Welding Hazards

Conference examines new and emerging concerns

By Michael T. Weeks and Jolinda Cappello

HUNDREDS OF THOUSANDS of people work in welding, cutting and brazing. It is estimated that welders compose 1 to 2% of the U.S. working population, including a significant segment of the aging workforce. According to OSHA's Christine Petitti, the most commonly used welding processes are:

1) Flux-cored arc welding (FCAW). This process uses an arc between a continuous filler metal electrode and the weld pool. It also uses shielding gas from a flux contained within the tubular electrode, with or without additional shielding gas and without the application of pressure.

2) Gas metal arc welding (GMAW). Like FCAW, this process uses an arc between a continuous filler metal electrode and the weld pool. It uses shielding from an externally supplied gas and without the application of pressure.

3) Gas tungsten arc welding (GTAW). This process uses an arc between a tungsten electrode (nonconsumable) and the weld pool. It is used with a shielding gas and without pressure.

4) Shielded metal arc welding (SMAW). This process uses an arc between a covered electrode and the weld pool. It is used with shielding from the decomposition of the electrode covering without pressure and with filler metal from the electrode.

5) Submerged arc welding (SAW). This process uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. A blanket of granular flux on the workpiece shields the arc and molten metal. It is used without pressure and with filler metal from the electrode.

6) Oxyacetylene welding (OAW). This process uses acetylene as the fuel gas. It is used without pressure.

Petitti then identified the three most common cutting processes used in welding:

1) Oxygen cutting: This group of thermal cutting methods severs or removes metal by means of the chemical reaction between oxygen and the base metal at elevated temperatures.

2) Oxyacetylene cutting: This variation uses acetylene as the fuel gas.

3) Plasma arc cutting: This method uses a constricted arc and removes the molten metal with a high-velocity jet of ionized gas issued from the constricting orifice.

Welding Safety & Health Hazards

Welding Fumes

One of the most serious hazards welders face is welding fumes. According to Clifford Frey of 3M's Occupational Health and Environmental Safety Division, welding fumes are not gases or vapors but metal oxides that condense to form solid aggregate particles or "fumes" which may contain heavy metals, organic compounds and fine particulates. The electrode, base metal or base metal coating used during the welding process can generate these fumes.

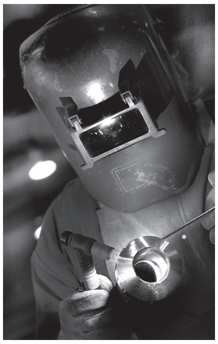
Welding fumes as well as grinding and polishing, arc radiation and chemical interactions within the fume can all create hazards for welders. Frey classified these hazards into two groups—particles and vapors. Examples of welding particles include aluminum, beryllium, lead, ferrous oxide, cadmium, chromium, copper, manganese, magnesium, nickel, silicon dioxide, vanadium oxide and zinc. Examples of welding vapors include argon, carbon dioxide, carbon monoxide, fluoride, helium, hydrogen chloride, hydrogen fluoride, hydrogen sulphide, nitrogen dioxide, nitrogen oxide, ozone, phosgene, phosphine and sulphur dioxide.

Frey also noted that the levels of such respiratory exposures depend on the type of welding performed, the type of electrode, base metal, base metal coating, flux and shielding gas used, the welding voltage and amperage, and the position of the welder.

Abstract: *In late 2005, ASSE's Northeastern Illinois Chapter and AIHA's Chicago Local Section jointly presented a seminar on welding safety and health. During the last few years, SH&E professionals have received conflicting information regarding welding hazards, while an increase in mass tort litigation among workers exposed to welding fumes has raised even more questions. To help SH&E professionals better address welding safety and health concerns, the seminar examined the latest developments in controlling welding hazards. This article provides an overview of the presentations.*

Michael T. Weeks, CIH, *is an environmental consultant with Boelter & Yates Inc. in Park Ridge, IL. He has practiced industrial hygiene since 1996, both as a consultant and in the private sector in the industries of electric power generation and integrated steel. Weeks is a member of AIHA's Exposure Assessment Strategies and Student and Early Career Professionals committees, and he was a member of the inaugural class of AIHA's Future Leaders Institute. He has also been chair of the Safety Committee of the Northwest Indiana Business Roundtable. Weeks is a graduate of Purdue University.*

Jolinda Cappello *is a communications specialist with ASSE.*



To prevent eye and face injuries, welders should wear a shield or helmet with a filtered lens that is of the proper shade.

Health Hazards

Although they are exposure-dependent, several illnesses have been linked to the contaminants that make up welding particles, vapors and fumes. Short-term illnesses commonly reported among welders include respiratory tract irritation and metal fume fever, an ailment that may result from overexposure to zinc (present in galvanized metal), cadmium, copper or magnesium. This "fever" produces flu-like symptoms that usually subside within 24 to 48 hours. However, long-term overexposure to iron fumes can cause siderosis or "welder's lung," which can in turn exacerbate the effects of other pulmonary diseases such as silicosis, asbestosis and emphysema.

Perhaps the most hotly debated topic within the welding industry today is the relationship between long-term manganese fume exposure and "manganism," an illness that can cause symptoms similar to Parkinson's disease—including fixed gaze, paralysis, psychological disturbances, slurred speech, tremors and weakness/lethargy. Some contend that manganese exposure directly contributes to Parkinson's disease, but as Daniel Tessier of the University of Illinois at Chicago indicated in his presentation, it has yet to be determined whether the low concentrations of manganese found in welding fumes are enough to cause neurotoxicity.

In addition to manganese, hexavalent chromium has garnered attention within the welding industry. This highly reactive oxidizing agent is often used as a rust and corrosion inhibitor, and it is also used in the production of stainless steel and chromium alloys, ferrochromium, chromium, pigments and dyes. Hexavalent chromium exposures may occur during chromium plating, paint application and removal, refractory brick production, metal and plastic surface treatments and welding on stainless steel or hexavalent chromium-painted surfaces. Potential adverse health effects associated with hexavalent chromium exposure may include asthma, contact dermatitis, eye and skin irritation, lung, nasal and sinus cancer, nasal ulcerations and perforations, nosebleeds, pulmonary congestion, skin ulcerations and teeth discoloration.

Ken Proskie, a consultant with Compass Health & Safety, indicated that more than 300,000 workers within 80 industry groups may be exposed to hexavalent chromium in their occupations. Many human and animal studies have been conducted to determine the health effects of overexposure to hexavalent chromium, but according to Proskie, only a few of these studies were well-controlled and contained exposure data. And while lung, nasal and sinus cancer are prevalent among those working in the chromate, pigment manufacturing and chromium plating industries, the carcinogenic effects among stainless steel welders are mild and inconclusive.

On Feb. 28, 2006, OSHA published a new standard for occupational exposure to hexavalent chromium. The standard, which applies to general industry, construction and shipyards, lowers the agency's permissible exposure limit (PEL) for hexavalent chromium from 52 to 5 micrograms per cubic meter of air as an 8-hour time-weighted average. The standard also includes guidelines for exposure control, respiratory protection, protective clothing and equipment, industrial hygiene practices, medical surveillance, hazard communication and recordkeeping.

Despite such rulings, insufficient studies and the variation in welding processes, conditions and materials make it difficult to determine exactly how welding fumes impair human health. For example, Frey pointed out that some studies show a 30 to 40% increased risk of lung cancer among welders, but these studies are often based on a low number of subjects and do not always take into account welders' smoking history or previous asbestos exposure. In addition, he noted that while some have suggested a connection between lung cancer and exposure to chromium, nickel and thorium, studies do not support these claims.

Other possible harmful health effects associated with welding include asthma, distorted posture, hearing loss, heat stress, lowered immunity, repetitive stress and reproductive problems. Welders may also suffer from photokeratoconjunctivitis, better known as "welder's flash." This temporary inflammation of the cornea is caused by overexposure to ultraviolet light, which most frequently occurs when a welder views an arc directly. In fact, OSHA's Petitti confirmed that welder's flash causes 5.6% of all eye injuries in the construction industry.

Safety Hazards

According to Petitti, welders regularly work with equipment that poses numerous safety hazards. If not properly handled and stored, devices such as gas cylinders, drums and containers can combust or explode. Other tools such as manifolds, hoses, torches, manual electrode holders and cables can cause fires or electrocution if they are faulty or misused. Welders must also exercise caution when working in confined spaces or in areas that contain potential fire hazards.

Welding Safety Measures

SH&E professionals play a critical role in protecting welders from the many hazards that they encounter in their work. The seminar speakers discussed practical methods for evaluating and controlling welding hazards.

Personal Protective Equipment

Petitti emphasized the importance of welders' PPE. To prevent eye and face injuries, welders should wear a shield or helmet with a filtered lens that is of the proper shade. Frey noted that one recent innovation, the autodarkening shade, has greatly advanced welder eye protection. This shade reacts instantly to ultraviolet and infrared light so that welders do not have to change shades based on the type of welding work performed or electrode used. This shade also increases welding accuracy, quality and productivity because welders are not temporarily blinded by a predarkened shade in positioning the weld, and they do not have to raise their helmets as often to see.

In addition, Petitti stressed the use of flameproof screens to protect workers in surrounding welding areas from accidentally viewing the arc. Welders should also wear protective garments such as fire-resistant gloves, full-sleeved shirts (without cuffs or pockets), leather aprons and spats, boots and felt skull-caps to protect against stray sparks and spatter.

Ventilation

3M's Frey explained that ventilation in welding can be complex because welding processes often occur in areas with general exhaust ventilation as opposed to local exhaust ventilation. Ventilation can disrupt the shielding gases some welding processes use to protect welds from oxidation. According to Fred Boelter of Boelter & Yates Inc., the amount and type of ventilation used can also affect exposure assessments. However, proper ventilation is necessary to protect welders from harmful respiratory exposures.

Air Sampling Methods

Routine air sampling can help SH&E professionals determine how to effectively control and reduce welders' respiratory exposures. Frey proposed several air sampling strategies to evaluate exposures in the workplace. He stressed that air samples should represent welders' exposures based on specific work tasks, since certain variables such as ventilation, work rate and time can change exposure levels. Worker selection for personal sampling should also be based on the contaminant and job task. Frey underscored that in addition to documenting all events and observations, SH&E professionals should clearly communicate the purpose of any sampling to employees and explain how they may obtain the sampling results.

Exposure Assessments

Laurel Berman, who studied welding fume exposures among artist welders, advised that welding activities be isolated during exposure assessments in order to ensure accuracy. Berman monitored three different artist welders' exposures to respirable particulate and metal components in welding fume as they worked in isolated conditions. She then recreated each artist's welding practices in a laboratory setting to compare field and controlled exposure measurements.

Her results indicated that none of the artists were exposed to welding fumes or metals that exceeded full-shift (8-hour) occupational exposure limits. However, when Berman recreated the welding activities in a laboratory exposure chamber, the fume composition varied from that collected in the artists' studios and overpredicted exposure to welding fume when compared to field-based data. The artists also performed grinding and cutting operations in their studios, whereas in the "welding-only" setting of the laboratory exposure chamber, ventilation, welding arc time and the amount of electrode consumed during welding were all tightly controlled. Berman's field-based data more closely represented realistic welding practices because it included grinding and cutting activities, ventilation variability, intermittent activity and particulate that naturally occurs in the studio spaces.

Boelter also presented findings from recent welding fume exposure assessments that he conducted in the field and reviewed factors to consider when conducting such assessments. These factors include:

- amount and type of ventilation;
- workplace configuration;
- diameter and composition of consumables used;
- electrical current and voltage used;
- environmental conditions of the workspace;
- PPE used;
- presence of coatings on the base metal;
- time spent welding, including actual arc time;
- type of base metal used;
- unique properties of each welding method;
- welder's skill, speed and position.

SH&E professionals performing exposure assessments must consider other confounding factors that may affect results. Welding processes being performed near the assessment area as well as grinding work can bias results for particulate sampling. Welding in nonmanufacturing environments, such as construction, maintenance and repair work, can also influence assessment results, as the work may change quickly; under time constraints, decisions regarding safety may be customized to fit the situation.

Boelter performed a welding exposure assessment during pipefitting operations. He conducted personal sampling of a welder during SMAW work on mild steel, and he took samples for dust and metals, including from inside and outside of the welder's helmet simultaneously. Comparisons made during the sampling period indicated that all sample results taken outdoors were less than the results of those taken indoors. In addition, results of samples taken from outside of the welder's helmet were only slightly higher than those taken from inside the helmet with a difference of approximately 10%.

Boelter took indoor samples when the air in the room was mixed mechanically with fans and when no mechanical mixing took place. Sample results from the mechanically mixed air were approximately twice as high as those from the air that was not mechanically mixed.

He simultaneously measured the ventilation rate of the room and confirmed that the air change rate of the room remained fairly constant throughout the sampling. Boelter also noted that since the particulate in the fume is so small, it tends to behave like a gas. Using fans to mix the air disturbed the stratified welding plume and created a uniform fume concentration throughout the room, thus causing an elevated concentration within the welder's breathing zone.

Equipment Handling & Storage

Petitti recommended that welders follow established practices for the safe use, transportation and storage of welding equipment, particularly compressed gas cylinders. To safely open a cylinder valve, it should always be opened slowly and by not more than one and a half turns of the spindle. Regulators must also be used while working with compressed gases in order to reduce pressure throughout the system.

General Mills Hot Work Management Program Incorporates FM-Approved Products to Minimize Risk

A yearlong study of fire losses among its clients led FM Global, a commercial and industrial insurance company, to evaluate available protection products. FM Global discovered a wide variation in the quality and effectiveness of fabrics used in hot work operations. Poor hot-work guidelines, including confusion about proper fabric uses and limitations, was identified as the major cause of $750 million in fire and property loss experienced by FM clients over a 10-year period—an average of $1.3 million cost per fire. Subsequently, FM Approvals, a product testing and certification company and business unit of FM Global, set out to improve hot work management policies by developing a performance-based standard for fabrics. Approval Standard 4950, "Welding Pads, Welding Blankets and Welding Curtains for Hot Work Operations" specifies testing requirements for these loss prevention products.

General Mills Inc., a global food manufacturer, is an FM Global client. When plant personnel heard about FM Approval Standard 4950, they were anxious to incorporate FM-approved products into the plant's overall hot work management program. However, when it came to using FM-approved products, General Mills quickly learned that no one was yet selling them.

After doing some research, the company learned that FM Approvals was testing high-temperature products for Auburn Manufacturing Inc., a manufacturer of extreme temperature textiles. At that time, Auburn was the only company seeking FM approval for its fabrics.

Fabrics Undergo Rigorous Testing

The FM Approvals testing process requires hot work fabrics to undergo a battery of tests that simulate the extreme conditions of harsh, real-world hot-work applications. "Until this standard came about, there were all kinds of fabrics that were marketed under the generic 'heat-resistant tarpaulin' requirement," explains Auburn Manufacturing CEO Kathie Leonard. "Many of those fabrics wouldn't hold up in most hot-work operations." The standard helps to ensure that manufacturers that go through the testing and certification process are playing on a level field. The standard also requires manufacturers to demonstrate a quality control program and submit to manufacturing facility inspections as part of the approval process.

Auburn Manufacturing received FM approvals for 17 of its fabrics. Once the products became available, General Mills implemented its new hot-work policy. Under that policy, all contractors and inside maintenance had to begin using FM-approved fabrics for all hot-work operations by June 1, 2006.

Communicating the Standard Is Critical to Success

When it comes to hot-work safety, communicating standards is key. "It's not unusual to have many contractors of all different trades performing hot-work operations at the Cedar Rapids plant," explains Terry Cunningham, emergency response coordinator at the plant. "We contract a majority of our capital work to contractors and we work closely with them regarding all our safety policies. We meet with the company owners once a month to communicate our safety policies and, in turn, we expect them to have good safety programs with a low accident rate. If contractors get into too many accidents they are not going to be able to work for us. In addition, all our contractors must be insured."

The company issues hot-work permits that track each step of a hot work job, and serve as a guide, a warning tag and careful record. According to Cunningham, plant personnel collect the permits each day and once a year they are reviewed by FM Global. "In one year's time, we could issue more than 4,700 hot work permits," Cunningham says.

The permits now recommend protection with FM-approved welding pads, blankets and curtains installed under and around hot work operations. Before these products were available, the permits recommended only heat-resistant tarpaulins, a term that could allow fabrics made of substandard materials to be used for fire protection.

Plant & Corporate Benefits

Establishing a clear, consistent hot-work safety program has produced several benefits. In addition to reduced risk, Cunningham points to returns in terms of loss prevention and savings. "The program builds in accountability as well as safety and has enabled us to achieve solid performance-based working relationships with our contractors and our inside maintenance teams."

Once the new hot-work program was fully implemented at the Cedar Rapids plant, it began to be communicated to all General Mills facilities via presentations and the Internet. According to Cunningham, "There is a lot of excitement about implementing the policy throughout all of General Mills. Once one big company starts doing this, others will follow suit because they know it's going to reduce their risk."

However, before connecting the regulator, the cylinder must be opened slightly then closed again to clear the valve of dirt. This "cracking" of the cylinder should never be performed in the presence of open flames or in an area where the gas could reach welding sparks. Before removing the regulator, the cylinder valve must be closed and the gas must be released from the regulator. While in use, cylinders must be secured by a chain, cart or other steadying device, and valves must remain closed on cylinders that are not in use. Most importantly, compressed gas cylinders should never be brought into confined spaces.

In addition, cylinders should never be moved unless the regulator has been removed and the valve protection caps are in place. When cylinders are transported by any type of powered vehicle, the cylinders must be kept in an upright position and should never be hoisted by the valve protection caps. Stored cylinders must be kept at least 20 ft away from oxygen and fuel cylinders or be separated from them by a 5 ft high noncombustible barrier with a fire rating of 30 minutes. Storage areas should be dry, protected from outside contact, well-ventilated and 20 ft away from flammable or combustible materials.

Equipment such as manifolds, hoses and torches can also present safety hazards for welders. Welders can remember that a green hose is always used for oxygen and has a right-hand thread, while a red hose is used for acetylene and has a left-hand thread. Hose couplings must be the type that rotate to disconnect—quick disconnects are not allowed. Although it is a common practice to tape the two hoses together to prevent tangling, no more than 4 of every 12 in. of hose should be covered with tape. Fuel hoses must be inspected prior to each shift, and any defective hoses must be promptly removed from service.

Torches must also be inspected before each shift, and clogged torch tips should be cleaned with suitable devices. Torches should only be lit by strikers or by other approved methods, never with matches or off of other hot work.

When welders enter confined spaces, means must be provided to quickly remove them in case of an emergency. Welders who work in these spaces should always wear lifelines, and an attendant with a preplanned rescue procedure should be stationed outside the space at all times to observe welding activities.

Fire Protection

Petitti cited fire protection as one of the most critical components in welding safety. If welding work cannot be performed in a safe area that contains no fire hazards, then all fire hazards must be removed from the welding area. Fire extinguishing equipment must be present and ready at all times, and welders must be trained in its proper use. Sparks, slag and heat must be contained within the welding area, and no combustible materials should be present on the floor below the welding activity or in other areas where sparks may reach.

A fire watch must be present any time combustible materials are within 35 ft of the welding area or easily ignited materials are present past 35 ft. This person must maintain the fire watch for at least 30 minutes following the completion of welding activities. If the welding is performed in an area with a combustible floor, the floor must be swept clean and kept wet, covered with damp sand or protected by fire-resistant materials. Welding should never occur near degreasing operations or spray booths, and smoking must always be avoided near welding operations. When welding in a confined space, the torch and hoses must be removed from the space when finished to ensure that hazardous gases do not build up.

Welding Fume Litigation

To summarize the current status of welding fume litigation, Mark Roberts, a senior managing scientist with Exponent, drew on his experience as an oilfield welder, public health official, academician, corporate medical director and consultant. According to Roberts, most claims assert that welders are at an increased risk of neurological and neuropsychological conditions. In response to these claims, scientists have researched welding exposures, specifically exposure to manganese and its relationship to Parkinson's disease, but to date much of the available research is litigation-driven and scientifically unsound.

Furthermore, since solid epidemiologic studies on the health effects of welding fumes are also lacking, many litigation-based health claims rely heavily on case reports. Most known information on manganese toxicity is based on individual studies of high manganese exposures among miners, battery manufacturers and smelters. Although some cross-sectional studies exist, their limitations and design make it difficult to extract concrete conclusions from the data. Roberts advised that data consistency, confounding variables and adherence to scientific principles should all be considered during review of these studies. He further explained that since science is a slow process, it will be some time before any definitive conclusions are reached.

Roberts concluded that even though case reports of isolated incidents indicate a potential link between high-level welding fume exposure and manganism, no credible scientific evidence shows that welders are at an increased risk of developing Parkinson's disease. He stressed the importance of adhering to scientific principles in the design and communication of study results and of upholding these principles with the same fervor with which attorneys defend the legal system.

Conclusion

Based on the information given in the presentations, more research must be conducted to confirm the direct health effects of welding fume exposure, especially when those fumes contain manganese. In the meantime, welders, as well as SH&E professionals, should continue to follow established practices to guard against the safety and health hazards associated with welding, while staying abreast of scientific developments and court proceedings. ■

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