ppm for ten minutes reported a tickling sensation of the nose, but no one experienced coughing or bronchospasm.[9] In contrast to HZ, MMH appears to cause marked dizziness and nausea. Severity of anorexia remains the same. MMH poisoning also causes fatty degeneration of the liver; however, it appears not to affect the levels of liver glycogen. MMH causes methemoglobinemia and Heinz body formation at concentrations eight to ten times lower than hydrazine. MMH also exerts extremely toxic effects on the central nervous system. Animal studies have shown that convulsions are due to the direct action of MMH on the brain. MMH is also a carcinogen suspect.

Unsymmetrical Dimethylhydrazine (UDMH)

UDMH is a respiratory irritant and a convulsant. In high concentrations, it can cause pulmonary edema. In contrast to MMH, UDMH does not cause methemoglobinemia or Heinz body formation nor does it affect the rate of glucose resorption. Past studies and reported cases of hu-

man exposure have not confirmed UDMH as a cause of fatty degeneration of the liver. Other animal studies of repeated exposure suggest a cumulative effect in some animals.[8] UDMH is also a carcinogen suspect.

N-Nitrosodimethylamine (NDMA)

When UDMH vapors are exposed to air, an oxidation process occurs producing varying quantities of NDMA. It is highly toxic in animals and man. Routes of entry are inhalation and possibly percutaneous absorption. Systemically, NDMA poisoning causes nausea, vomiting, abdominal cramps and diarrhea. Other symptoms may include headache, fever, and weakness. Chronic exposures may cause liver damage with jaundice and ascites.

Human cases have been reported to show severe liver damage. One autopsy revealed acute diffuse centrolobular necrosis of the liver.[10] NDMA is a highly potent carcinogen in several animal species, producing malignant tumors of the liver, kidney and lung. To date, a safe exposure standard has not been established. Therefore, all contact with NDMA should be avoided. Exposure to NDMA must always be considered when working with UDMH.

Treatment

Any exposure to hydrazine, MMH, UDMH-NDMA should be treated as an emergency. Contaminated areas of the body should be washed with copious amounts of water. Medical therapy is mainly symptomatic and supportive including intravenous therapy, oxygen and sedation if necessary. Determining the levels of methemoglobin and examination of red blood cells for Heinz bodies may aid in the diagnosis of MMH poisoning. Convulsions caused by the hydrazines may be alleviated by injection of sufficient doses, of pyridoxine hydrochloride. The pyridoxal form should not be given as it may increase toxicity.

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THAMES WATER. *Colored etching by William Heath (English, 1795-1840), ca. 1828. A satire on the contamination of the water supply, which no doubt would be applicable to many other places at various times. A London commission, appointed in 1827, reported in 1828, but suggested no remedy for the deplorable contamination. The complaint, among other things, stated that the water taken from the Thames at Chelsea was "charged with the contents of the great common-sewers, the drainings of the dunghills and laystalls, the refuse of hospitals, slaughterhouses, and manufactures."*

Occupational Health Surveillance

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Why and how should the medical community monitor service members and civilians with potentially hazardous exposures? The rationale for occupational health surveillance and the methods used are presented. The need for surveillance program objectives and evaluation criteria is stressed and related to current initiatives to automate surveillance systems.

Since the establishment of the Occupational Safety and Health Administration in the early 1970s, interest in determining the nature, magnitude and distribution of the occupational health problem on a national level and within specific industries has been increasing.[1] This, along with increasing compensation costs, have stimulated development of comprehensive occupational health surveillance programs both within private industry and in agencies of state and federal government.[2] Just as there are widely varying ideas about the magnitude of the national occupational health problem, there are also widely varying ideas about what constitutes surveillance and what the expected outcomes of surveillance programs should be.[3-5]

In some instances, comprehensive occupational health surveillance programs are established in an attempt to lower the business costs both by maintaining a healthier, more productive work force and by reducing worker compensation costs. In other instances, the obligation to meet regulatory or reporting requirements seems to be the primary motivator. With the increasing number of these programs, a new area for automated data systems has emerged. Several commercially available software packages have appeared which attempt to combine into comprehensive packages many of the features common in surveillance activities.[6,7] Often, computer systems are automating an existing manual surveillance program incapable of managing the massive amount of data generated by surveillance of a large work force.

Many federal agencies (including the Army, the Navy, the Air Force, the Coast Guard and the National Aeronautics and Space Administration), and many private companies are either developing their own automated systems, hiring contractors to develop them, or are considering buying one of the commercial systems. There is a disturbing lack of consensus among the federal and private agencies using these systems as to why they are necessary and just what the desired benefits are, both for the employer and the worker. This may be due in large measure to the political and economic expedients dictating the procurement of funds and manpower necessary to develop and run occupational health surveillance programs. Nevertheless it is disconcerting that large sums of money are being spent to develop a variety of different automated systems which are performing many of the same functions.

Medical Monitoring

Ideally, the fundamental goal of a comprehensive occupational health surveillance program is to prevent adverse health effects resulting from exposure to chemical, physical, biological or psychological hazards encountered in the workplace (health effect/exposure relationships). Medical monitoring is the mechanism used to accomplish this goal.[8] Properly designed medical monitoring programs can identify health effects related to exposure to a specific agent, whether already well recognized or previously unrecognized. Medical monitoring serves a dual purpose. It can be used to detect trends in the health status of workers (epidemiologic surveillance); in cases where a known disease results from a particular exposure, it can be used to identify individual workers with potentially reversible health effects (screening for case finding).[9,10] Once the health effect/exposure relationships and the processes contributing to them are known, a mechanism must exist for preventing occurrence of the adverse health effect in other workers and/or worsening of the condition in workers already affected (hazard control).

Epidemiologic surveillance is used to determine the types of health risks associated with the work environment by: (1) detecting new or previously unrecognized conditions; or (2) establishing that an risk of illness is present for a group not previously thought to be at risk; or (3) demonstrating that an increased risk for a common illness is associated with a given exposure (a nonspecific effect of exposure).[11]

Epidemiologic surveillance also clarifies the relationship between exposure and effect by quantifying dose-response relationships and by identifying interactions between exposures and host characteristics that modify dose-response relationships. Epidemiologic surveillance is also a powerful tool that can be used in evaluating the effectiveness of hazard control measures designed to reduce adverse health effects.[12]

Screening for case findings should be done to detect workers with conditions which will lead to future clinical impairment for which intervention can reverse or minimize the health consequences. Though screen-

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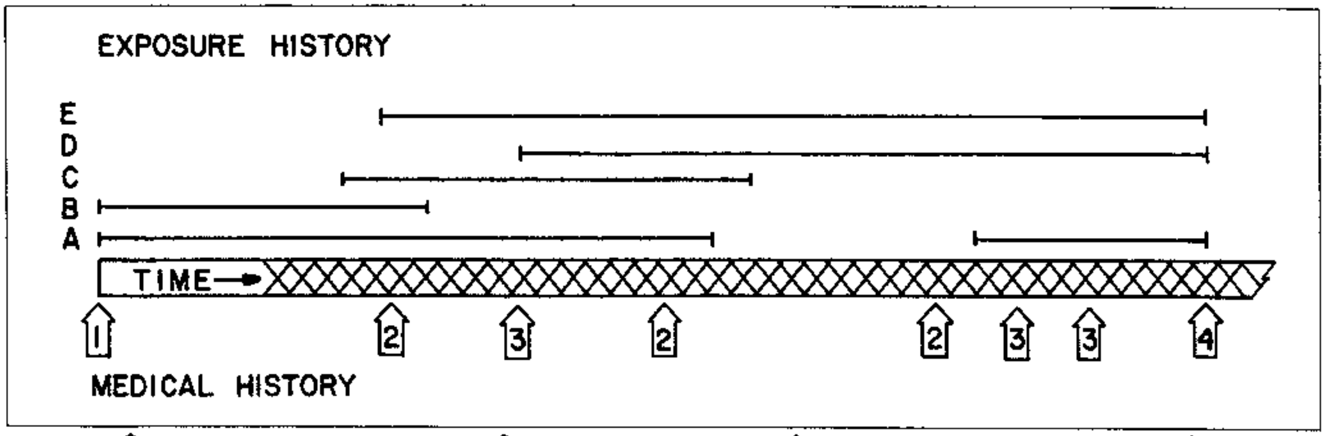

Figure 1. 1 = Pre-Employment Examination, 2 = Periodic Examination, 3 = The Occurrence of an Illness and 4 = Termination Examination. The letters on the extreme left indicate agents to which the individual was exposed.

ing for case findings may also be done to meet regulatory requirements or to aid in an epidemiologic study, it is of little benefit to the individual worker if there is no effective intervention for the disease.[13,14] For diseases like occupational cancers or irreversible lung diseases, it would be more appropriate to use resources to implement controls aimed at preventing the disease and doing epidemiologic surveillance to evaluate the effectiveness of the hazard control measures.

Environmental Monitoring and Personnel Tracking

If it were possible to achieve the ideal, each worker would have on record the data needed to compile a complete work history record. This record would consist of two basic parts: a medical record and an exposure record. A visual representation of such a work record is shown in Figure 1. This figure depicts both the medical and the exposure history of a worker through time. It also illustrates many of the components encountered in existing occupational health surveillance programs.

Medical History

- The record in Figure 1 begins with initial employment. *Pre-employment examinations* should be done to characterize the status of the workers' health at the time of initial employment. If there are conditions of employment which must be met (such as visual acuity among pilots), the examination should clearly document these. Also prior exposures should be documented and a set of baseline data established for comparison purposes.

Establishing a set of baseline data does not mean every employee should receive every test available in the laboratory. Tests should be ordered to establish the condition of a particular organ system when a prior exposure or an exposure related to employment is known to have effects on that system. For example, it is reasonable to document the status of pulmonary function in a new employee who has been or will be exposed to fibrogenic dusts, but it makes little sense to test clerical workers who will not have this exposure. This same principle applies to workers who change jobs within a company or agency and are beginning new or are leaving old exposures for which known effects need to be documented.

- Point 2 on the medical history side of the work record time line is the *periodic physical examination.* These examinations are done at regular intervals to:

(1) Characterize physical status in relation to job demands.

(2) Identify both clinically detectable and subclinical diseases.

(3) Characterize exposure status.

(4) Collect data for comparison to the baseline. This type of examination is most useful for detecting known health effects related to specific exposures (screening for case findings), but is generally of little use in detecting new health/effect exposure relationships.

Some tests are included in pre-employment and periodic physical examinations which may have no bearing on the health status of the employee or the ability to perform a particular job. Examples of this include drug screening tests, lie detector tests, low back x-rays, and HIV screening. These tests are usually done for administrative purposes in conjunction with either stated or implied conditions of employment (ie, an organization may decide, as the military did recently, that they do not want to employ anyone that might be using illicit drugs [as determined by a urine screening test] or anyone at risk for developing the acquired immunodeficiency syndrome [as determined by the presence of antibodies to the virus in serum]). While the use of these tests in this manner may not be scientifically sound and may or may not be legally or morally valid, it is nonetheless occurring. However, the distinction between occupational health surveillance and these types of activities should be clearly

maintained, even though they may occur within the framework of a medical monitoring program.

- Point 3 on the medical history side of the record in Figure 1 is the *occurrence of an illness.* If records like this existed on a work force and the only information contained in the records were exposure and illness data, the prevalence and incidence of known occupational diseases could be deduced. In addition, unknown exposure/health effect relationships could be detected by using epidemiologic techniques. Unfortunately, few (if any) of the existing comprehensive surveillance programs attempt to gather illness information or do epidemiologic surveillance. As an unyielding compromise, an interim history may be recorded at the time of the periodic physical examination. However, illness data collected in this manner are subject to a variety of errors; even if attempts to use them were being made, any conclusions drawn from these data would be of questionable value.

The reasons for illness information not being collected within the framework of a comprehensive surveillance system (while disappointing) are nonetheless easy to understand. Most workers are seen in occupational medical clinics only when they perceive their health problem to be work-related (as with an injury) and have no incentive to report other medical problems to their employers. The medical profession is poorly educated for the recognition of occupational disease when the association is not acute and, in general, does not recognize, report, or investigate suspected cases.[4] Also, employers have no reason to fund programs which may increase compensation costs by identifying new cases of occupational disease.

- Point 4 on the medical history side of the record is the *termination examination.* This examination has functions similar to the periodic examination, but it may also be used to: (1) collect data for comparison to the baseline for use in disability and compensation evaluations; and (2) establish followup schedules for latent disease.

However, there is absolutely no incentive for an employer (other than regulatory requirements) to maintain the medical or exposure histories of prior employees, much less to continue to follow them looking for the occurrence of latent disease related to their employment.

Exposure History

The other side of the work record is the exposure history. Compiling personal sampling for any particular worker is extremely difficult. To be accurate, frequent personal sampling and extensive recordkeeping is necessary. For these reasons many surveillance programs do personal sampling on only a portion of the work force and assign exposures to the unsampled workers based on these "representative" samples. Similarly, area sampling may be done and workers in that area of the plant or with a particular job title may be assigned exposures based on these samples. Both of these methods of assigning exposures to workers are less than ideal but should provide much better information than is currently available.

The real difficulty lies in maintaining environmental monitoring and personnel records detailed enough to establish agent-person-time relationships. This is an especially difficult task in large organizations where individuals move from job to job and site to site. In these situations merely keeping track of who worked where and when is an enormously difficult task.

Compiling exposure histories is further complicated by not only trying to track the worker through time and from site to site but by trying to track multiple, frequently changing exposures. The work history record depicted in Figure 1 shows exposure to only five agents (A through E) and depicts the length of exposure and temporal relationships of the various exposures. The level of exposure is not depicted in the diagram but is extremely important in conducting epidemiological surveillance of an exposed population. It would be extremely unusual if an industrial worker was only exposed to five hazardous agents in the course of employment. Undoubtedly, most complete exposure records would contain a multitude of agents with exposures of varying duration and magnitude.

Again, compiling this type or record is difficult and can, at best, contain only the major exposures encountered in the workplace. Some of the comprehensive occupational health surveillance programs are far exceeding the minimum regulatory requirements for environmental monitoring by attempting to compile very detailed and complete exposure histories. However, they all lack the necessary illness data to make them truly useful in epidemiologic surveillance.

Hazard Control

Realizing the limitations involved in doing epidemiologic surveillance and that the desired outcome is control of the hazardous exposures, *hazard surveillance* might be used "as an alternative means to guide public health controls of work environments."[1] Hazard surveillance involves tracking hazardous materials or processes rather than disease or abnormal function. The recent chemical tragedy in Bhopal and the nuclear accident at the Chernobyl generating plant in the Soviet Union have emphasized the potential importance of hazard surveillance in not only protecting the health of the workers but of the public at large. However, hazard surveillance is only useful as a preventive strategy when a process or material is already *known* to be a hazard. Although hazard surveillance is an extremely important component in hazard control, it should not be used in place of medical and environmental monitoring.

Table I. Major Components in a Comprehensive Occupational Health Surveillance Program.

- **I. Medical Monitoring**
  - A. Pre-Employment Examinations
  - B. Periodic Examinations
  - C. Collection of Illness and Mortality Data
  - D. Termination Examinations
- **II. Environmental Monitoring**
  - A. Personal Sampling
  - B. Area Sampling
- **III. Personnel Tracking**
- **IV. Hazard Control**
  - A. Hazard Surveillance
  - B. Maintaining Hazardous Agent Inventory
  - C. Hazard Tracking
- **V. Program Evaluation**
  - A. Goal Setting
  - B. Outcome and Process Objectives
  - C. Cost-Benefit Analysis

Program Evaluation

One of the most significant shortcomings of many of the existing comprehensive occupational health surveillance programs is the lack of clearly stated objectives. Although some of these programs are being implemented for pragmatic reasons (such as lowering compensation costs), many are being implemented for reasons which are much more vague. Without a clearly defined set of outcome objectives which can be used to evaluate success (or failure), it may become very difficult to justify continuation of these programs. Therefore, before a program is implemented, a clear statement of purpose and concise outcome objectives should be set. Likewise in the implementation phase, a well-designed program should have a number of process objectives which will aid in assessing the effectiveness of the implementation strategy.

SUMMARY

As outlined in the preceding discussion, a comprehensive occupational health surveillance program should involve processes designed to identify and control exposures which produce adverse health effects. Table I is an outline of the processes involved in a comprehensive occupational health surveillance program. Existing comprehensive occupational health programs (automated or manual) most likely will not be able to adequately perform all of the functions in Table I. The level of interest in developing these programs is currently high. At least this is encouraging. Unfortunately, as they are currently being implemented, it may never be possible to determine their real impact on the health of the work force or to evaluate the cost-benefit of the various program components. The lack of evaluation criteria in the form of process or outcome objectives may, in the future, seriously hinder the ability of occupational health professionals to produce adequate justification and maintain funding for these programs. Therefore, occupational health professionals should be aware of the basic issues involved in implementing and evaluating these programs.

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THE RAT CATCHER. *Engraving by Cornelis Visscher (Dutch, 1629-1658), 1655. The Latin quotation may be translated as follows: "You chase away mice (and rats) with a cat! If you do away with petty thieves by means of big thieves, you are crazy. Call upon me and, provided that there is a little money in the transaction, I will chase away both mice and cats." In olden days rats and mice were treated as thieving nuisances and not as potential carriers of disease. The artist, in his short life, attained a reputation as the most brilliant technician of the Dutch graphic school, and his engraving of the "Rat Catcher," after his own design, is still considered one of the great masterpieces of engraving.*

Occupational Health for the Soldier

CWO3 Ronald J. Lott, PA*

The Occupational Safety and Health Act (OSHA) does apply to soldiers. The Army Medical Department must learn and practice occupational medicine because soldiers are exposed to industrial agents. This article introduces the Army Occupational Health Program as it applies to active duty members. Discussions include selected program elements and initiatives aimed at assessing needs and providing military occupational health services. The program presented is a pilot project at Fort Campbell, Kentucky, in support of the 101st Airbone (Air Assault) Division. This program has made significant contributions to unit readiness and protecting the health of our soldiers.

The Soldier in Garrison

One usually thinks of a soldier as a fighter trained in military tactics, a young person in helmet, field trousers and blouse, with weapon and gas mask. Images of smoky battlefields with roaring guns in frozen wastelands or humid jungles or dry deserts come to mind. These are settings in which soldiers of the United States Army have fought our country's wars. But, what of those months in which the soldier exists in another setting, a setting where combat preparation occurs, a setting commonly referred to as a garrison.

In garrison, soldiers prepare for combat by training and maintaining weapons, vehicles, and equipment. In performing maintenance functions, their roles change from combat soldiers to those of industrial soldiers. To succeed in combat, the soldier must be healthy, fit, and able to perform at peak effectiveness. The effects of uncontrolled, hazardous, industrial exposures are detrimental to the combat readiness of the individual soldier and of entire combat units. Soldiers with irritating dermatitis related to solvent exposures at their work places, impaired visions due to industrial accidents, or hearing losses from noise exposures are not going to perform at peak effectiveness. The success or failure of any organization is determined by how well its manpower, talents, and, resources are used and protected.[1]

The Army Occupational Health Program (OHP)

The requirement to provide occupational health services to active duty soldiers is not new. Army Regulation 40-5 stipulates that health standards "not specifically established by this and other Army directives will conform with the health standards promulgated under the authority of the 1970 William-Steiger Occupational Safety and Health Act (OSHA)."[2] This requirement was reiterated and further clarified by the Department of Defense Instruction (DODI) 6055.1.[3] DODI 6055.1 provides guidance for the administration of a comprehensive DOD occupational safety and health program and directs that the provisions of OSHA apply to federal employees (both military and civilian) and operations worldwide.[3]

The DODI clearly indicates that OSHA guidelines apply to military personnel while in nonmilitarily-unique settings. Nonmilitarily-unique settings are workplaces and/or operations comparable to those of private, civilian business and industry. Settings considered militarily-unique are those where field maneuvers, combat training, and combat are performed.

The Fort Campbell Project Program

Fort Campbell, located on the Tennessee-Kentucky border, is the home of the 101st Airbone (Air Assault) Division and several other supporting units including medical, dental, and veterinary ones. The working population includes approximately 22,000 active duty soldiers and 3,000 Department of the Army civilians.

A model test program for occupational health services for Fort Campbell soldiers began in July 1984 with the overall program goal of maintaining the health of soldiers during peacetime so that they will be better able to fight during wartime. The final objective in reaching this goal is the development and maintenance of a viable occupational health program for soldiers. This program would be expected to: (1) accurately identify and define workplace hazards; (2) ensure all soldiers are adequately protected against these hazards; and (3) provide education about job related hazards.

A review of garrison activities was conducted to obtain an inventory of hazards. This identified 769 nonmilitarily-unique industrial operations, 530 of which were being performed exclusively by soldiers. Examples of some of these operations are listed below:

- Acid cleaning
- Battery charging
- Brush painting
- Chemical handling
- Degreasing
- Electrical repair
- Fuel handling
- Medical laboratory work
- Metalworking
- Soldering
- Spray painting
- Steam cleaning
- Warehousing
- Welding
- Woodworking

Protecting Against Health Hazards

An article published in January 1985 identified a problem with occupational health training in US medical schools. Of 127 schools queried, 111 responded. Of the responders, only 34% required occupational medicine as part of their curriculum during the 1977-78 academic year. During 1982-83, 50% required such training. The median required curriculum time for occupational medicine training was four hours during both academic years studied.[11] Physicians train physician

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assistants, so one assumes that both groups will have very little occupational health orientation. This situation indicates that most front-line health care providers for soldiers do not have a reasonable index of suspicion when evaluating the etiologies of diseases and injuries. This was found to be the case at Fort Campbell, Kentucky.

Health care providers for soldiers must be aware that the etiology of the conditions they are evaluating may be occupational. Most often differential diagnoses are made by determining whether a disorder is due to either a bacteria, a virus, a fungus, or an injury. Providers who evaluate illnesses and injuries of soldiers working in industrial settings must add industrial chemical and physical factors (such as vibration and radiation) to their etiological differential list. Only after this is done can one expect to identify occupational sources of illness and injury and eliminate them.

Safety glasses and respirators are important items of personal protective equipment. None of these items are part of the equipment list a soldier uses to pack his gear for deployment. They are items necessary for protection while performing industrial tasks in the garrison.

In the Fiscal Year 1983, the Fort Campbell installation safety officer reported that there were only four eye injuries during the year. This report included only major eye injuries such as globe punctures and corneal lacerations. In order to ascertain a realistic number for advising the command, a survey of occupational eye injuries and illnesses was submitted to the division's medical officers (physicians and physician assistants). Twenty-six officers were surveyed; 18 (70%) responded. The survey results are provided in Table I.

The estimated, overall number of occupational and non-occupational cases of eye injuries and illnesses seen per week was 95. Of these, 51 (or 54%) were thought to be occupationally related. The average number of man-hours lost for each case was estimated to be 33.6 hours. If safety glasses had been available and used, an estimated 48% of these occupationally related eye problems could have been prevented. If these data were to hold true throughout the year (52 weeks), there would be approximately 2,652 cases per year involving the loss of 89,107 man-hours. If the dollar loss is calculated in salary alone (E-4 at two years), a total of $454,446.72 is lost. These approximations were significant enough for the Fort Campbell Command to allocate monies to begin immediate purchasing of safety spectacles for soldiers in areas hazardous to the eye. Also, the Comptroller's Division began to select the appropriate means to continue funding of these and other items of PPE. Resource analysis indicated the appropriate funding to be P-2 (combat training) funds. This determination was made within the US Army Forces Command Comptroller Division.

Another area in which PPE is vital to the health of the soldier is that of respiratory protection. The provision of respirators will become more and more important as the Army begins to use Chemical Agent Resistant Coating (CARC) on its equipment, vehicles and weapons. CARC is a polyurethane paint containing isocyanates which may require the user to wear an air-supplied, hooded respirator. Acquiring respirators is the responsibility of the unit safety officer. Procuring respirators may be a long and arduous process but medical costs and loss of readiness are more trying.

Table I. Estimated Eye Injury and Illness Survey Results.

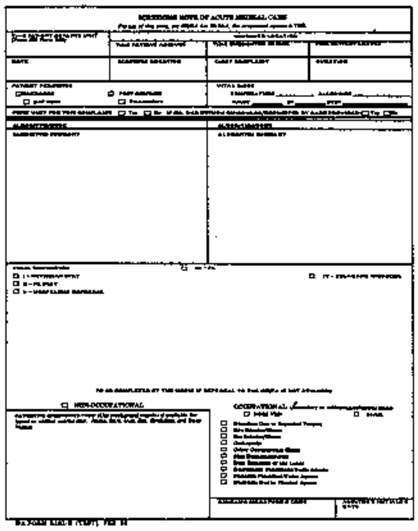
Number of cases per week (all cases)	95
Number by type per week (occupationally related only)	
A. Foreign Bodies	21
B. Corneal Abrasions: Chemical	12
Physical	18
Total occupationally related	51
Average number man-hours lost per each condition	33.6
Eye problems preventable with protection	48%

Medical Records

In an attempt to develop a permanent system of gathering accurate data on the incidence of occupational illnesses and injuries, Fort Campbell personnel conducted a retrospective records review on a major industrial maintenance unit. The review indicated that health care providers did not make annotations as to whether the illness or injury was occupationally related in 53% of the entries reviewed. To alleviate this problem, an existing Department of the Army form has been altered and is being tested (Fig 1). It provides an appropriate area where the practitioner can check a block related to the existing condition. An administrative test form was also devised to accumulate the data. These data are submitted to the program project officer at the end of each month. The data are analyzed and a summary is sent through the medical chain to each unit's medical officer.

Personnel

Occupational health is a team effort that requires command emphasis at all levels. Strong support from safety personnel also is essential. Unit safety officers must take their jobs seriously and be active proponents of the total occupational health and safety effort. Additionally, all medical personnel must be knowledgable about and practice sound occupational medicine. A major concern is the limited availability of formally trained occupational health personnel. These personnel resources are too sparse to accomplish the workload on their own. Therefore, at Fort Campbell the occupational health physician and physician assistant take advantage of every opportunity to be teacher and consultant to commanders, unit safety officers, and other medical personnel.



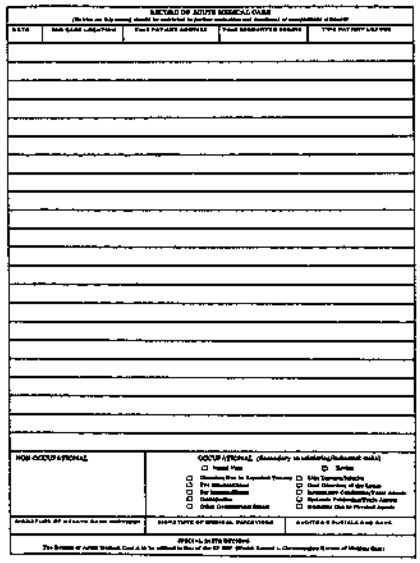


Figure 1. Altered DA Form.

SUMMARY

Methods to successfully provide occupational health services to active duty soldiers can and must be developed and implemented. These methods include:

(1) Efforts to orient health care personnel to soldiers' occupational health needs.

(2) Development of informational systems to gather and analyze epidemiological data.

(3) Increased command emphasis on occupational safety and health.

The success of the AMEDD's efforts to maintain combat readiness may very well depend on efforts to protect combat soldiers while they perform industrial tasks.

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Lt Col (Ret.) Theodore F. Hatch (AUS)

Dies

Theodore F. Hatch, ScD., 84, professor emeritus of health engineering at the University of Pittsburgh's Graduate School of Public Health, died July 5, 1986 in Concord, New Hampshire, of cancer.

Dr. Hatch won numerous awards for his work in public health for both his civilian service and while serving as a Lieutenant Colonel in the Army (1942-1945). During World War II, he was assigned to the Armored Force Medical Research Laboratory, Fort Knox, Kentucky. His remembrances of his World War II experiences are published in the January 1985 issue of the *Medical Bulletin.* In 1946, he received the Legion of Merit for contributions to lifesaving advances in armored warfare operations.

In 1962, Dr. Hatch was awarded the Bronfman Prize for Public Health Achievement by the American Public Health Association. This award was given in recognition of international accomplishment in the betterment of health. He was praised as an "engineer, environmentalist, educator—creative leader of the multidisciplinary approach to environmental health and of the application of engineering principles to the physiology of man."

Following World War II, Dr. Hatch joined the Industrial Hygiene Foundation in the Mellon Institute, Pittsburgh, Pennsylvania. While working for the Foundation, he was appointed professor of industrial health engineering at the University of Pittsburgh Graduate School of Public Health in 1949. During his academic tenure, he served as a consultant, committee member, and task force member to many civilian and military governmental organizations.

Dr. Hatch retired in 1968 and moved to New Hampshire shortly thereafter. Since 1982, the University of Pittsburgh Graduate School of Public Health has honored him with a symposium focusing on industrial and occupational health issues.

Memorial contributions may be made to the Theodore F. Hatch Fellowship, University of Pittsburgh, Graduate School of Public Health, 130 DeSoto St., 111 Parren Hall, Pittsburgh 15261.

(Taken in part from an obituary in: The Pittsburgh Press, Tuesday, July 8, p. B-4.)

Submission of Articles

The *Medical Bulletin of the US Army Medical Department* is published monthly as the medium for disseminating information of professional and administrative interest to all Army Medical Department personnel.

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2. Black and white, 8″ x 10″ glossy photographs of the pertinent slides referred to in the article should be submitted. Using a light pencil on the back of each photograph, the top of the illustration should be indicated by an arrow. Appropriate captions should accompany each illustration. If only slides are available they may be submitted to us and this office will forward them to the Illustration Department for processing. The original slides and/or x-rays will be returned to the author.

3. Figures and charts should be in black (India) ink and on good quality white paper. Clear, glossy print photographs of original drawings are preferred, but if this is not feasible the original drawings will suffice.

4. The position that figures, charts and tables occupy in the text should be indicated.

5. A brief factual summary, complete in itself, should accompany each paper.

6. A complete list of references referred to in the text should be included. There should, however, be no more than 20 references. Each reference should contain the author's last name and initials, the title of the article, the name of the periodical, volume number, inclusive page number and year of publication. The geographical location of book publishers should also be listed.

7. Drugs should be listed by their generic designation. Trade names can follow the generic names inclosed in brackets.

8. A list identifying abbreviations used in the article should be supplied.

9. Articles that would benefit by exact, professional medical illustrations can be forwarded to the Army's medical illustrator, Mike Belknap, at the Illustration Department, 10th Medical Laboratory, Landstuhl, APO NY 09180.

The editors follow the style guide of the American Medical Association. If you have any questions concerning your paper, please contact Ms. Sosa, Telephone: ETS 370-2782.

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