Noise-Induced Hearing Loss Among Blacksmiths, Boilermakers, and Metalsmiths

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When evaluating an employee's standard threshold shift (STS) for workers' compensation benefits, factors such as job description, noise characteristics, years of employment, timeline of audiometric changes, noise notching, time-weighted averages (TWA), and peak noise levels are very important. Of the hundreds of job descriptions in our modern world, people working with metals are generally at higher risk for acquiring hearing loss. Data from the Bureau of Labor Statistics reveal the incidence of hearing loss in all primary metal manufacturing (40.6/10,000 up to 103/10,000) is much higher than that in chemical (3.8/10,000), food (20.3/10,000), or furniture (13.2/10,000) manufacturing, construction (18.5/10,000), oil and gas extraction (4.8/10,000), and many other fields.[1] Metals are damaging to hearing because of how they are handled and processed and their properties.

Historically, the emergence of blacksmiths, boilermakers, and metalsmiths developed with the discovery of various metals and new manufacturing methods to make domestic tools, jewelry, and weapons such as handguns, rifles, cannons, ships, and tanks for war. Following the Industrial Revolution, modern metalworkers and boilermakers were employed by foundries, gas, nuclear and electric powerplants, machine shops, sheet and metal can fabricators, wire, pipe and machinery manufacturing, forging and stamping plants, ship and tank builders, construction companies, among many others.

HISTORY OF METALS & METALWORKERS

The history of metalworking started when archaeologists unearthed a copper pendant in Iraq dating back to 8700 B.C. signaling the ending of the Stone Age. By 6000 B.C., smelting in Southwestern Asia was commonplace since copper was heated and hammered into household objects, tools, and weapons. In the Americas, copper objects were similarly found at sites dating back to 4000-5000 B.C. As methods improved, bronze was created by smelting copper and tin together around 3300 B.C., marking the beginning of the Bronze Age.

Forge magazine places the origins of blacksmithing back to about 1350 B.C. when iron forging was first developed in Egypt.[2] As these methods proliferated around the world, the Iron Age emerged.[3] However, it was not until the colonization of the Americas when metal alloys were used for weaponry and cannons that the blacksmith's position as a profession was established. These techniques were improved upon over the centuries, and some are still being used today.

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Figure 1. Rosie the Riveter was an icon of World War II representing women who toiled in factories and shipyards, replacing the male workers who went to war.

It was not until the early 19th century when water boilers were needed to power wooden ships that the boilermaker's job was identified. Boilermakers were craftsman who made boilers and constructed and maintained large vessels and steel containers. They came into high demand to make war machines and fuel the needs of the Industrial Revolution. One of the most famous boilermakers is Rosie the Riveter (Fig. 1), seen in this iconic photo representing women metalworkers during World War II; they worked in this industry in place of men who went to war.

Today's boilermakers have a wide variety of jobs, ranging from boiler maintenance for domestic hot water in commercial building, arc and gas welding, plasma cutting (Fig. 2), piping replacement, to the fabrication of pressure-controlled systems. Modern boilermakers are critical to the operation of petroleum plants, power plants, and nuclear power construction and production to manage regular maintenance and repairs and avoid corrosion, thereby ensuring safe and adequate production

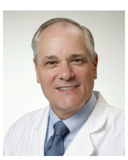

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Figure 2. Plasma cutters use high-pressure gas mixtures and electronic ignition to transfer energy through a plasma jet to a conductive material such as iron. This results in a faster and cleaner cutting process. SPL values typically reach 110-115 dB.

levels. During the shutdown, the processing unit is turned off and every component is inspected and cleaned, while some sections require repairs or are replaced by boilermakers.

SOUND PROPERTIES OF METALS

Sound levels from metal working or tolling are typically higher than those in most other professions, primarily due to the complex properties of metals.[4] For instance, sound travels through air at 1,130 ft/sec compared with 16,000 ft/sec in steel. This is why train robbers would listen for vibrations on the railroad tracks to identify an oncoming train well before they could see it. Metals have varying densities and acoustic impedances that play a role in the transmission of sound at its boundaries. For example, tungsten steel has an acoustic impedance of 99.72 g/cm^2-sec x10^5, aluminum has 17.10 g/cm^2-sec x10^5, and ivory has 1.4 g/cm^2-sec x10^5.[5] These measurements tell us how the pressure wave gets particles in the solid to move. The higher the number, the greater the elasticity. Therefore, tungsten steel would carry a signal better than aluminum or ivory. Compared with all other materials used in industry, metals are by far the best conductors and reflectors of sound.

When metal is tolled by hammering, pressing, forging, chiseling, or stamping, the sound is characterized by an instantaneous signal with intensities that varying between 120 and 140 dB or more. When tools are used on metal, the signal occurs randomly and at different impact rates per second. Compared with continuous noise, metal sounds are extremely variable, unpredictable, and typically higher in frequency response. In addition to acoustic impedance and product design, another cause of variability is signal duration. According to the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), longer signal durations are considered more damaging than short impulses. This is demonstrated by comparing the permissible one per day exposure peak level of 153 dB for a grazing sound with a duration of $>$ 200 msec against a signal duration of 0.3 msec at 172 dB.[6] The longer the duration, the lower the permissible level must be, and this variable alone makes risk assessment difficult. It should be noted that the Occupational Safety and Health Administration (OSHA) regulations limit peak impact noise levels to 140 dB regardless of the duration, with no limitations on the number of impacts per day.

AUDIOMETRIC CHARACTERISTICS OF STEEL WORKERS

In two recent studies on steel workers who did not use[7] or partly used hearing protection,[8] the changes and patterns of hearing loss were similar, highlighting the fact that part-time hearing protection is ineffective. In the early years of exposure, changes at 4,000 Hz were most prevalent with recovery at 6,000 to 8,000 Hz. This configuration is classically known as the boilermaker's notch. Compared with workers in continuous noise, metal workers typically demonstrate a greater degree of hearing loss, more involvement in the adjacent frequencies, a pronounced noise notch in the 4,000 to 6,000 Hz range, and differences in asymmetry between the ears (worse on the left side).[6] Although similar findings of hearing loss were observed in all noise-exposed employees, metal workers were found to have been impacted the most.

EVOLUTION OF HEARING PROTECTION

Over the ages, metalworking was done without any hearing protection. According to the Acoustic Society of America, hearing protection was recorded going back to the ancient Greeks.[9] However, it was not until 1864, during the Civil War, that the first patent for hearing protection was registered. By 1884, ear plugs and canal caps with a headband were supplied to sailors and soldiers. Subsequently, disposable plugs were patented in 1914, soft-foam ear plugs emerged in the 1970s, and electronic earmuff systems in the 1980s.[9] With few exceptions before the 1940s, hearing protection was not part of the manufacturing culture. In fact, many industries in the United States did not offer hearing protection until the Walsh-Healy Noise Standards of 1969 were enacted. In some industries, hearing protection were either not used correctly or not used at all.

ROLE OF AUDIOLOGISTS

Patients who acquire significant hearing loss from industrial metalworking and age present a special challenge to audiologists. This is because noise, especially impact noise, can have devastating effects on cochlear function, resulting in inner hair cell loss, dead zones, and synaptopathy. The audiologist's responsibility is to ensure hearing protection is properly selected, fit-tested, and always worn in noisy settings. When choosing hearing protection, several vital issues can make or break attenuation, including ensuring that the tip of the protection fits close to the second bend and the ear contour allows for fit stability and snugness, and most importantly, providing employee counseling on benefits of hearing protecting and the adverse effects of not using them in noisy occupational conditions.[10] Hearing protection with built-in communication for radio or Bluetooth is the best and an accessible option for workers in the field. Without these components, hearing protection will fail to maximize attenuation, and employers will be faced with worker's compensation claims.

When determining the causation of a high-frequency hearing loss in an industry, the effects of impact noise should be taken into consideration. Because of the variability of impact noise, it's critical to understand someone's risk level based on his or her job description, TWA, and peak data, as well as to develop a boilermaker's notch and chronicle one's hearing changes. Recommending the correct and consistent use of hearing protection could help preserve the hearing of boilermakers and metalworkers. Should a permanent and stationary hearing loss occur and is determined to be from an occupational causation, the permanent impairment can be calculated.[11,12] Using appropriate amplification with transposition may help to recover some perception, but in more involved cases, cochlear implantation may be the only option if neural function is amenable.