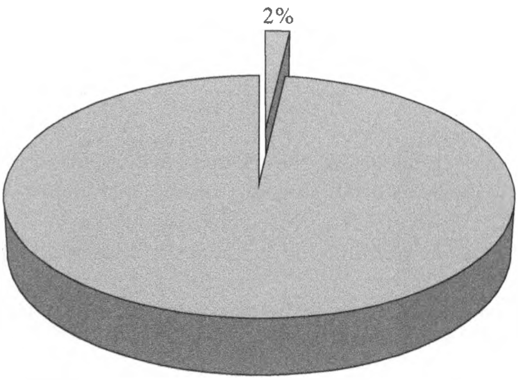
CHAPTER 16

Welding



Percentage of OSHA General Industry citations addressing this subject

After as broad a subject as machine guarding, it may seem ridiculously specific to address a field as narrow as welding. However, it may surprise some to learn that welding processes present some of the greatest hazards to both safety and health. In terms of breadth of hazard, this chapter encompasses even more than the chapter on machine guarding, and for that matter, more than any other chapter of this book.

The term *welding* is to be taken in a very broad sense to include gas welding, electric-arc welding, resistance welding, and even related processes such as soldering and brazing, which technically are not welding processes at all. Welding processes are so diverse that before addressing the hazards of these processes, it is necessary to name them and to provide the necessary background in welding process terminology.

PROCESS TERMINOLOGY

The key to understanding welding hazards is to know how the process itself works, and unless safety and health managers have this knowledge, their credibility with their manufacturing and operations counterparts will be minimal. Everyone knows that welding requires that material melt or fuse to form a rigid joint. The first question to ask to determine the process is "What material melts?" If the melted material is of the parts to be joined themselves or of like filler material, the process is *welding*. If the material is some other material of lower melting temperature, the process is *brazing* or *soldering*. The breakpoint between brazing and soldering is 800°F (427°C), with brazing above and soldering below 800°F.

Since welding requires materials to be melted, heat is required, usually applied intensely, to meet the demands of high melting points of welding materials. The method of applying this intense heat usually identifies the process. Excluding the unusual and exotic processes, such as thermit and laser processes, the three basic categories of conventional welding are as follows:

- Gas welding
- Electric-arc welding
- Resistance welding

Gas welding is typified by the familiar oxyacetylene torch process, in which the very hot burning acetylene gas is made to burn even hotter by supplying pure oxygen to the flame. For welding materials with lower melting points, alternate and safer gases such as natural gas, propane, or MAPP gas (a trade name) can be used. These alternate gases are often used for brazing and soldering.

The safety and health manager should be careful not to confuse gas welding with some types of electric-arc welding that use an inert gas to facilitate the process. Indeed, some of these processes have names such as "gas metal arc welding" or "gas tungsten arc welding," but they are not gas welding. The telling feature of gas welding is that the gas must be used as a fuel for the process, not as an inert gas.

Even more diverse than the types of gas welding are the various types of *electric-arc welding*. Arc welding requires a small gap between electrodes, one of which is usually the workpiece itself. The intense heat is provided by the electric arc that forms between the electrodes. The process that typifies electric arc is *stick electrode* or shielded metal arc welding (SMAW),[1] shown in Figure 16.1. This highly portable and most popular operation is seen in welding structural steel for buildings, in repair of steel components, and in a wide variety of manufacturing processes. The *stick* is a piece of *welding rod* that is held by a gripper and is consumed by the process. The stick consists of a filler metal surrounded by a *flux*, a term to be explained later. Similar to SMAW welding is *flux-cored arc welding* (FCAW), in which the flux is on the inside of the rod, reminiscent of acid- or resin-core solder. Sometimes the welding process does not consume the electrode, a good example being the process commonly called TIG (tungsten inert gas) or GTAW (gas tungsten arc welding) shown in Figure 16.2. In a related process, GMAW (gas metal arc welding), the electric arc consumes a *flexible* electrode that is spooled on a reel and is continuously fed to the arc during welding.

The terms *flux* and *inert gas* have been used earlier and need some explanation. The extremely hot melting temperatures of steel and other metals make these metals

[1]American Welding Society recommended abbreviation.

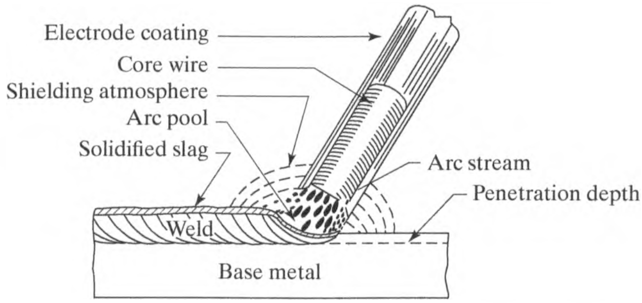


FIGURE 16.1

Stick electrode or SMAW (shielded metal arc welding).

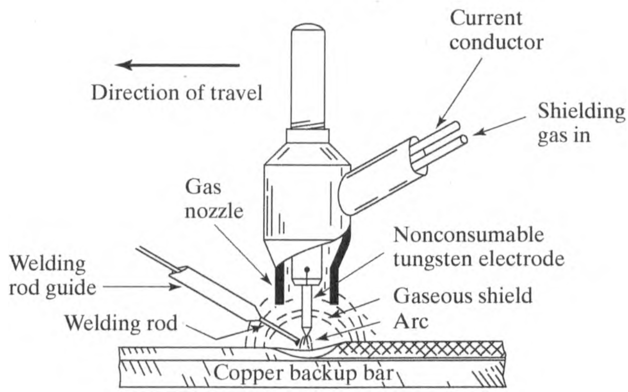


FIGURE 16.2

TIG (tungsten inert gas) welding or GTAW (gas tungsten arc welding).

very vulnerable to oxidation, which is harmful to the weld. Flux is typically a chemical compound that combines with impurities and with oxygen to prevent harmful oxidation of the hot metals. The flux combines with impurities while in the molten state and the resultant molten liquid is called *slag*, which later solidifies and must be removed from the finished weld. With some processes, one of the inert gases, such as argon or helium, is used for the same purpose. The inert gas displaces the air ambient to the weld and thus keeps harmful oxygen away from the hot metals. Unfortunately, this inert gas also sometimes keeps the oxygen away from the worker who is doing the welding, an obviously undesirable characteristic that will be explored subsequently in the section on hazards mechanisms.

One other electric-arc process should be mentioned at this point: *submerged arc welding*, or SAW. In this process, the flux is granular and, as can be seen in Figure 16.3, the electric arc is hidden under the pile and puddle of granular and melted flux, respectively. This has great safety and health advantages, and submerged arc is growing in popularity. Automatic welding machines are often programmed to apply flux automatically and move the electrode over a long, straight path in the manufacture of large structural steel beams or plate girders. However, SAW welding in overhead positions is a problem because the granular flux will fall by gravity instead of covering the weld.

Resistance welding (Figure 16.4) is one of the least hazardous welding processes. It is widely used in mass-production manufacturing. However, resistance is generally restricted to relatively thin sheets of material. The concept of resistance welding is to

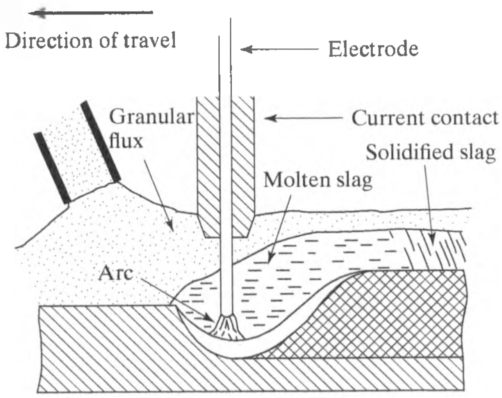


FIGURE 16.3

Submerged arc welding (SAW).

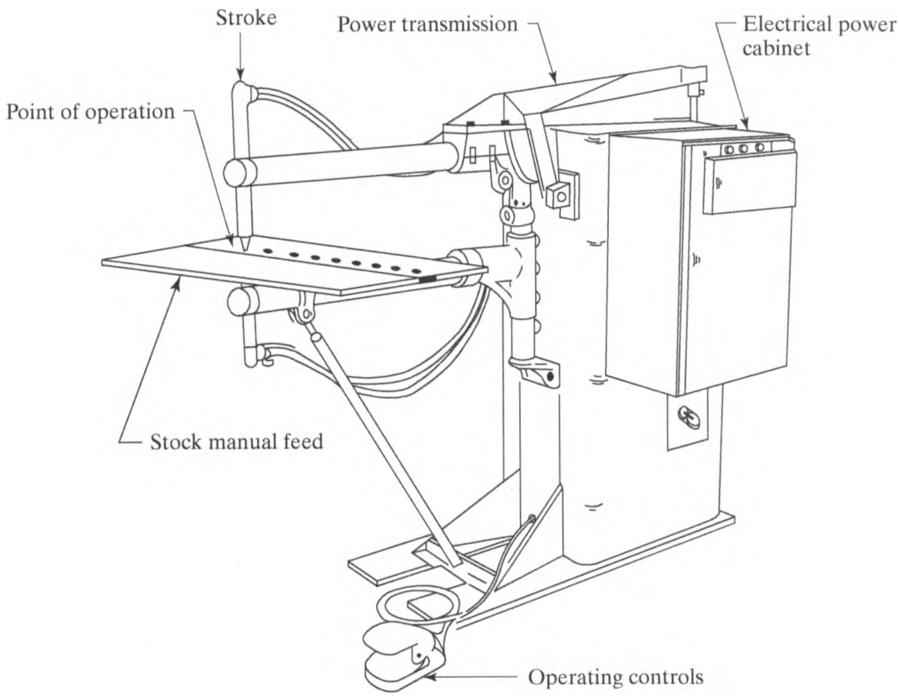


FIGURE 16.4

Resistance spot welder.

pass electrical current *through* the material to be welded, enabling the heat so generated to melt the material. Physical pressure is also applied at the point of the weld. The attractive thing about resistance welding is that the melting generally occurs only where the mating surfaces meet. The outside and adjacent surfaces that are exposed to atmospheric contaminants harmful to the weld do not reach melting point, and damage to the material is minimal. This fact also precludes the need for a flux or inert gas to complicate both the production process and the safety and health aspects.

Resistance spot welding (RSW) is widely used to join sheet metal coverings, housings, guards, and shields on such products as space heaters and grain bins. Another important industry for spot welding is the automobile industry. Seam welding (RSEW) is generally preferred over spot welding for watertight seals because a pair of rollers apply continuous pressure and a series of electrical pulses make, in effect, a seam of overlapping spot welds.

Some of the more unusual or exotic processes should be mentioned because, although they may rarely be used or seen by the safety and health manager, the nature of their hazards may be entirely different. The *thermit* method of welding (TW) employs a chemical reaction to produce the welding heat. Thermit is good for awkward applications or perhaps where the welding to be done is remote from convenient electrical power or gas sources. *Laser beam welding* (LBW) uses a concentrated laser light beam to generate the welding heat. Lasers pinpoint the weld so precisely that they are used for almost microscopic applications on tiny parts.

GAS WELDING HAZARDS

The myriad of different processes for welding should give some clue as to why the breadth of welding hazards is so great. We now examine these hazards, beginning with gas welding because it has given safety and health managers the most problems.

Acetylene Hazards

Gas welding cylinders are so familiar that it is difficult to keep in mind their devastating destructive power. Acetylene gas, the fuel gas for most gas welding, is so unstable that its pressurization in manifolds to pressures greater than 15 psig (30 psia) is prohibited. Contrast this low pressure with the familiar oxygen, nitrogen, or other ordinary compressed-gas cylinder, which contains pressure greater than 2000 psi.

There are tricks to avoid the instability hazards of acetylene gas; the most popular one is to dissolve the gas in a suitable solvent, usually acetone. Then the pressure can be raised to around 200 psi. As the acetylene gas is used from the acetylene cylinder, the pressure is lowered slightly, permitting a greater quantity of gas to bubble out of the solution, resulting in equilibrium at a pressure suitable for welding. In this manner, a relatively large quantity of acetylene can be stored in a reasonably portable cylinder.

Figure 16.5 shows the inside of an acetylene cylinder. Most people do not know that the cylinder contains a solid absorbent filler material for the acetone–acetylene solution. The contents are more liquid than gas, and this gives rise to a hazard mechanism. Acetylene cylinders should be kept valve end up both while in storage and while in use. There is no harm in tilting cylinders slightly, and in fact this is common practice in the use of hand trucks to handle cylinders connected for use. Good advice, however, is not to tip acetylene cylinders to an angle more than 45° from vertical.

If the cylinders are stored horizontally or valve end down, liquid acetone could enter the valve passages instead of the intended acetylene gas. Then later, when the valve is opened, the welder could get an unexpected flow of highly flammable liquid acetone instead of acetylene gas. Since the purpose of opening the valve is usually to ignite the torch with a sparking source, it is obvious that it would be easy to ignite the liquid acetone accidentally. A burning quantity of spilled acetone is difficult to control

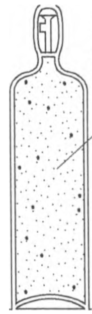


FIGURE 16.5
Acetylene cylinder.

and is quite dangerous. The reader is referred to Chapter 11 to consider the flammability characteristics of acetone.

Another way to get liquid acetone through the cylinder valve is to use the cylinder when it is nearly empty. Acetone coming through the valve or leaking elsewhere is easy to detect. The principal active ingredient in nail-polish remover is acetone, the odor of which is familiar to most everyone.

Acetylene cylinders have been known to leak around the valve stem, causing what welders call "stem fires." Another place to check for leaks is from the plug in the bottom of the cylinder. In one incident, fortunately not a serious accident, the welder was perplexed by occasionally hearing a small explosion, audible but causing no damage. The mystery was finally solved when it was discovered that the explosions were occurring in the small concave area beneath the bottom of the cylinder. The little explosions were harmless, but imagine the hazard that could have accumulated if there had been no ignition, and the defective cylinder had been allowed to slowly release acetylene, as in overnight storage.

It is important to be able to turn off the fuel flow quickly in an emergency, especially when the fuel is acetylene. Some acetylene cylinder valves are designed to accept a special wrench, but ordinary hammers and wrenches are in general inappropriate for opening cylinder valves. The special wrench should be kept available for immediate use.

A carbide "miner's lamp" burns on acetylene by dropping lumps of calcium carbide into water. The resulting chemical reaction is as follows:

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\uparrow$$

Thus, acetylene gas slowly bubbles out of the water solution and fuels the lamp. The same chemical reaction can be used for generating acetylene gas for welding by means of an acetylene generator. This process avoids the hazards of large-scale storage of acetylene cylinders. However, the process of storing acetylene in cylinders has been so perfected, so commercialized, and made relatively safe, that acetylene generators are rarely seen anymore. The cylinder supplier has a large acetylene generator somewhere, but this is of no concern to most safety and health managers.

Before leaving the subject of acetylene hazards, we should consider alternative fuel gases. If a safety and health manager really wants to win the approval of top management, he or she will offer a production innovation that will make the workplace safer, reduce the company's legal vulnerability, and cut production costs—*all at the same time!* It is difficult to do, but not impossible, and the selection of welding fuel gas presents a potential opportunity. It takes some "homework" and particular diligence to pursue the issue, but the rewards to the company and to everyone involved can be dramatic.

MAPP gas, natural gas, and propane were mentioned earlier as possible alternatives to acetylene. The first objection that the safety and health manager will hear to the idea of using these gases is that they do not burn hot enough. It is true that acetylene excels when a very hot flame is needed, but many industrial applications do not need temperatures as high as welders want for *some* applications. Alternate gases are certainly hot enough for brazing and soldering, as well as being hot enough for some welding applications.

One reason that halfhearted attempts to switch to alternate gases do not work is that welders attempt to switch gases while using the same torch tips they used with acetylene. Special torch tips may be the secret to making the new idea a success. Welders may also need to be taught how to adjust their torches to achieve a "neutral flame" with the proper burning characteristics.

Case Study 16.1 will illustrate how one safety and health manager had a positive economic impact on his company by making a suggestion that improved safety while reducing production costs.

CASE STUDY 16.1

REDUCING A HAZARD BY SUBSTITUTION

The safety and health manager of a manufacturing plant noticed that a production operation was using conventional gas welding equipment to perform a brazing operation. The conventional gas welding setup is a portable cart with a torch connected to oxygen and acetylene cylinders. However, in a production operation in which the process stays in one place within the plant, there is no need for the welding equipment to be on a portable cart and use fuel gases supplied in expensive portable bottles or tanks. Furthermore, since the operation was brazing, not welding, a much lower temperature was needed to do the job, which gave the safety and health manager the idea that perhaps dangerous and expensive acetylene gas, with its characteristic hot flame, might not be needed. The cheapest alternative welding fuel of all, natural gas piped into manifolds in the plant, was suggested as an alternative to acetylene. Unfortunately, public utility supplies of natural gas are at very low pressures, approximately 4 ounces/square inch and welders scoffed at the idea, saying that the natural gas pressures were too low to be effective in this production process. Not giving up easily, the safety and health manager negotiated an arrangement with the utility company to supply the natural gas to the plant at higher pressures than is normally used for other gas customers. The result was a very successful brazing operation using natural gas as a fuel substitute for the much more expensive acetylene gas. By following through with his idea, this safety and health manager gained prestige with the plant manager and throughout the plant by demonstrating that he was a problem solver with an eye for production cost and efficiency as well as for safety. At the same time, he succeeded in reducing the plant's exposure to OSHA citation for some of the most frequently cited OSHA standards ever.

Oxygen Cylinders

We have seen the hazards of highly unstable acetylene, and by comparison, oxygen is much more stable; in fact, it is almost completely safe *if* it is kept away from fuel sources. However, ironically, oxygen cylinders are more dangerous than acetylene cylinders. The reason for this danger is the extremely high pressure contained by the oxygen cylinder. Figure 16.6 depicts the familiar oxygen cylinder; note its resemblance to the shape of a bomb or a rocket. It is difficult to comprehend the energy that can be released by the sudden rupture of the valve on an oxygen cylinder containing 2000-psi pressure. There have been numerous accounts of cylinders becoming airborne and crashing into brick walls, demolishing the walls. If a cylinder valve ruptures while the cylinder is confined in a relatively small room, it may ricochet off walls until it kills anyone unfortunate enough to happen to be in the same room when the valve breaks. Consider the hazard of a heavy cylinder flying wildly around the room like a rapidly deflating balloon.

Workers often unwittingly drop oxygen cylinders onto the ground or bang them violently together. Oxygen cylinders are often seen standing alone and unsupported. Even though they are quite heavy, their small bases make them easy to tip over, with the resultant danger of knocking off the valve. The temptation to leave oxygen cylinders standing alone and unsecured needs to be dealt with in safety training sessions.

Another temptation with oxygen cylinders is that they seem to make perfect rollers for supporting and moving heavy items about. No matter whether the cylinders are full or "empty" (even a spent cylinder is not completely empty), use of cylinders as rollers or support can damage the cylinder and perhaps the valve. Furthermore, the large, heavy cylinders used as rollers present a problem of *control*. Once a heavy load begins to roll on a set of welding cylinders, it can even *run over* an unsuspecting victim.

A perennial problem is keeping track of the valve protection cap, which must be removed to use the cylinder, but which also must be screwed back into place when the cylinder is in storage. This cap protects the important valve from damage, and if the cylinder is ever moved about without it, there is a risk of the cylinder falling and knocking off the valve, with disastrous results.

When an oxygen cylinder is strapped to a wheeled cart or hand truck along with its companion acetylene cylinder and the regulator assembly is in place for welding, the

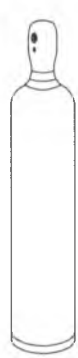


FIGURE 16.6

Oxygen cylinder.

cylinder is generally considered to be in operational status, not in storage. Therefore, industry practice says that the valve protection caps do not have to be in place in these situations.

By looking carefully at the valve protection cap in Figure 16.6, a somewhat odd-looking vertical slot can be seen; actually, there are two, but one is hidden in this view. These slots have a definite engineering purpose, but not the purpose most people think. If the valve comes off while the protection cap is screwed into place, the escaping gas will impact at high velocity on the closed top portion of the cap, tending to counter the force of the gas escaping at the valve. The slotted parts on the sides of the cap permit the gas to escape, but in directions exactly opposite to each other, balancing forces and leaving the cylinder relatively at rest.

Unfortunately, the existence of the slotted openings on the cap are an invitation to their misuse by the worker who is attempting to handle the cylinder. Cylinders are heavy and unwieldy, especially to the worker who has had to handle a lot of them in one day. Furthermore, in cold weather, these cylinders have a tendency to become frozen to the ground, to a slab, or even to each other. The worker will want to find a means to break them apart from each other or from the slab to which they are frozen. The slotted opening on the cap seems to be an ideal place to insert a pry bar to obtain some leverage. However, this is *not* the purpose of the slots, and misuse in this fashion is what can lead to a broken or damaged valve.

As if the extreme pressure hazards were not enough, oxygen presents additional hazards owing to its chemical properties. As stated before, it is relatively stable in the absence of fuel sources, but the fire hazard of pure oxygen under pressure in the presence of a combustible substance is extraordinary. A substance as benign as ordinary grease can suddenly become explosively combustible in the presence of pure oxygen under pressure. A worker will often hold his or her hand over the valve opening when first opening the valve to test the cylinder. If the hands or gloves are greasy, an explosive combustion can follow in which the hand can easily be lost.

We have examined the separate hazards of acetylene and oxygen, but when oxygen and acetylene cylinders are stored together, the hazards are multiplied. There is always the possibility that one or more cylinders will leak. The reader will perhaps recall the earlier account describing small explosions from a leaking plug in the bottom of an acetylene cylinder. Acetylene is already highly flammable, and the presence of pure oxygen makes the situation about five times as serious. A noncombustible barrier at least 5 feet high must separate oxygen and acetylene cylinders, or they must be moved apart at least 20 feet.

Torches and Apparatus

Because of their vital role in safety, torches, manifolds, regulators, and related apparatus must be "approved," usually by a recognized testing laboratory, such as Underwriters' or Factory Mutual.

The familiar torch, illustrated in Figure 16.7, is a more sophisticated piece of engineering than most people realize. The torch is often taken to be simply a handy double tube-and-valve assembly for delivering both oxygen and fuel gas to the weld flame, but it is more than that. Note in the figure that the torch has a *mixing chamber*. The torch

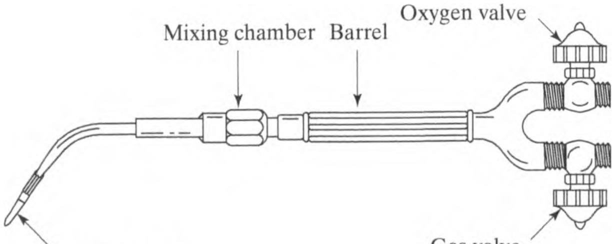


FIGURE 16.7
Oxyacetylene torch.

is designed so that the mixing takes place at the right time and in the correct *total* volume. The welder controls the *proportion* of volumes of the mix by adjusting the torch valves for oxygen or acetylene, an oxidizing flame being oxygen rich and a reducing flame being fuel rich, but the total volume of the mixture is determined by the torch itself. The mixing chamber is mated to the various correct apertures for the approved torch tips, and this also is an important balance. If the balance is disturbed, flow rates may also be disturbed, and the flame may begin to travel back up the mixture stream and begin to burn *inside* the torch! This is really not all that uncommon; all welders know this phenomenon and commonly call it *flashback*. A popping or snapping sound is a warning that flashback is about to occur. Once the flashback begins, a distinctive humming sound can be heard. The heat being generated inside the torch will soon ruin it, and it also presents a safety hazard. The dangerous situation is alleviated by turning off both torch valves quickly.

Even with approved torches and tips, flashback can occur because of the deterioration of the equipment, especially the tips. The tips are close to the heat and naturally become brittle or burned and crack, or pieces may break off. If the tip is not replaced, flashback is likely.

Despite the importance and sophistication of the torch and tip, it is not uncommon to see the torch being used as a hammer or chisel! This temptation arises because of the formation of a slag, a waste product of the flux mentioned earlier. This hard coating of slag generally covers the weld and sticks to it. To finish the job, the welder or helper must chip the brittle slag off the finished weld. The torch and tip are so handy for this purpose (take note of shape in Figure 16.7) that welders will often take the shortcut of using the torch as a chipping tool. This is a good way to ruin an expensive piece of apparatus and at the same time increase the likelihood of flashback due to a damaged torch or tip.

The torch assembly is expensive and may be owned personally by the welder. Even when the company owns the torch, the individual welder to whom it is assigned may rightfully be very possessive because of the importance of care of the apparatus. This can cause another safety problem. Welders may want to keep their torches in their locked toolboxes, but the danger here is that almost all toolboxes contain at least some grease or oil materials. Grease or oil on the torch is dangerous because of the oxygen hazards discussed earlier. Case Study 16.2 illustrates a related hazard, locking welding torches in personal lockers.

CASE STUDY 16.2

WELDING TORCH SAFETY

Welding torches are valuable pieces of equipment, and welders are reluctant to leave them unsecured at the end of a work day. Personal lockers for personal valuables are sometimes designed so that welding torches can be locked inside while the torches remain connected to the hoses that in turn remain connected to the welding fuel and oxygen cylinders used by the welder. In the state of Iowa, a welder once locked his torch inside his personal locker in this way. The welder closed his torch valves before leaving work, but he did not close the cylinder valves on the welding cart. The torch valves leaked a small amount of acetylene gas and oxygen, which overnight built up an explosive mixture in the confined space inside the locker. The next morning the welder opened his locker and was apparently smoking a cigarette at the time. The acetylene–oxygen mixture inside the locker ignited in a powerful explosion that decapitated the welder.

At this point, the reader might like to review the Chapter 3 concept of Swiss cheese theory as a method of accident causation. In Case Study 16.2, if the welding torch valves had not leaked, or if the welder had been trained not to lock his connected torch in the enclosed space of the locker, or if he had turned off the cylinder valves, not just the torch valves, or if he had not been smoking when he opened his locker in the morning, his life might have been spared. Either Swiss cheese theory or fault-tree analysis might have pointed to the possibility of the combination of errors that led to the fatal accident.

After the welding torch, the next most abused piece of welding apparatus is the hose for delivering gas to the torch. To be practical, this hose must be flexible, and it is thus subject to the physical hazards of wear and tear and deterioration to which such materials are generally susceptible. Multiple hoses can easily become entangled, and because of this, welders commonly wrap the acetylene and oxygen hoses together with tape simply to keep them more orderly, but such taping practices may hide defects in the hose. It is a good idea to keep at least 8 of every 12 inches uncovered.

Manifolds are the rigid tubing networks that enable one or more cylinders to supply one or more torches. Manifold setups are sometimes found when a regular production operation requires long-term, regular use of welding gas. The principal purpose of welding manifolds is to increase gas welding volumes, but safety is also usually enhanced by the more permanent arrangement. An example manifold setup was described in Case Study 16.1.

Service Piping

Manifolds, described in the previous section, are not to be confused with *service piping*, an even more permanent arrangement. Some plants use so much welding gas that it becomes practical to pipe the gas to the workstation, which can present some problems. The piping for acetylene must be either steel or wrought iron because copper might react with the acetylene to produce copper acetylide, a dangerous explosive. A danger with oxygen piping is again the possibility of contact with oil or grease. Fittings and pipe must be checked before assembly and thoroughly cleaned if necessary. A solution of hot water and caustic soda or trisodium phosphate is suggested for this purpose. A modern solvent such as chlorothane (1,1,1-trichloroethylene) is recommended by some engineers today. Oxygen piping systems should be purged after assembly by blowing them out with oil-free nitrogen or oil-free carbon dioxide. Chlorothane should be used to be sure that every trace of oil is removed.

Flashback can occur in service pipe systems, too, and flashback protection devices are specified, as are check valves in appropriate positions. One design for flashback protection devices involves a simple water lock. However, if the water freezes, the system will not work, so antifreeze protection is needed.

The things that can go wrong with a service piping system for welding are numerous and sometimes subtle. These problems involve inadequate emergency venting, improper joints, mistakes in installation in tunnels, and other items too numerous to mention here. The purpose of this book is to alert the safety and health manager to the potential problems accompanying these systems so that he or she can be sure that personnel obtain and follow the appropriate standards for installing these systems.

ARC WELDING HAZARDS

Arc welding is a more popular process and is in many ways even more hazardous than is gas welding, even with gas welding's more stormy safety record. This is one of the ironies of the subject. The major hazards of arc welding are health hazards, fires and explosions, eye (radiation) hazards, and confined space hazards, but they also appear to a lesser degree in gas welding and other welding. Therefore, these subjects are addressed in later sections. As was seen with gas welding, an appreciation of the hazards of arc welding requires an understanding of the electric arc welding processes and equipment themselves.

Equipment Design

Industrial arc welding manufacturers do all they can, by means of federal standards, they have helped to write and in other ways, to promote their equipment to the exclusion of lesser and cheaper models that might compete. However, there is a logic to their efforts other than the profit motive. Small and relatively inexpensive models of arc welding machines are available that operate off ordinary household 110-volt current. However, there are physical disadvantages with welding that uses ordinary household current. Welding requires large amounts of electrical power in the form of low-voltage, high-amperage circuits. Since household circuits are rated for amperages insufficient for effective welding, the small household machines make up in voltage what they lack in amperage. The high-voltage hazards of these small welding machines are admittedly difficult to understand because the industrial welding machines are supplied by much higher voltages—typically 240 to 480 volts! The key to this paradox is that the industrial machines step down the high voltage to less than 80 volts while raising the amperage to effective levels. Chapter 17 will return to the subject of voltage and amperage and will perhaps add clarity to the welding machine problem.

Grounding

Even with machines operating at proper voltages, the welder or other personnel can receive an electrical shock from contact with the machine if something goes wrong. The protection for this is to be sure that the frame of the welding machine is properly grounded. Thus, if there is a dangerous short to the frame of the machine, the overcurrent protection mechanism on the circuit will be tripped, protecting personnel. Welding machine grounding needs to be strong, both physically and electrically, to meet the demands of the current that may be applied to it. This is an especially important consideration for portable machines.

Operation

In the case of welding equipment, safety and health training will pay dividends in longer service lives on the equipment, a point sometimes overlooked. Welding cable carries so much electrical current that it can overheat and damage the insulation. Coiling the cable, although convenient, contributes to this hazard. Coiled cable should be spread out before welding. Splices in the cable are not permitted within 10 feet of the electrode holder. The splices themselves must be properly insulated. Some judgment is required to determine when welding cables should be replaced. Certainly, damage to the extent that some conductors have bare spots is cause for replacement.

Care must be taken by the welder to prevent the wrong items from becoming a part of the welding circuit, either during welding or while the electrode holders are not in use. Voltage is not so much the danger as is heat produced by the potentially high amperages. Compressed gas tanks or cylinders must not be part of the electrical circuit, regardless of the flammability of their contents. The heat buildup caused by a high-amperage current through the conducting metal cylinder can cause pressure buildup in the cylinder that can exceed its design limits.

Some types of arc welding are safer than others, and they are gaining in popularity. This is especially true with respect to the hazards of fume generation and radiation, which will be discussed later.

RESISTANCE WELDING HAZARDS

The cleanest, most healthful, and probably safest form of welding is resistance welding. There are still hazards from electrical shock, but more important are the mechanical hazards surrounding the point of operation.

Shock Hazards

As in the spark coil of an automobile, many resistance welding machines build up electrical energy in a bank of capacitors for sudden release when the weld is made. The voltage may reach hundreds or even thousands of volts at peak. These voltages are not the empty variety seen in discharges of static electricity collected by walking on a thick carpet. The voltages may be at the same level, but the welding machine voltages carry with them the capacity to deliver a burning current. The capacitors that store this electrical energy should have interlocked doors and access panels. Not only must the interlock stop the power to the machine, but also short-circuit all capacitors. Without this short-circuiting, the capacitors could deliver a lethal shock even with the power *disconnected*. The short-circuiting of welding machine capacitors when the machine is turned off is an example of the concept of "zero mechanical state," discussed in Chapter 15, and of the general fail-safe principle, discussed in Chapter 3.

Guarding

Spot and seam welding machines apply pressure to the materials when the weld is made. For spot welding machines, this pressure makes the machine analogous to a power press, and the operator can be injured from the mechanical hazards alone. The reader may want to refer back to Figure 16.4 to study the operation of the spot welder.

Seam welding machines are not like power presses, but they, too, have point-of-operation hazards. The nature of the hazard for seam welders is that the opposing rotation of the rollers produces a pair of in-running nip points both above and below the material being welded. The hazards of seam welders do not seem to be as pressing as those of spot welders because seam welding is more often a part of an automatic or mechanized production operation, and thus operator exposure is not as great.

FIRES AND EXPLOSIONS

Welding is one of the principal causes of industrial fires. Perhaps even more than for any other welding hazards, the safety and health manager can have an impact on this particular hazard because preventing welding fires is more of a procedural matter than anything else. This means that training becomes a very important element in the hazard prevention strategy. Fortunately for the safety and health manager, there is a wealth of audiovisual aids, literature materials, and case studies on the subject of welding fires.

To use just one case history as an example, one of the most devastating and tragic industrial accidents in the nation's history occurred in Arkansas in the 1960s. A welder's spark started a fire in a missile silo, and 53 workers trapped inside the silo were killed. This accident dramatically illustrates how welding adds to other hazards, such as confined workspaces, flammable and combustible materials, and lack of ventilation. Welding on old oil drums or pipes that have contained asphalt or other petroleum products has resulted in a large number of explosions and senseless fatalities.

Welding, a dangerous operation, and confined spaces, which are dangerous locations, often appear together. In Chapter 12, we addressed primarily the health hazards of working in confined spaces. When the job to be done in the confined space is welding, both health and safety hazards are compounded. The use of inert gas to protect the weld can cause oxygen deficiency in a confined space. In another scenario, the presence of oxygen and ignition sources from gas welding processes can aggravate the problem of fires and explosions when the welding is in a confined space. Welding is often a repair operation, and unfortunately the location of the necessary repair is in a confined space.

People do not seem to realize the ignition potentials of welding operations. Welding is not safe to watch directly because of the eye hazards, so unfortunately, except for welders themselves or their helpers, few people realize what kind of a fireworks display is really taking place. Some industrial movies are good for illustration of these fireworks. Sparks are flying everywhere—not just the benign variety as seen flying from a typical bench grinder, but visible chunks and spatters of red-hot molten metal that can burn a hole completely through heavy fabric, plastic containers, and cracks in floors. Welders are more likely to know the potential for fires generated by the arcs and sparks generated by the welding process. One would think that the welder would thus hesitate to weld in areas in which the welding sparks could cause fires. The subtlety lies in the fact that welding is often a short repair operation, and the temptation is to take a few chances because of the short duration of the hazard. This temptation often leads to the type of tragedy described in Case Study 16.3.

CASE STUDY 16.3

WELDING IN A CONFINED SPACE

An employee of a trailer service company entered a 8500-gallon cargo tank to weld a leak on the interior wall of the tanker. Despite the presence of strong fumes of lacquer thinner (the material previously carried in the tanker), the welder decided to proceed with the repairs even though the written company safety policy required the use of an explosion meter at that point. When he began welding, an explosion occurred. The employee was removed from the tank and taken to a nearby hospital, where he was declared dead by the attending physician (Preamble to the OSHA Lockout/Tagout Standard, 1989).

Hot Work Permits

A permit system for confined spaces was discussed in Chapter 12. Even before federal standards required permits for entering certain confined spaces, the advantages of a permit system for welding operations were recognized. The previous section established the potential of fires and explosions in the vicinity of welding operations. Although welding is the principal hazardous operation with respect to fires and explosions, other candidates for a permit system should be considered, such as the generation of sparks from metal grinding operations. The significance and general nature of these hazards has led to a system of permits, not just welding permits, but the more generic HOT WORK PERMITS. There is sometimes a tendency to ignore the short-term hazards of welding and hot work repair operations and to proceed to get the job done quickly. The safety and health manager is wise to counter this natural tendency by instituting a system of requiring approval and written permits to do hot work operations, even for quick repairs. There are so many special precautions to take that a signed checklist is a good idea. The responsible party is usually the supervisor of the area in which the hot work is to take place, but in some instances, the operator can make the necessary checks and sign the form. The safety and health manager's responsibility is to set up the permit system and ensure that it is executed properly by actually checking permits occasionally when hot work is seen to be taking place in areas of potential hazard. Any responsible party will give the matter some conscientious attention before signing a hot work permit, especially if personnel have received safety training that exposes them to the devastating hazards of fires such as the welding accident that killed 53 workers in Arkansas. Such training will certainly make the supervisor or welder himself think twice before signing the form.

One thing to consider when requiring a hot work permit is whether a "fire watch" might be needed. A fire watch is an extra person to stand by and observe the operation, possibly holding a fire extinguisher. The fire watch is in a better position than the welder, grinder, or other hot work operator to notice ignition and immediately stop any hot work before a fire gets out of hand. The welder or other hot work operator is usually focused on the work and may be unable to see what else is happening in the neighborhood of the operation. The specified distance away from any welding operation is 35 feet (10.7 m). Whenever appreciable combustible material is within 35 feet of the point of welding operation a fire watch is needed. Special attention must be given to concealed spaces in walls or floors that might contain ignitable material. Sometimes combustible materials on the other side of a wall or partition can be ignited by conduction or radiation from the hot work process, so it may even be necessary to appoint a second fire watch to observe zones outside the immediate area. Another way that welding fires propagate is through holes in the floor or ceiling. The purpose of the permit system is to assure that proper consideration and reason are applied to the potential for fire ignited by the hot work. The hazard potential is not to be taken lightly.

Judgment should be exercised to be sure to set up a permit system that will be considered reasonable by welders and plant personnel alike. The key to this reasonableness will be to set up blanket permits or exemptions from the permit system in those areas of the plant in which fire hazards are minimal. Hot work done in the welder's own welding shop, for instance, should be his or her responsibility, and for the safety and health manager to attempt to impose a hot work permit system in the welding shop would obviously constitute unwise interference. For some plants, the entire plant might be reasonably safe from fires, and no permit system may be needed, except for confined spaces. Hazard identification surveys and advance planning for exactly when and where the permit system is really needed will go a long way toward the establishment of a reasonable system.

EYE PROTECTION

Eye protection comes under the topic of personal protective equipment (Chapter 12), but eye protection for welding operations is so important that this chapter on welding would not be complete without a section on this subject.

Note the careful reference in the preceding paragraph to welding operat*ions*, not welding operat*ors*. The welders themselves need protection, of course, but it is easy to forget about welding helpers and others in the area. Almost every welder has received an eye burn at some time during his or her career and knows to be careful to wear eye

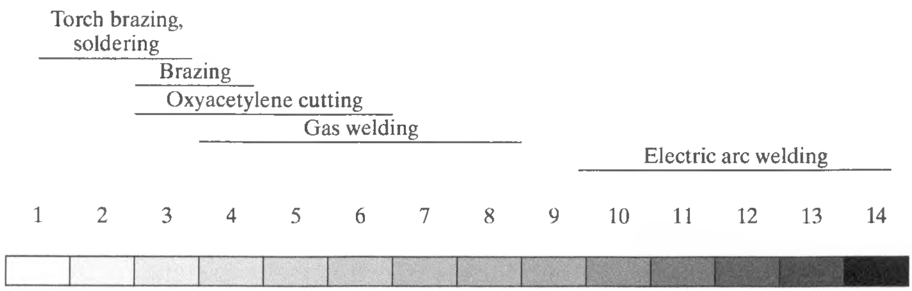


FIGURE 16.8

Summary of recommended shade numbers for various welding, cutting, brazing, and soldering operations (Data from OSHA standard 1910 Subpart I, Appendix B).

protection as much to prevent pain and discomfort as to prevent long-range eye injury. However, less experienced personnel may need more supervision and administrative controls to ensure protection.

A summary of minimum appropriate eye protection shades is shown in Figure 16.8. In selecting eye protection, one should remember that the darker shades (higher shade numbers) provide more protection than do the lighter (lower shade number) shades. The trade-off is visibility. Some shades are so dark that the user can hardly see the workpiece until the arc is turned on. To get the maximum protection, the darkest shade consistent with adequate visibility should be used. The various arc welding methods produce much more intense radiation and thus require higher shade numbers than does gas welding. The radiation from arc welding, except submerged arc methods, is so intense that a helmet is necessary to protect the entire face area from painful burns. Gas welding is typically done while wearing goggles.

PROTECTIVE CLOTHING

Proper clothing is serious business to the professional welder. Virtually every experienced arc welder has, at some time in his or her career, sustained a "sunburn" from the ultraviolet rays produced by the welding arc. Such a welder does not need to be told to use protective clothing to cover all skin areas that would otherwise be exposed to the arc rays. However, ultraviolet burn is only one of several hazards against which protective clothing is intended. Hot, burning sparks or small pieces of molten metal can fall into openings around shoes or between pieces of clothing. Even when the clothing is seamless or when openings are well shielded, a hot piece of molten metal can be trapped in a fold and burn its way through to the welder.

Leather is the traditional favorite material for welding gloves, aprons, and leggings because of its superior thermal protective qualities. Wool is also very durable. However, Nomex and other synthetic materials are also becoming popular for welders' protective clothing. Cotton fabric is attacked by the radiation and soon disintegrates even if it escapes ignition by the sparks.

Hazards to the welder from falling sparks and weld metal are greatly increased when the welding must be done overhead. The welder is virtually taking a shower in welding sparks. All clothing openings must be carefully shielded, and even under the helmet, the welder's head must be protected from such misfortunes as a welding spark in the ear.

GASES AND FUMES

There are two extremes in degree of concern over welder breathing hazards. One extreme, call it position A, is taken generally by welders themselves, who often have no concern at all over chronic exposure to welding "smoke." Some welders even enjoy the smell of welding fumes in the air. The other extreme, position B, is the occasionally overzealous industrial hygienist who can find a hazard somewhere in almost all welding fume situations. Both extremes are only partially correct and can lead to dangerous errors in safety and health strategies.

The principal error in position A is that persons taking this extreme position are usually overlooking the long-term effects of chronic exposure. These persons tend to believe that if the welding smoke does not make them nauseated, dizzy, or give rise to some other acute symptom, the fumes are safe. From the principles covered in Chapters 1 and 9, the chronic exposures can actually be the most dangerous because of their adverse effects on worker health.

Position B exaggerates the effects of tiny exposures to dangerous contaminants. It is terrifying to realize that some welding releases phosgene gas, the same gas that has been used in chemical warfare. However, the exposures are generally very low and can be controlled by appropriate procedures. In the final analysis, no epidemiological studies have shown welding to be an extremely dangerous occupation. From a health standpoint, welders do not have significantly shorter life spans than workers in general. Having considered this perspective, let us categorize the hazards of welding atmospheres and rationally examine what should be done about them.

Contaminant Categories

Figure 16.9 diagrams the major kinds of welding atmosphere contaminants: particulates and gases. The particulates are dust particles or even tinier smoke particles. Metal fumes in the welding atmosphere are tiny particles of metal that have been vaporized by the arc and then resolidified into particles as they cool. The gases may be either already present, as in inert shielding gases, or they may be chemical reaction products of the process.

The term *pneumoconioses* in Figure 16.9 was explained in Chapter 9; it is merely a general term that literally means "reactions to dust in the lungs." Everyone's lungs must deal with dust to some extent, and some welders' pneumoconioses are no more hazardous than would be caused by sweeping the floor. Some welding dusts are more hazardous, however, because they cause *fibrosis*, the building up of useless fibrous tissue in the lungs. The most harmful dusts are those in which the microscopic particles have the shape of fibers instead of more rounded particles. Asbestos and silica are examples of such dusts.

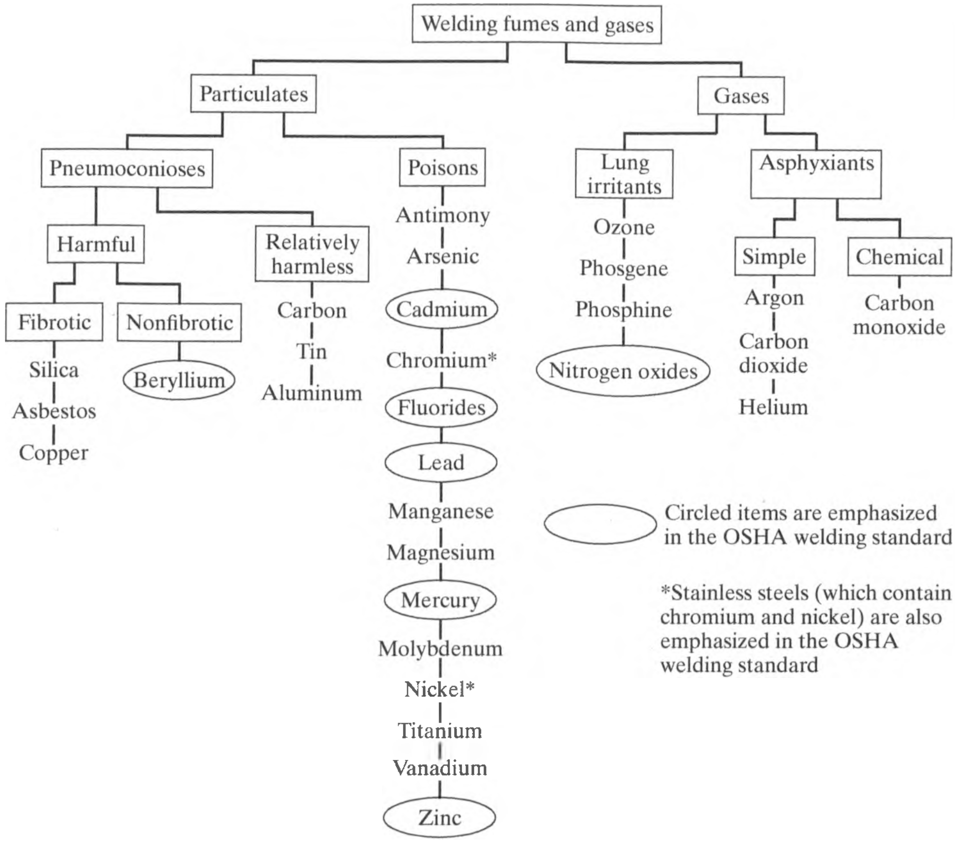


FIGURE 16.9

Classification of welding fumes and gases by hazard.

The "pulmonary irritants" are simpler in that they attack the lungs directly, whether the irritants be particulate or gas. The more insidious hazards, though, are from those particulates or gases that do not irritate the lungs directly, but through the lungs gain access to the rest of the body, where they act as systemic poisons.

It would be nice to have quantified tables of expected contaminant levels for various atmospheric constituents for various types of welding. There have been some experimental attempts at this (Fumes and Gases in the Welding Environment, 1979; The Welding Environment, 1973), but there are so many variables to be controlled that it is almost impossible to obtain reliable predictions of weld fume content. The best strategy is to be aware of potential hazardous contaminants and to know what conditions are most likely to produce these contaminants. Atmospheric sampling can then be used in suspect situations to establish whether contaminant levels are indeed excessive.

Hazard Potentials

The biggest contributor to atmospheric contaminants around welding is the coating or condition of the surfaces to be joined. It is true that welding on clean iron or ordinary construction steel produces fairly large concentrations of iron oxide fume, but fortunately siderosis, the pneumoconiosis resulting from iron oxide, is not really a very dangerous disease when it occurs alone. If the surface of the metal has a coating of material containing asbestos, however, this coating must be removed to prevent asbestos contamination of the air.

Even the act of cleaning the metal surfaces to be welded can result in secondary hazards. If chlorinated hydrocarbons, such as trichloroethylene, are used to clean the metal, these solvents must also be removed thoroughly before the welding takes place. The energy of the welding arc can cause decomposition of the solvent into dangerous phosgene gas.

Galvanized is a term referring to a zinc coating on the metal to prevent rust. Welding on galvanized steel needs extra caution and good ventilation because the welding arc can produce fumes of zinc or zinc oxide. Zinc is not as dangerous as its relative, lead, but it can cause a brief but uncomfortable "metal fume fever." Daily exposure results in a sort of immunity, but this immunity is lost in a few days, even in just a weekend away from exposure. The next Monday morning the nausea and chills are back again, causing this disease to be known as "Monday morning sickness," although admittedly there are other things about Mondays that often make workers "sick."

Plating metals are usually much more dangerous to weld than the iron or steel on which the plating is used. Cadmium is a plating metal for which welding fumes are considered very dangerous. This is one fume that has been known to be fatal in a single acute exposure. Even worse, acute exposures to cadmium usually do not display warning symptoms. Chronic exposures have been associated with emphysema and kidney impairment.

Stainless steel is one of the most dangerous materials to weld because of its high chromium content. Chromium trioxide is formed by the oxidation triggered by the welding heat and reacts with water to produce chromic acid. Ample sources of water can be found on human skin and the mucous membranes, resulting in chromic acid ulceration of these surfaces. Other chromic acid hazards were discussed in Chapter 12, where the phenomenon of chrome holes was discussed.

Welding in confined spaces complicates the atmospheric contamination problem. In confined spaces, the hazards of gases increase dramatically. Nitrogen and argon are inerting agents for the protection of the weld, but they are also simple asphyxiants to the welder. Another simple asphyxiant in welding atmospheres is carbon dioxide. Contrasted with the simple asphyxiants is the chemical asphyxiant carbon monoxide, also present to some extent in welding atmospheres, especially for gas welding.

Nitrogen is not as inert as argon or helium, mentioned earlier as inerting agents, although it is true that nitrogen is a relatively stable element. However, nitrogen can be oxidized, especially in the extremes of welding temperatures, creating oxides that can be harmful. Since there are several oxides of nitrogen and they are somewhat difficult to isolate, industrial hygienists often refer to them as a group, naming them "NO_x." Nitrous oxide, N_2O, sometimes called "laughing gas," was once considered harmless and was even used as a dental anesthetic. Much more harmful are its dangerous cousins, nitric oxide (NO) and especially nitrogen dioxide (NO_2). According to Sax (1975), NO_x in concentrations of 60 to 150 ppm can have a delayed effect after the initial irritation of nose and throat. After breathing fresh air, the irritation goes away and the victim may feel all right. However, some 6 to 24 hours later, the following chain of symptoms can begin: tightness and burning sensation in the chest, shortness of breath, restlessness, air hunger, cyanosis, loss of consciousness, and, finally, death. Welding atmospheres are usually not this concentrated, but it should be noted that 100 ppm is only 0.01%.

Lead and mercury are well-known systemic poisons, and airborne fumes are the prime avenues for entry of these poisons into the body. Most welding does not involve these two metals. Soldering is used widely with lead alloys, but the low temperatures of soldering render the lead fumes relatively harmless.

Beryllium is a very useful alloy metal used in steel, copper, and aluminum. Unfortunately, the presence of the beryllium alloy in the material makes the metal very dangerous to weld. Since beryllium fume (particulate) hazards are both acute and chronic, most welders are wary of beryllium dangers.

Fluorine and fluorine compounds, usually fluorides, enter the welding atmosphere through welding flux or coverings. The popular shielded metal arc welding (SMAW) process is subject to hazards of fluorine compounds. The principal hazard is chronic, not acute, exposure, and long-term exposures cause abnormalities in the victim's bones. Other cleaning compounds and fluxes may also be hazardous, and personnel should check ingredients and heed manufacturer's instructions.

Before leaving the subject of welding gases and fumes, an important point is to be emphasized: None of the toxic materials or hazardous conditions described in this section is so dangerous as to prohibit welding. Welding atmospheres can be made safe by local or general exhaust ventilation or by personal protective equipment. The key is to recognize the potentially hazardous conditions, test atmospheres for excessive contaminant levels, and take corrective action if required.

SUMMARY

Welding represents a microcosm for the study of the entire field of occupational safety and health. It involves mechanical hazards, fire hazards, air-contamination hazards, personal protective equipment considerations, and almost every other subject addressed in this book. Welding processes are many and varied, and most safety and health managers know little about the technical aspects and terminology. A little study of the basics of welding, however, can open up opportunities for revision or substitution of processes that can enhance health and safety and at the same time improve efficiency and cut production costs. No other subject area seems to offer so much opportunity for safety and health managers.

EXERCISES AND STUDY QUESTIONS

16.1 What are the three basic categories of conventional welding? Which of the three is the cleanest and most healthful?
16.2 What distinguishes soldering and brazing from welding?
16.3 What distinguishes soldering from brazing?
16.4 What is the commonly used name for the most popular process of arc welding? What is the official AWS (American Welding Society) designation for this process?
16.5 Identify the following welding processes:

- **(a)** GTAW
- **(b)** GMAW
- **(c)** SAW
- **(d)** RSEW
- **(e)** RSW

16.6 Why should acetylene cylinders be stored valve end up?
16.7 Why are oxygen cylinders charged at so much higher pressures than acetylene cylinders?
16.8 In what ways are greasy gloves of particular hazard to the oxyacetylene welder?
16.9 Describe a way in which gas welding can sometimes be modified to cut production costs and at the same time avoid hazards.
16.10 Why are valve protection caps important to safety? Explain the purpose of the slots in the caps.
16.11 Explain the phenomenon of flashback in welding operations.
16.12 How can taping welding hoses together to keep them orderly result in a hazard?
16.13 Which of the following materials should be avoided in pipes used for delivering acetylene to the work station: steel, wrought iron, or copper? Explain.
16.14 How can small arc welding machines that use ordinary household current be more dangerous than industrial arc welding machines.
16.15 Why should welding cables be uncoiled before using?
16.16 What is the principal hazard of allowing metal tanks to become a part of a welding circuit?
16.17 What arc welding process is gaining popularity because it is more healthful than other arc welding processes? What big disadvantage does it have?
16.18 What is the principal mechanical hazard of spot welders?
16.19 Give at least two reasons why people are psychologically inclined to risk the chance of welding fires.
16.20 Against what principal hazard are welding permits aimed?
16.21 Which of the following welding operations requires the most eye protection: SMAW, SAW, or RSEW? Explain.
16.22 What is the best natural material for welders' protective aprons, gloves, and leggings?
16.23 Name the pneumoconiosis resulting from exposure to iron oxide fume. Is it a severe hazard?
16.24 Why is it difficult to provide accurate tables of welding fume content?
16.25 What distinguishes welding fumes from toxic gases produced by the welding process?
16.26 Describe some workplace material characteristics that, when present, make welding fumes and gases more dangerous to the welder.
16.27 Consider the conditions narrated in Case Study 16.4 (obviously contrived), and describe apparent hazard mechanisms along with potential consequences.

CASE STUDY 16.4

A welder has constructed a manifolding arrangement for an assortment of oxygen and acetylene cylinders stored together lying on the floor. The manifold pressurizes the gaseous acetylene and depressurizes the oxygen to 50 psig for both. The room smells strongly of nail-polish remover. The welder is wearing greasy gloves and is chipping welding slag from the weld using his torch tip. The welding torch is connected to the manifold by two flexible hoses that are carefully wrapped together with duct tape, completely covering the hoses.

16.28 Nitrogen is a gas very widely used in welding operations, except gas welding. Explain.
16.29 In parts per million, calculate the approximate concentration of nitrogen in normal breathing air. How can nitrogen in breathing air be a hazard?
16.30 Acetylene is an unstable gas. Describe steps taken to make it safe to containerize and handle.
16.31 Discuss the principal hazards associated with oxygen cylinders used for welding.
16.32 Name some alternative fuels for acetylene in welding processes. In what way is acetylene superior to these fuels?
16.33 Explain why some people exaggerate the hazards of welding operations. Also explain why some people overly minimize the hazards of welding.
16.34 If items to be welded are cleaned with a solvent before welding, what dangerous gas may be generated if the solvent is not thoroughly removed before welding commences?
16.35 Describe the welders' illness "Monday morning sickness." What causes it?
16.36 Is exposure to welding flux an acute or chronic hazard? What adverse effect does welding flux have on the body?
16.37 For what type of job is laser beam welding particularly suited?
16.38 Identify at least two scenarios that would justify the use of the thermit welding process.
16.39 A welder begins a common welding process by opening an acetylene cylinder valve. However, instead of releasing a small amount of acetylene gas, the welder sees a liquid come out of the valve. What is this liquid? Why is this liquid being released? What is the hazard? How can it be prevented?
16.40 Oxyacetylene welding typically employs two cylinders: one for oxygen and the other for acetylene. Which of these two is under high pressure? What is the hazard of putting the other under high pressure?
16.41 The cap on the top of an oxygen cylinder has two slots on opposite sides of the cap. Why are the slots exactly opposite each other?
16.42 An oxyacetylene welding torch in use suddenly begins to make a popping noise and then begins to make a humming noise. What is happening to this torch? What is the hazard? What must be done immediately when these signs appear? What is the long-range solution to this problem?
16.43 Tell the story of the Iowa welder who locked his torch in his locker at the end of his shift. What happened the next morning? Why? How can the story be used to prevent future accidents? What concepts of hazard avoidance and control discussed in Chapter 3 of this book applies in this case?
16.44 What is "service piping" for welding? How does service piping differ from manifolds or flexible hose for gas welding? Identify some subtle problems associated with the design of service piping systems.
16.45 How can a resistance welding machine be a shock hazard even when it is turned off? What design feature of the machine mitigates this hazard?

16.46 What general machine guarding principles are applicable to spot and seam welders? Which of these two types of welding machines presents the greater exposure problem? Why?
16.47 Describe the circumstances in the welding accident in the 1960s that claimed the lives of 53 workers.
16.48 Why are welding fire ignition hazards worse than they seem?
16.49 In what way should the safety and health manager exercise special care and judgment in setting up the welding permit system? What are the adverse consequences of error in this area?
16.50 Which eye shade number is more protective, Number 8 or Number 12? Why not use the more protective shade number all the time? How many different shade numbers are there? Why are there so many?
16.51 Identify the two principal welding hazards for which special protective clothing, such as gloves, aprons, and leggings, is intended.
16.52 Why is ordinary cotton fabric not very effective as a protective clothing material for welders?
16.53 Explain why welding air contaminants that do NOT irritate the lungs can be more hazardous than those that do.
16.54 Name some metal coatings for iron and steel products that can make these products more dangerous to weld.
16.55 Identify some adverse symptoms of exposure to the oxides of nitrogen. At what fraction of one percent do concentrations of these oxides become dangerous?
16.56 What makes the subject of welding so important to the safety and health manager?
16.57 A popular and useful type of metal is galvanized steel, useful because it prevents rust. Welding galvanized steel introduces a hazard not associated with ordinary steel. What is this extra hazard?
16.58 Rank the hazards of the following three plating metals: lead, zinc, and cadmium.
16.59 Which method of welding uses a chemical reaction to produce the welding heat? Where is it often used?
16.60 Which type of welding uses a concentrated beam of light to produce the welding heat?
16.61 Besides safety and health what added benefit can come from a safety and health manager's study of the basics of welding?
16.62 Delayed symptoms are a problem associated with what type of gas associated with welding?
16.63 What is a "fire watch" and why is it recommended for many welding operations?
16.64 A welding cylinder is stored outside and due to exposure to the weather becomes frozen to the ground. A worker tries to pry cylinder loose by inserting a bar into the vertical slot in the cap. Why is this an unsafe and illegal practice?
16.65 A welder often needs to chip away welding slag produced during the process and is tempted to tap the weld with the torch tip to accomplish this. Why is such practice wrong and what problem can it cause?
16.66 In the event of accidental rupture of the end of the storage cylinder, how might oxygen cylinders possibly be even more dangerous than LPG or other fuel gas cylinders?

RESEARCH EXERCISES

16.67 Research the historic welding accident that occurred in Anderson, IN, in 2012.
16.68 Research the welding accident in Iowa City, IA, in which welding heat-melted cable suspending a worker, and the worker fell to his death.
16.69 Research the welding explosion that killed a worker in Odessa, TX, in 2012.
16.70 Research the 2017 fire to a wooden building in Overland Park, KS that was ignited by a welder's torch.

16.71 Examine the relative dangers of the various oxides of nitrogen, generically labeled NO_x. Which ones have both acute and chronic effects?

16.72 Look up records of industrial disasters involving welding.

16.73 Check the Internet home page for the American Welding Society. What sources of information there are valuable to the safety and health manager?

STANDARDS RESEARCH QUESTIONS

16.74 This chapter made a point about separating oxygen cylinders from acetylene cylinders in storage either by distance or by a noncombustible barrier at least 5 feet high. Search the OSHA standards for a provision dealing with this problem. Check the database on the Companion Website to determine whether this is a frequently cited standard.

16.75 Suppose your company is comparing processes to decide whether to use an arc welding process or a gas welding process. Do some research on the OSHA standards to compare these two types of welding. How do they compare with respect to the generation of OSHA citation activity?

16.76 This chapter states that the hazard from flammable acetylene can become "about five times as serious" in the presence of pure oxygen. Justify this position using principles and knowledge from other chapters in this book.