Chapter 4

THE EVOLUTION OF OCCUPATIONAL MEDICINE PRACTICE IN THE US NAVY

PAMELA L. KRAHL, MD, MPH*; BRIAN RILEY, DO, MPH†; AND RICHARD J. THOMAS, MD, MPH‡

*Captain, Medical Corps, US Navy; National Capital Consortium Occupational and Environmental Medicine Residency Program Director, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, Maryland 20817

†Commander, Medical Corps, US Navy; Occupational Medicine Department Head, Naval Branch Health Clinic, 881 USS James Madison Road, Kings Bay, Georgia 31547

‡Captain (Retired), Medical Corps, US Navy; Associate Professor, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, Maryland 20817

> That men are exposed to particular diseases from the occupations which they follow, is a fact well known; but to remedy this evil, is a matter of some difficulty.
>
> . . .
>
> SAILORS may also be numbered amongst the laborious. They undergo great hardships from change of climate, the violence of weather, hard labour, bad provisions &c. Sailors are of so great importance both to the trade and safety of this kingdom, that too much pains can never be bestowed in pointing out the means of preserving their lives.[1]
>
> —*William Buchan, 1785*

INTRODUCTION

Dr. William Buchan (1729–1805) was a Scottish physician who practiced in England and Scotland. His medical textbook, *Domestic Medicine,*[1] was widely republished in North America during the period of the American Revolution and the formation of the new United States of America. Buchan clearly understood and succinctly described the occupational challenges of those who man ships.[1] The evolution of occupational medicine practice in the US Navy is inextricably linked to the service's history of medical support. This chapter will describe the history of medical support to the US Navy and how today's practice of occupational and environmental medicine in the Navy evolved from these early foundations.

THE COLONIAL NAVY: BASIC CARE FOR SAILORS AND MARINES

The American colonies emerged in the maritime tradition of the British Royal Navy and the strong tradition of civilian sailors of the United Kingdom. The first civilian shipyard to build warships in North America opened in 1690, when *HMS Falkland* was constructed for the British Royal Navy. This shipyard was located in the Piscataqua River Estuary between New Hampshire and Maine, near the current location of the US Naval Shipyard in Portsmouth.[2,3] Early medical care of sailors in the colonial Navy mirrored that of the British Royal Navy. The underpinnings of what would become naval occupational medicine were first documented in 1617 by the "father of marine medicine," John Woodall (1569–1643), when he wrote about his experiences at sea and the impact of the seafaring life on the health of the men.[4]

Prior to the Revolutionary War, a medical contingent of a surgeon, surgeon's mate, or both, was employed onboard due to the length of voyages between the various colonies in the new world and for voyages across the Atlantic Ocean.[2] Congress established the colonial Navy in October 1775, and the Marines one month later, in November 1775.[5,6] The naval forces of the insurrection against King George III and his British government consisted of three types of vessels: privateers authorized by letters from the Continental Congress, civilian merchant ships converted into warships, and ships commissioned by the colonies (such as the Board of War of the State of Massachusetts Bay) or by the Continental Congress.[7]

The eventual US Navy Medical Department began with a small number of surgeons, assistant surgeons, and surgeon's mates who were either hired by local advertisement or reassigned from Army units (possibly seeking better working conditions than the care of the sick and injured in the field). John Adams of Massachusetts, a signer of the Declaration of Independence and second president of the United States, played a role in adopting regulations from the British Royal Navy for the organization of US Navy ships. These regulations were published as "Rules for the Regulation of the Navy of the United Colonies of North-America" on November 28, 1775.[8] Article 11 specifically called for the assignment of a surgeon's mate, and Article 16 delineated that a "convenient place shall be set aside for sick or hurt men . . . when the surgeon shall advise."[8] In *Naval and Maritime Medicine During the American Revolution,*[2] Dr. Maurice Bear Gordon describes the meager training of the men who fulfilled these roles, only a fraction of whom had formal medical education in either North America or England. In 1775 Dr. John Jones of New York published the first American surgery text, a pamphlet titled "Plain, Concise, Practical Remarks on the Treatment of Wounds and Fractures,"[9] which was widely used in the war by surgeons of the Continental Army and Navy.[2]

Gordon summarized the diaries of four physicians who served as ship surgeons during the American Revolutionary War.[2] One of them, Dr. Ezra Green of Massachusetts, served in both the Continental Army and Navy. His extensive diaries chronicle his time serving as surgeon on the *Ranger*, an 18-gun Continental Navy sloop commanded by Captain John Paul Jones. Gordon speculates that Greene was personally appointed by Jones, who "had authority from the Continental Congress to appoint his officers, both commissioned and warrant."[2] Historical records of

the names of 136 men who served as surgeons in the American Navy[2] overlaps somewhat with a list published in an 1876 monograph by J.M. Toner[10] of "nearly twelve hundred" physicians who served in the Medical Department of the Continental Army.

Preventive Care

The primary duties of the surgeon and his staff were to provide the crew with daily sick-call and the emergent care of wounds that resulted from the inherent dangers of life at sea, in port, or from combat. Sailing ships required large crews to keep the ship sailing, and although preventive medicine and occupational medicine were not practiced by name in the Navy at that time, their underlying principles were a critical part of the mission of the surgeon and his staff. As an example, scurvy was a major health threat for the crews of these sailing ships. Dr James Lind determined that the use of lemon juice could control scurvy in sailors in his *Treatise of the Scurvy* in 1753. But perhaps because he was "an undistinguished physician in the eyes of his contemporaries, the naval medical service being on the lowest rung of the professional ladder,"[11] it was not until nearly 50 years later that Sir Gilbert Blane succeeded in convincing the Royal Navy to adopt the policy of regular administration of lemon or lime juice.[2] Perseverance in advocating for preventive measures remains a fundamental characteristic of preventive medicine practice, including in the Navy.

Pre-Employment Physicals

A historical antecedent to the 20th century occupational medicine concept of pre-employment physicals can be found as early as 1783 in the instructions of the Maryland commissioners of ships. The parameters for successfully enlisting into this component of the fledgling American Navy included being able bodied and without any abnormalities of the limbs; in good health without hernias or other visible infirmities; taller than 5 feet, 4 inches; and between the ages of 16 and 50 years.[2] No surviving documents describe whether examinations for these qualifications were regularly performed or document what percentages of potential sailors were disqualified.

THE NEW US NAVY AND FOUNDATIONS OF NAVY OCCUPATIONAL MEDICINE

According to the Naval History and Heritage Center website:

> Over the course of the War of Independence, the Continental Navy sent to sea more than fifty armed vessels of various types. The navy's squadrons and cruisers seized enemy supplies and carried correspondence and diplomats to Europe, returning with needed munitions. They took nearly 200 British vessels as prizes, some off the British Isles themselves, contributing to the demoralization of the enemy and forcing the British to divert warships to protect convoys and trade routes. In addition, the navy provoked diplomatic crises that helped bring France into the war against Great Britain.[12]

But following the Revolutionary War, the humble experiment of a Continental Navy to support and defend the American colonies came to a close with the sale of *Alliance*, the Continental Navy's last vessel, in 1785.[13]

The US Navy was reborn 5 years after the formation of the United States in 1789, when the Congress of the United States commissioned six new frigates, of which only three were completed and manned.[14] From the beginning, these vessels were authorized to have a medical department. The Naval Armament Act of 1797 authorized the completion of three additional frigates: the *United States*, the *Constitution* (Figure 4-1), and the *Constellation*, and also specified the guidelines for compensation if a sailor or marine was wounded or disabled while serving in the line of duty.

Figure 4-1. The USS *Constitution*, launched October 21, 1797, and authorized by the Naval Act of 1794, was one of the three original frigates of the US Navy and is today the oldest commissioned warship afloat. Boston Harbor, MA, August 29, 2014.
Reproduced from: http://www.navy.mil/management/photodb/photos/140829-N-XP344-282.JPG.

Thus, by the 1790s the following basic tenets of military public health were in place:

- medical personnel assigned to defined roles in the operational and support forces, and recognized as important to the mission and welfare of the fighting forces;
- pre-employment screening;
- treatment of illness and injury at the worksite for sailors and marines (though not for civilian workers);
- methodologies to study the risk factors for morbidity and mortality;
- prevention of disease and injury; and
- compensation for sailors or marines injured on the job and no longer able to work (again, not for civilian workers).

The life and practice of a Naval surgeon in the early 19th century was illuminated in 1979 by a fortuitous discovery at the *USS Constitution* Museum, located at the former Charlestown Naval Yard (now called the Boston Historical Park). Dr J. Worth Estes of Boston University discovered the medical records that Dr Peter St. Medard penned during his cruise aboard the frigate *New York* from 1802 to 1803. St. Medard's meticulous records provide an unparalleled view of the injuries, illness, and care of sailors during this era.[13] After his cruise on the *New York*, St. Medard attained a position as a surgeon at the Charlestown Navy Yard.

The Navy Yard was opened in Charlestown, Massachusetts, after Secretary of the Navy Benjamin Stoddert purchased tracts of land in six cities for shipyards in 1801. During the War of 1812, the Charlestown Navy Yard completed the Navy's first ship-of-the-line, the 74-gun *Independence*.[15] A surgeon and surgeon's mate were assigned to each yard for the care of sailors assigned to the ships "in ordinary," referring to ships that were taken out of service during periods of relative inactivity and maintained by a skeleton crew and civilian yard workers. The surgeon was responsible for care of the sailors and marines assigned to the yard, as well as "any workman who was injured or taken sick in the yard."[14] Thus, by 1804, the additional element of onsite treatment of illness and injury for civilian workers was added to the US Navy's occupational health program.

Doctor Edward Cutbush: A Medical Pioneer in the New Navy

Surgeon Edward Cutbush (1772–1843) embodied the Naval surgeon's dual responsibilities to maintain the combat strength of the ship and the individual health of the crew during his 30-year naval career, which spanned from 1799 to 1829.[16] Cutbush graduated from what is now the University of Pennsylvania in Philadelphia as a medical doctor at age 22. Two formative experiences in his early medical training in the 1790s influenced his later career. The first was his care for wounded soldiers, both French and British, who were brought to Philadelphia after a sea battle off the coast of Delaware, which was facilitated by his fluency in French as well as English. The second was his arduous work among the quarantined patients and staff of the Pennsylvania Hospital in the center of Philadelphia during a yellow fever outbreak. This service brought him commendation from the City of Philadelphia.[17]

Cutbush subsequently served with the Pennsylvania militia, including a brief tour as surgeon general during the Whiskey Rebellion of 1794.[10] He began his naval career by applying in writing to the secretary of the Navy for a position, and he was appointed in 1799. He served aboard the frigate *United States* as a surgeon and quickly convinced the captain to vaccinate the crew against smallpox using Edward Jenner's method.[18]

In 1804 Cutbush sailed on the frigate *President* and was sent ashore in Italy to establish the first overseas US Naval hospital for care of sick and injured sailors of the US Navy Mediterranean Squadron who were too ill or injured to remain at sea. Using ingenuity and resourcefulness, he established this hospital in the city of Siracusa on the island of Sicily.

Cutbush returned to duty at the Philadelphia Naval Shipyard in 1807. Based on his experiences with both the Army and Navy, Cutbush and his former teacher, Dr Benjamin Rush of the University of Pennsylvania (a signer of the Declaration of Independence in 1776 and a founder of the Pennsylvania Hospital), published one of the first American treatises on the medical care of military personnel: *Observations on the Means of Preserving the Health of Soldiers and Sailors; and on the Duties of the Medical Department of the Army and Navy: with Remarks on Hospitals and their Internal Arrangement*.[19]

In 1813, Cutbush left the Philadelphia Naval Shipyard for duty in Washington, DC. There he served as advisor to the secretary of the Navy on medical matters while simultaneously serving as the senior medical officer of the Washington Navy Yard. Cutbush was among a group of senior surgeons who developed a formal training program for new Naval surgeons and surgeon's mates in Philadelphia and established a board of medical examiners. He also was involved with the precursors of the Smithsonian Institution and George Washington University School of Medicine,

and after over 30 years of service to his country, was instrumental in the formation of the Geneva Medical College, now known as the State University of New York Upstate School of Medicine.

By the time of his retirement in 1829 at age 57, Edward Cutbush's career exemplified many of the qualities of a successful US Navy occupational medicine physician even today:

- strong academic credentials;
- the ability to serve in precarious medical conditions, including being quarantined among the sick;
- service to the fleet on operating ships and to the civilian personnel who maintained ships in shipyards;
- the ability to develop new solutions for challenges as they emerge, such as the first overseas US Naval hospital and the formation of the board of medical examiners;
- publishing medical findings to advance the discipline of military medicine;
- serving as a senior medical officer at an installation;
- advising the senior line leadership of the Navy; and
- teaching new Navy personnel as well as maintaining an academic association with civilian colleagues.

The Screening of Recruits

G.R.B. Horner, MD, a graduate of the University of Pennsylvania School of Medicine, thoroughly described the duties and resultant diseases and injuries of seamen in 1854. Horner devoted a chapter of his book to the process of examination of young men who wished to join the US Navy and Marine Corps in a variety of positions including, "seaman of any grade, marines, warrant and commissioned officers."[20] At the time of Horner's description of the diseases and injuries of sailors, though, the majority of Navy ships were still powered by sail. In the 1874 Report of the Navy Surgeon General, Surgeon James Kleghorn (1838–1909) described the ongoing difficulties of screening suitable candidates for the fleet and the Marines. The dire work conditions of a receiving ship (Figure 4-2), with cramped spaces and poor lighting, did not make the difficult task of discerning who was "the deceptive recruit" any easier, in the words of Kleghorn.[21]

Hospital care for Navy and Merchant Marine sailors and marines began with the Seaman's Sickness and Disability Act of 1798. These naval personnel had funds deducted from their pay (starting at 20 cents per month) to support this care.[2] The manning and organization of ship's medical departments changed little between 1798 and the formation of Navy Bureau of Medicine and Surgery (BUMED) in 1842.[22] A professional Medical Corps for the US Navy with uniformed officers would emerge in 1871, followed by the Hospital Corps (1898), Nurse Corps (1908), Dental Corps (1912), and Medical Service Corps (1947).

Figure 4-2. Spar deck of USS *Independence* while it was in use as a receiving ship in the early 1900s at Mare Island Navy Yard, California. Note hammocks stowed atop the bulwark, light guns installed in some of the gun ports, and the large wooden roof.
Photo courtesy of Naval History and Heritage Command, catalog no. 52636. Donation of Rear Admiral Ammen Farenholt, Medical Corps, US Navy.

Steam-Powered Ships: More Capable and More Dangerous

The development of steam-powered ships is considered the greatest technological advance in the history of the Navy.[23] Visionaries such as Commodore Matthew Perry pushed for the development of steam-powered ships, which advanced from small prototypes developed as early as the War of 1812 to later large side-wheelers. The *USS Princeton* was commissioned in 1843 as the first propeller-driven, steam-powered warship and carried the largest naval gun in the world, the "Peacemaker." During a demonstration of the "Peacemaker" for dignitaries including President John Tyler on February 28, 1844, the gun exploded, killing six people, including Secretary of the Navy Thomas Gilmer, Secretary of State Abel Upshur, and Captain Beverly Kennon, the chief of the Bureau of Construction and Repair (Figure 4-3). Investigation of

the disaster led to the development of new techniques for constructing stronger, more structurally sound cannons.[24]

This event was a fitting start to this new era of steam-powered ships, which placed sailors in harm's way due to a multitude of new hazards such as heat, noise, fuel fires, and moving equipment. Although the March 1862 battle between the ironclads *USS Monitor* and *CSS Virginia* (converted from the former *USS Merrimac* that had been scuttled in Portsmouth, VA) tactically came to a draw, the damage and sinking of adjacent Union sailing ships by the *CSS Virginia* in Hampton Roads, Virginia, signaled the eventual end of the era of sailing warships in the US Navy. Over the remainder of the 19th century, the fleet would shift to steam power, with the majority being steam powered by the late 1880s.[25]

THE NAVY IN THE 20TH CENTURY: INCREASING HAZARDS

After the Civil War, interest in maintaining a standing Navy decreased, and in 1877 the strength of the US Navy reached a low point of 8,609 men, only 21 percent of the Civil War peak of 43,787 in 1864. Influenced by the writings of Albert Thayer Mahan and others, the country began to realize the need for the United States and its Navy to have the ability to project sea power as a military force in defense of national interests and maritime trade anywhere in the world. The first steam-powered cruisers were launched in the 1880s, and the first dreadnaughts (battleships), *USS Texas* and *USS Maine,* joined the fleet in 1895.[25]

Figure 4-3. "Awful Explosion of the 'Peace-Maker' on board the U.S. Steam Frigate Princeton, on Wednesday, 28th Feby. 1844." Lithograph published by N. Currier, New York, 1844. It depicts the explosion of a heavy gun on board USS *Princeton*, in the Potomac River, which killed or mortally wounded seven and injured about twenty people. Some of those present are identified below the image, including (from left): Mr. Wilkins; Mr. Perrine; Lieutenant Hunt; Representative Virgil Maxcy of Maryland; Secretary of State Abel P. Upshur; Captain Beverly Kennon, chief of the Bureau of Construction, Equipment and Repair; Thomas Gilmer, secretary of the Navy; Captain Robert F. Stockton; sailors; Senator Phelps and Senator Thomas Hart Benton. Maxcy, Upshur, Kennon and Gilmer were among those killed. Stockton and Benton were among the injured.
Courtesy of the US Navy Art Collection, Washington, DC; US Naval History and Heritage Command photograph, catalog no. NH 58906-KN.

England sparked a naval arms race with its launch of the "world's most powerful battleship," the *HMS Dreadnaught,* in 1906.[26] The United States, along with Germany, Japan, and other countries, responded by building increasingly larger and more heavily armed warships, starting with the *USS Michigan* on May 26, 1908.[27] Other advances followed quickly, and these changes further shaped the Navy Medical Department.

The study of the diseases of workers related to naval shipbuilding and duty onboard ships at sea became more scientific with the publication of annual reports of the Navy surgeon general beginning in 1907. The same year, the first numbered volume of the *Bulletin of the Naval Medical Department* appeared, described as "relating to hygiene, tropical and preventive medicine, pathology, laboratory suggestions, advanced therapeutics, surgery, medical department organization for battle, new methods of treatment, and all other matters of more or less professional interest and importance under the conditions peculiar to the service and pertaining to the physical welfare of the naval personnel."[28] By the time the third volume was published in 1909, Navy medical officers in the fleet and at shore stations made regular contributions regarding treatment and preventive strategies for occupational injuries and illnesses. For example, hearing loss in boiler tenders and gunners' mates was an "accepted way of life"[29] prior to a 1909 study of early hearing protection efforts such as the Elliot hearing protector, Plasticine flexible inserts in the US Navy, and Antiphon (a German invention) flexible inserts in the British Royal Navy.[30]

The Advent of Navy Flight Medicine and Dive Medicine

The advent of military aviation and the submarine force required military medical professionals to develop new medical research technology and treatment regimens for both preventive and curative aspects of

these specific fields of military medicine. BUMED Circular Letter 125221 defined the first physical requirements for prospective naval aviators.[31] In July 1922, eight US Navy medical officers reported to flight training at Naval Air Station Pensacola, and four had already completed the flight surgeon's course at the US Army Technical School of Aviation Medicine at Mitchell Field, Long Island, New York, in November 1921. The eight officers were subsequently designated the US Navy's first flight surgeons. Qualifications for flight surgeons were formalized on November 14, 1924, that required completion of the 3-month Army course, as well as 3 months of "satisfactory service with a Naval Aviation unit before designation."[32] The interservice agreement with the Army for providing aviation medicine training ended on January 18, 1927, with the establishment of the Aviation Section of the Naval Medical School in Washington, DC. Flight surgeons have served continuously since then (Figure 4-4).

Although professional diving is documented as early as the 5th century BCE, the 18th and 19th centuries brought experiments with new forms of diving bells and submersible vehicles in Europe and the United States.[33] The physiology of extreme atmospheres in relation to both caisson disease in workers building supports for bridges and the medical experiences of submariners led to manuscripts written by Navy medical officers starting in 1916.[34] The first US Navy diving school opened in 1915, and the Navy's famous Experimental Diving Unit was established in 1927. US Navy helium-oxygen diving experiments began in the l930s, and the mixed gas was first used extensively in the rescue of 33 sailors trapped on the stricken submarine *USS Squalus* and its subsequent salvage from a depth of 243 feet in 1939 (Figure 4-5).[35]

Figure 4-4. Flight surgeon and two hospital corpsmen (white caps and jerseys with red crosses) at their flight station in the starboard catwalk, amidships, on a training escort carrier, during World War II. They stand ready with medical kits, stretcher, blankets and other emergency gear.
Photo courtesy of the National Archives and Records Administration, catalog no. 80-G-K-2618.

Care for Occupational Injuries and Illnesses in Civilian Employees

Prior to the current federal and state workers' compensation laws, injured employees who needed a doctor's care had only a slim possibility of winning a civil tort action in court. But a century before these laws, sailors, marines, and civilian workers assigned to ships out of service ("in ordinary") or to naval shipyards received medical care for immediate injuries from medical officers.[14] Based on a European model, the first workers' compensation law for federal employees was passed in 1882. This law provided compensation for employees or survivors of members of the US Life Saving Service (now called the US Coast Guard) who were disabled or killed in the line of duty.[36] Workers' compensation legislation for civilian employees at the

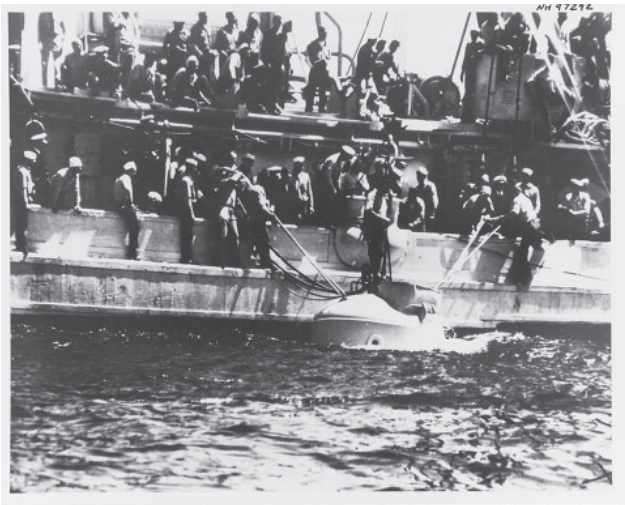

Figure 4-5. McCann rescue chamber in the water alongside the USS *Falcon* (ASR-2) during the rescue of 33 men still alive and trapped in the sunken submarine *Squalus*, off the New Hampshire coast, circa May 24–25, 1939. The submarine sank when the main induction valve in the engine room stuck in the open position, flooding the after compartments when it submerged.
Photo courtesy of the National Museum of the US Navy, US Naval History and Heritage Command Photograph Collection.

state level began in Wisconsin in 1911.[37] Two important federal acts followed and are the basis of the modern system for care of occupational injuries for civil service and non-appropriated fund workers: the Federal Employees' Compensation Act of September 7, 1916 (5 USC 81), and the Longshore and Harbor Workers' Compensation Act of 1927 (33 USC 901–950). The US Navy's occupational health policies paralleled these advances in legislation, and by 1914, the *Manual for the Medical Department of the United States Navy* clearly delineated several additional facets of occupational medicine: initial and periodic physical examinations related to Navy yard service, compensation for injury, prevention of eye injuries, and medical standards for acceptance or rejection of applicants.[38]

World War I: The Need for Occupational Health Programs Is Recognized

With the United States' entry into World War I in April 1917, mass-production of cargo and transport ships became an immediate priority. The federal government formed the Emergency Fleet Corporation to build these ships. The largest shipyard in the world at that time was Hog Island, near Philadelphia, which launched a ship every 5 1/2 days at the peak of production. Many of Hog Island's 30,000 workers had no previous factory experience.[39]

Initial safety and occupational health services in these shipyards were directed to the care of civilian workers' injuries and the abatement of the numerous safety hazards causing them. These rudimentary programs aimed to keep the workforce on the job, but were largely ineffective and considered to be an impairment to the war effort. By 1917 the amount of lost-time injuries and associated costs prompted the federal workers' compensation program administrator to request inspections of several Navy shipyards.[29]

As the war wound down, the need for robust occupational medicine programs for the civilian workforce became clear, and these comprehensive programs were beginning to take shape. Starting in 1917, safety engineers were assigned to the shipyards, with full-time medical officers following in 1922. Under the leadership of Dr Robert Jones, the preventive medicine division at BUMED incorporated occupational health practices, recommending job-specific pre-employment physical examinations and periodic examinations based on occupational exposures such as asbestos, silica, and lead. For instance, a 1922 issue of the *United States Naval Bulletin* contained an article called "Occupational Hazards and Diagnostic Signs: A Guide to Impairments to Be Looked for in Hazardous Occupations."[40] In 1923, Lieutenant Linwood Smith, a physician from the Boston Naval Shipyard clinic, completed a postgraduate program at the Harvard School of Public Health, becoming the Navy's first formally trained physician in occupational health.[41]

At the Philadelphia Naval Shipyard in 1925, Dr Ernest Brown conducted a pioneering survey of lead poisoning in welders that included clinical assessment, evaluation of work practices, environmental sampling, and the development of hazard control strategies such as changes in work practice and adaptation of respiratory protective equipment. Brown would go on to present "Industrial Hygiene and the Navy in National Defense"[42] at the fifth annual meeting of the Air Hygiene Foundation of America in New York in 1940. This work describes the organization and functions of the New York Navy Yard's medical department. Consisting of ten medical officers, five dental officers, one nurse, forty-five enlisted men, and two civilian clerks, the department's chief activities were pre-employment, periodic, and retirement physical examinations, with special emphasis on crane operators, engine men (hoisting and portable), and locomotive engineers; the diagnosis, treatment, and disposition of industrial injuries and occupational diseases; the administration of compensation cases; and industrial hygiene and plant sanitation. Duties are described for the industrial medical officer and the safety engineer, including guidance on conducting industrial hygiene surveys and reporting industrial accidents and illnesses. Brown also named thirteen occupational hazards found in US Navy yards, including silica, lead, metal fumes, and asbestos.

World War II: Comprehensive Navy Occupational Health Programs

The lessons learned about how to mass-produce ships during World War I set the stage for shipbuilding in advance of World War II. At the time of the attack on Pearl Harbor in 1941, eight naval shipyards were hurriedly building America's "two-ocean Navy."[43] Eighteen new shipyards were later added just to mass-produce cargo ships (known as "Liberty" ships), and the number of American shipyard workers increased exponentially from 168,000 in 1940 to 1,772,000 by November 1943. The high turnover rate of the workforce meant that the total number of workers exposed to the shipyard environment was even higher. As the intensity of the war effort exploded, the inexperienced and untrained new laborers faced demanding production rates in the shipyards. They worked in an often dangerous environment while performing unfamiliar industrial processes, such as electric arc welding, with potentially harmful health effects.[44]

The Navy's small team of occupational medicine physicians had diligently evaluated both military operational and civilian working environments between World War I and World War II. But the need to dedicate additional resources for occupational health programs to support the war effort was clear, and the secretary of the Navy allocated 1% of the payroll toward developing and expanding occupational medicine services at the shipyards.[43] Rear Admiral Charles Stephenson, in charge of preventive medicine at BUMED, developed a comprehensive strategy for occupational health services, complete with marketing posters. These occupational health services were based on the framework described by Brown in 1940, which included pre-employment examinations, injury care, medical surveillance of known occupational health hazards, and industrial hygiene field surveys.[29] Safety and medical departments were established at each shipyard, with the medical department led by a medical officer reporting directly to the shipyard commander. The first industrial hygiene offices were established within these shipyard medical departments, and filled with newly commissioned officers, the US Navy's first industrial hygienists. These officers were fresh from courses at the Harvard and Columbia schools of public health, where they trained alongside Navy medical officers completing occupational medicine master's degree programs.[29,43]

Medical officers provided health examinations and concentrated efforts on the treatment of numerous eye, hand, foot, and head injuries; illnesses such as silicosis, lead poisoning, and metal fume fever; and effects of other known toxic hazards such as carbon monoxide, chromium, mercury, cyanide, and solvents. Less attention was paid to noise and asbestos exposure until the late 1950s. Although asbestosis was a known occupational hazard, studies conducted in the shipyards at that time erroneously concluded that asbestos was relatively safe.[29,43]

The end of World War II signaled the beginning of the "nuclear age," and with it new types of specialists joined the occupational health team: radiation health officers and radiation specialist officers. Originally, their primary duties were to provide radiation safety and biology support to the nuclear weapons testing program, but these duties soon expanded as the Navy developed radiation control practices for nuclear powered ships, conducted radiobiology research, and expanded clinical applications of radioisotopes and radiography. Corpsmen received new training in ionizing radiation when assigned to duties onboard nuclear submarines and as nuclear medicine technicians, and physicians attended a new nuclear medicine course. Since 1946, Navy personnel occupationally exposed to ionizing radiation have been monitored to ensure recommended exposure limits are not exceeded. Additionally, radiation physical exams have been required in some form since 1951.[45]

In the early to mid-1950s, toxicology also garnered additional interest from BUMED. Two shipboard explosions, on the *USS Leyte Gulf* and the *USS Bennington*, were linked to hydraulic fluids that were both explosive and flammable. But the search for a safer hydraulic fluid led to unanswered questions about toxicity of the proposed substitutes. Around that time, initial trials of the *USS Nautilus*, the first nuclear-powered submarine, showed that the scrubbers in its atmospheric control plant contaminated the air with monoethanolamine, which threatened to limit the duration of submerged operations. However, little information about the health effects of continuous exposure to air contaminants over long periods of time existed on which to make decisions. Inquiry into these two issues led BUMED to begin planning for an operational toxicology and health engineering unit in early 1957. In January 1959, the secretary of the Navy formally established the US Navy Toxicology Unit to rapidly conduct toxicologic investigations and research in response to fleet requirements.[46]

The Navy and Marine Corps Public Health Center

Recognizing the need for occupational health programs encompassing all fleet readiness and training ordnance field activities, in 1964 the Navy Bureau of Weapons directed the senior medical officer at Naval Ammunition Depot Crane, Indiana, to coordinate efforts at all Naval ammunition depots and Naval stations and established the Naval Ordnance Systems Command Environmental Health Center. By 1971, this function was consolidated under BUMED as the Navy Industrial Environmental Health Center (NIEHC). This command was described in a 1976 edition of *Environmental Research*:

> This organization is located in Cincinnati, Ohio, and is being developed as a prime coordinator for occupational and environmental health programs. This center is staffed with occupational health physicians, industrial hygienists, chemists, engineers, and a nurse. This group provides field support and consultative services to Regional Medical Officers and other Commands on request. Their services include in-depth and specialized industrial hygiene and occupational health evaluations and analyses. They have an additional mission to ensure the wide dissemination of pertinent information on occupational and environmental health having Navy significance. NIEHC provides assistance to BUMED in education

> and training. NIEHC also serves as the third-year residence training for Navy occupational health physicians.[43]

The requirement for an integrated computer system to assist the Navy with compliance with the Occupational Safety and Health Act of 1970 was identified January 29-30, 1979, during a conference on Navy occupational health in Seattle, Washington:

> The conference objectives were to consider organizational factors in the implementation of Navy occupational health programs, to address issues of cost effectiveness in Navy occupational health programs, and to facilitate the development of a meaningful research program in this area. Participants included operations and line managers, safety experts, industrial hygienists, epidemiologists, behavioral researchers, and physicians. Individual perspectives, viewpoints, and goals were diverse and often contradictory. The threads that bound the participants together were a deep commitment to improved occupational health care in the Navy and a clear conviction that the current occupational health program faces serious difficulties. The conference demonstrated the wealth of available expertise that can be brought to bear immediately on the Navy's current occupational health problems. It also pinpointed several areas that require extensive research and development. Among the major areas in the latter group were epidemiological studies to identify additional hazardous agents in the work environment, development of environmental monitoring techniques, the design of training and reward systems that will increase compliance with sound occupational health practices, and the design of future work environments to minimize occupational health risks.[47]

BUMED subsequently tasked the Naval Health Research Center to develop this new, computerized occupational health monitoring system. After a review of commercially available systems failed to identify one that would meet the Navy's requirements, a prototype system was developed and installed in June 1981 at Naval Aviation Depot North Island. This system was known as the Navy Occupational Health Information Management System (NOHIMS). An enhanced version, NOHIMS Version 2.0, added numerous occupational safety functions, as well as additional environmental and medical functions, and was rolled out in 1987.[48]

The primary objectives of the NOHIMS project were to provide comprehensive workplace monitoring and medical surveillance, and also to make this data available for trend analyses, epidemiologic studies, and program compliance monitoring.[49] Although NOHIMS was a short-lived project, its enduring legacy is the Navy's Medical Surveillance Procedures Manual, known as the "Medical Matrix." In support of NOHIMS, the Medical Matrix Committee was established and developed the first Medical Matrix, which continues to provide guidance for all personnel conducting medical surveillance and certifications in the US Navy and Marine Corps.

NAVY OCCUPATIONAL AND ENVIRONMENTAL MEDICINE TODAY

Today, about 40 active duty and 40 civilian occupational medicine physicians are assigned around the world, providing medical surveillance and certification exams, treatment of work-related illnesses and injuries, and other occupational health services to active duty sailors and marines and civilian Navy and Marine Corps employees. They work hand in hand with industrial hygienists, occupational health nurses and technicians, environmental health officers, safety professionals, audiologists, and line leaders and management to maintain the readiness of the Navy and Marine Corps civilian workforces, and provide consultative support in the medical surveillance and certification of active duty sailors and marines. The Navy and Marine Corps Public Health Center provides consultation and manages execution of multiple occupational and environmental health programs relevant to today's practice, including asbestos medical surveillance, hearing conservation, radioactive material permitting, radiation dosimetry, blood-borne pathogen exposure, respiratory protection, Federal Employees' Compensation Act case management, drug screening, health hazard assessment, and risk communication, as well as continued updates of the Medical Surveillance Procedures Manual (Medical Matrix).[50]

Areas of increasing focus for the occupational medicine community today are environmental health and disaster preparedness and emergency management. The future of Navy occupational and environmental medicine lies in the further development of the electronic medical record and information systems to better support the coordinated efforts of the occupational and environmental health team, as well as advancements in trend analyses and epidemiologic studies. As in 1979 and throughout the history of Navy medicine, the occupational medicine community continues to demonstrate a deep commitment to improved occupational healthcare in the Navy.

SUMMARY

Navy occupational medicine practice has evolved to support sailors, marines, and civilian employee from the US Navy's sailing origins through the development of steam-powered ships, Naval aviation, submarines, and nuclear power. With these technological advances, occupational medicine practice has become increasingly comprehensive, scientific, and interdisciplinary. Despite these changes, the key mission of Navy occupational medicine remains unchanged: to support the readiness of the US Navy and US Marine Corps by preventing occupational illnesses and injuries in the workforce.

REFERENCES

1. Buchan W. *Domestic Medicine, or, A Treatise on the Prevention and Cure of Diseases by Regimen and Simple medicines: With an appendix, containing a dispensatory for the Use of Private Practitioners.* Hartford, CT: Nathaniel Patten; 1789. https://collections.nlm.nih.gov/catalog/nlm:nlmuid-2544045R-bk. September 8, 2016.

2. Gordon M. *Naval and Maritime Medicine During the American Revolution*. Ventnor, NJ: Ventnor Publishers; 1978.

3. Rimer S. The battle to protect a shipyard from cuts. *New York Times*. June 20, 1995. http://query.nytimes.com/gst/fullpage.html?res=990CE3DD1E31F933A15755C0A963958260&sec=&spon=&partner=permalink&exprod=permalink. Accessed September 9, 2016.

4. Friedenberg Z. *Medicine Under Sail*. Annapolis, MD: Naval Institute Press; 2002.

5. Establishment of the Navy, 13 October 1775. Naval History and Heritage Command website. http://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/e/establishment-of-the-navy.html. Accessed September 9, 2016.

6. Potter EB, Fredland R, Adams HH, eds. *Sea Power: A Naval History*. 2nd ed. Annapolis, MD: Naval Institute Press; 1981.

7. Privateers and mariners in the Revolutionary War. American Merchant Marine at War website. http://www.usmm.org/revolution.html. Accessed September 9, 2016.

8. Navy regulations, 1775. Naval History and Heritage Center website. https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/r/navy-regulations-17751.html. Accessed October 20, 2017.

9. Jones J. *Plain Concise Practical Remarks on the Treatment of Wounds and Fractures: To Which Is Added, a Short Appendix on Camp and Military Hospitals; Principally Designed for the Use of Young Military Surgeons, in North-America*. New York, NY: John Holt; 1775. https://archive.org/details/2559023R.nlm.nih.gov. Accessed September 9, 2016.

10. Toner JM. *The Medical Men of the Revolution With a Brief History of the Medical Department of the Continental Army; Containing the Names of Nearly Twelve Hundred Physicians; An Address Before the Alumni Association of Jefferson Medical College, March 11, 1876*. Philadelphia: Collins; 1876.

11. Lloyd C. *The Health of Seamen*. London, England: Navy Records Society; 1965.

12. The birth of the navy of the United States. Naval History and Heritage Center website. http://www.history.navy.mil/browse-by-topic/commemorations-toolkits/navy-birthday/OriginsNavy/the-birth-of-the-navy-of-the-united-states.html. Accessed September 9, 2016.

13. Estes WJ. *Naval Surgeon: Life and Death at Sea in the Age of Sail*. Canton, MA: Science History; 1998.

14. Langley HD. *A History of Medicine in the Early U.S. Navy*. Baltimore, MD: Johns Hopkins University Press; 2000.

15. Development of ship building at the Charlestown Navy Yard. National Park Service, Boston National Historical Park website. http://www.nps.gov/bost/historyculture/shipbldg.htm. Accessed September 9, 2016.

16. Edward Cutbush. *Am J Surg*. 1934;25(1):188. doi:10.1016/s0002-9610(34)90157-4.

17. Luft EVD. *SUNY Upstate Medical University: A Pictorial History*. North Syracuse, NY: Gegensatz Press; 2005.

18. Military medicine during the eighteenth and nineteenth centuries. US Air Force, Air War College website. http://www.au.af.mil/au/awc/awcgate/milmedhist/chapter2.htm. Accessed September 9, 2016.

19. Cutbush E. *Observations on the Means of Preserving the Health of Soldiers and Sailors; and on the Duties of the Medical Department of the Army and Navy: With Remarks on Hospitals and Their Internal Arrangement.* Philadelphia, PA: Thomas Dobson, Fry and Kammerer, Printers; 1808.

20. Horner GRB. *Diseases and Injuries of Seamen: With Remarks on Their Enlistment, Naval Hygiene, and the Duties of Medical Officers*. Philadelphia, PA: Lippincott, Grambo & Co; 1854.

21. Cleborne CJ. From the annual reports of the surgeon general of the US Navy: recruiting in the Navy. *Grog Ration*. 2007;2(6):9–11. https://archive.org/details/TheGrogRationVol2Issue6NovDec2007. Accessed September 9, 2016.

22. US Naval Academy, Department of History. *New Aspects of Naval History: Selected Papers From the 5th Naval History Symposium*. Baltimore, MD: Nautical and Aviation Publishing Company of America; 1986.

23. Mahan AT. *From Sail to Steam: Recollections of Naval Life*. New York: Harper & Brothers Publishers; 1906.

24. Blackman A. Fatal cruise of the Princeton. *Nav Hist Magazine*. 2005;19(5). http://www.military.com/NewContent/0,13190,NH_0905_Cruise-P1,00.html. Accessed October 12, 2017.

25. Baer GW. *One Hundred Years of Sea Power: The U.S. Navy, 1890-1990*. Stanford, CA: Stanford University Press; 1996.

26. World's most powerful battleship launched. *Pensacola Journal*. February 11, 1906:1, 8. http://chroniclingamerica.loc.gov/lccn/sn87062268/1906-02-11/ed-1/seq-1/#words=ORLDS+MOST+POWERFUL. Accessed September 9, 2016.

27. Half billion in ships. *New-York Tribune*. April 24, 1910:4. http://chroniclingamerica.loc.gov/lccn/sn83030214/1910-04-24/ed-1/seq-20/#words=half+mi. Accessed September 9, 2016.

28. *US Nav Med Bull*. 1907;1:vii.

29. Forman SA. US Navy shipyard occupational medicine through World War II. *J Occup Med*. 1988;30:28–32.

30. Garton WM. Report relative to a series of experiments conducted on board the U.S. Ohio, during target practice, with "plasticine" for the protection of the ear drums during heavy gun fire. *US Nav Med Bull.* 1909;3:142–144.

31. *US Naval Flight Surgeons Manual*. 3rd ed. Washington, DC: Naval Aerospace Medical Institute, Bureau of Medicine and Surgery, Department of the Navy; 1991.

32. Grossnick RA, Armstrong WJ. *United States Naval Aviation, 1910-1995.* Washington, DC: Naval Historical Center, Department of the Navy; 1997.

33. *US Navy Diving Manual*. Rev 6. Washington, DC: Naval Sea Systems Command; April 15, 2008.

34. McDowell R. Diseases incident to submarine duty. *US Nav Med Bull*. 1917;11:44–45.

35. Phillips JL. *The Bends: Compressed Air in the History of Science, Diving, and Engineering*. New Haven, CT: Yale University Press; 1998.

36. Szymendera S. *Reviewing Workers' Compensation for Federal Employees*. Washington, DC: Congressional Research Service. May 12, 2011. http://edworkforce.house.gov/uploadedfiles/05.12.11_szymendera.pdf

37. Wisconsin Department of Workforce Development. Timeline history: Wisconsin Industrial Commission. http://dwd.wisconsin.gov/dwd/dwdhistory/year_pages/wis_indstrl_comm.htm. September 9, 2016.

38. US Navy Department Bureau of Medicine and Surgery. *Manual for the Medical Department of the United States Navy.* Washington, DC: Government Printing Office; 1914.

39. Smithsonian Institution, National Museum of American History. On the water: answering the call, 1917–1945, building ships for victory. http://americanhistory.si.edu/onthewater/exhibition/6_2.html. Accessed September 9, 2016.

40. Dublin LI, Leiboff P. *Occupation Hazards and Diagnostic Signs: A Guide to Impairments to Be Looked for in Hazardous Occupations.* Washington, DC: US Bureau of Labor Statistics, 1922. Bulletin 306.

41. Gillooly PF, ed. History of Navy industrial hygienists. [unpublished monograph prepared for 50th anniversary of the formation of the Navy Medical Service Corps, Navy Department, Bureau of Medicine and Surgery, Washington, DC, 1997].

42. Brown E. Industrial hygiene and the Navy in national defense. *War Med.* 1941(1):3–14.

43. Lawton GM, Snyder PJ. Occupational health programs in United States naval shipyards. *Environ Res*. 1976;11(2):162–165. doi:10.1016/0013-9351(76)90071-2.

44. Rieke FE. Lead intoxication in shipbuilding and shipscrapping, 1941 to 1968. *Arch Environ Health*. 1969;19(4):521–539. doi:10.1080/00039896.1969.10666879.

45. George J, Yacovissi R, Thompson R. History of radiation health officers and radiation medical specialists of the Medical Service Corps, US Navy, 1947–2003. May 23, 2003. http://www.slideshare.net/brucelee55/30-may-1996doc. Accessed September 9, 2016.

46. *Review of the U.S. Naval Medical Research Institute's Toxicology Program*. Washington, DC: National Academies Press; 1994.

47. Drexler JA Jr, Jones AP, Gunderson EKE, eds. *Problems and Strategies of Implementing Navy Occupational Health and Safety Programs.* Seattle, WA: Battelle Human Affairs Research Centers; San Diego, CA: Naval Health Research Center; 1979.

48. Pugh WM, Beck DD. *Preliminary Specifications for a Navy Occupational Health Information Monitoring System (NOHIMS).* San Diego, CA: Naval Health Research Center; 1981. Report no. 21-36. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA112661. Accessed September 9, 2016.

49. Hermansen LA, Pugh WM. *An Overview of the Navy Occupational Health Information Management System (NOHIMS).* San Diego, CA: Naval Health Research Center; 1988. Report no. 88-14. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADa198163. Accessed September 9, 2016.

50. Navy and Marine Corps Public Health Center. Our history. http://www.med.navy.mil/sites/nmcphc/about-us/Pages/our-history.aspx. Accessed September 9, 2016.