Metalworking Processes

This chapter describes the various methods used to shape, dimension, and finish metals. These include tool, electrical discharge, and electromechanical machining. The fire and explosion hazards of the various processes, metals, and fluids are indicated and the proper safeguards discussed.

THE METALWORKING PROCESS

The metalworking process includes shaping, dimensioning, or surface finishing of a wide variety of metals. The operations include turning, planing, shaping, slotting, milling, sawing, boring, drilling, grinding, abrasive cutting, filing, -threading, reaming, broaching, deburring, lapping, chamfering, spinning, and so on. Some at these same operations and equipment are also used to work on other-than-metal materials, such as plastics or wood.

On cursory observation of a machining operation, it would appear there are few, if any, fire hazards about which to be concerned. This is deceptive, for there are aspects of machining that require careful and constant attention. *The principal hazards involve the coolants/lubricants used for the lubrication of the cutting tools and the possible combustion of the cuttings (chips) and fine particles (fines) that are produced as the work piece is shaped and cut.* The three principal sources of ignition directly associated with the operation are (1) the heat generated by the work being done, (2) the friction created by the cutting tool, and (3) the spontaneous oxidation of materials used.
Other possible sources of ignition include smoking materials; hot surfaces such as furnaces and torches; electric sparks or arcing; and impact ignition of certain pyrophoric surface compounds, which sometimes form during the earlier stages of fabrication. It is important to remember that nearly all metals will burn in air under certain conditions, depending on size, shape, and quantity.

The machining operation can be broken down into five components for the purpose of analyzing the hazards present:
(1) machine tool; (2) cutting tool; (3) raw materials; (4) oils, including cutting oils, lubricating oils, and hydraulic oils; and (5) machine cuttings and their collection systems.

The Machine Tool

The modern industrial machine tool can be a single-motor machine, such as a drill press, or it can be a very large multi-motored automatic machine with a highly complex electronics control system. Stock can be brought as needed to an individual machine where a worker then mounts it to the machine and initiates the operation manually. More likely there is some degree of automation in these operations, and, in many cases, several machines can be located in close proximity to facilitate the easy movement of stock from one machining operation to the next.

Almost all machines **are electric-motor** operated and likely contain some **lubricating oils and grease.** Electrical supply to this equipment is generally **480 V** or less; however, some larger equipment will **operate at higher voltages.**

In almost all cases, the lubricating oil for the machine is self-contained (i.e., in the unit). Although the amount might be significant [50 to 100 gal (189 to 378 L)], it is generally not a significant hazard. The containment structures for these oils are usually substantial, and leaks are rare.

The electric motors and the lubricating oils systems on the machines usually do not alone constitute a hazard sufficient to warrant any automatic protection. However, portable extinguishers should be available in the area.

Traditionally, the machine tool is a stand-alone piece of equipment, usually operated manually by a trained operator, who sets up the stock, then controls the cutting operation. In the modern industrial setting, this arrangement has gradually given way to numerically and digitally controlled equipment, leading to more sophisticated electronic equipment in the vicinity of these operations. Usually, this equipment does not itself present a significant fire hazard, but it does present an additional loss potential from fire exposure. Malfunction or failure of the automatic control equipment can also create hazardous situations in the operation of the machine tool, leading to fires. A significant number of fires in these occupancies have "automatic failure" cited as their cause, so reliability of this control equipment is also important. In addition, modern electronic equipment due to its value and fragile construction is more susceptible to damage from exposure fires. This potential for increased loss due to exposure fires should be included in the evaluation of automatic protection in occupancies that include such equipment.

Cutting Tool

The cutting tool can be either fixed in place while the stock is moved past it, such as on a lathe, or the tool itself can be moving, such as in a mill, surface grinder, or boring machine. The tools can be pointed or bladed and can be of hardened high-carbon steel, high-speed steel, hard ceramics, or steel tipped with hard metal carbides of tungsten, cobalt, tantalum, or other hard metallic elements. Grinding abrasives are usually silicon carbide grains bonded with resin or ceramics and pressed into the shape of wheels. These cutting tools shape the raw materials into the finished part. They can also represent a point of ignition, as they can develop significant heat from the friction of the work they are performing.

Dull tools not only increase the requirement for power and influence the quality and tolerance of the work being done, but also can be the ignition source of fires in machines. Dull tools tend to produce finer particles that are more readily combustible or explosive than the larger chips, which are generally produced by sharp tools. Cutting tools normally do not require any special protection. Of course, if they are transported on wood pallets or in cardboard cartons or other combustible containers, those materials might necessitate the provision of sprinkler protection where they are being stored.

Raw Materials

The raw materials arriving at a machining plant can be in the form of clean castings, forgings, rough-cut plate, rolled or drawn bar or merchant mill stock, fabrications, tubes, or rolled or extruded shapes. In general, these raw materials have significant mass and so can be considered as noncombustible unless exposed to massive fire. This applies even to the light metals that are known to be mere readily combustible when they have a large surface-to-mass ratio. In most cases, though, the raw materials do not present any significant combustible loading. However, the packaging materials used in the transport of these materials must be considered, and, if sufficient combustibles are present, automatic sprinkler protection should be provided as necessary.

Other raw materials include cutting, lubricating, and hydraulic oils; cutting tools; and so on. Bulk shipments and storage of combustible oils should be handled in accordance with accepted standards.

Hazard potentials can change significantly once the raw materials are subjected to the metal working processes. Chips and fines significantly increase the surface-to-mass ratio of the material, and, in some cases, they can become subject to spontaneous ignition or to ignition from outside sources. Table 6.11.1 shows the combustibility of fine powders of various metals and the amount of energy needed to initiate combustion. Almost all metals have some degree of combustibility, and, in the case of such materials as aluminum, magnesium, and titanium, they can represent a very significant hazard. As mentioned, some chips in cuttings are subject to spontaneous ignition. Zirconium and uranium powders can ignite spontaneously. Spontaneous ignition in such noncombustible materials as iron and steel bearings and turnings has been recorded in scrapyards and in the holds of ships carrying scrap. In these cases, fires have occurred where the heat of oxidation cannot be dissipated sufficiently to the surrounding atmosphere to prevent the development

Oils

Oil is used during many metalworking operations. On the machines, lubricating oils and/or greases are often used to facilitate the operation of the equipment. Coolant/lubricants are often used to cool and lubricate the tool and stock at the point of operation, facilitating smoothness of the cut, life of the tool, and removal of chips and cutting fines.

Essentially all of the oil-based and compounded cutting fluids are combustible to some degree. Of course, as with other combustible liquids, these oils must be heated above their flashpoint to be ignited.

Water-oil emulsions are also used as cutting fluids, especially where only light machining operations are taking place. In the emulsion state these oils are nearly noncombustible.

In some cases where additional cooling is required, mineral oil, kerosene, or other materials having lower flash points are sometimes used. If these fluids are utilized within close proximity of their flash point {50°F (10°C)}, special extinguishing systems, such as local applications of CO_2 or other gaseous extinguishents or dry chemical systems, should be considered.

Cutting oils can **form fine mists around the cutting operations** that can drift from the equipment and condense on other machines, floors, and building structural members. Housekeeping in the surrounding areas is important in these instances, as severe fires can develop and spread over wide areas utilizing these oils. This is most significant where oil deposits have accumulated on vertical surfaces, such as the

sides of equipment and building columns. Where such accumulations occur, periodic cleaning of these areas is important.

Where central oil collection and cleaning systems are provided, the dirty oil is often collected in floor trenches that can interconnect numerous machines. If these systems are used, they should be tightly covered, or, preferably, fixed piping systems should be utilized. Where floor trenches are utilized, they create an avenue for spreading fire from one piece of equipment to the next; therefore, some form of automatic protection, such as sprinklers or carbon dioxide systems, should be considered.

Automatic ceiling sprinkler protection should be provided where combustible cutting oils are used on a general basis. This protection should be installed on an ordinary-hazard basis, with adequate water supplies provided.

Many machine tools employ hydraulic devices for various control actuators. Oil pressures used can vary from 400 to several thousand psi (400 psi equals approximately 42 kPa). The reservoirs and pumps for the hydraulic oil can be either self-contained, that is, contained within the machine itself, or part of a larger central system.

The fire resulting from a high-pressure hydraulic oil leak is usually a very intense torch-like flame that characteristically has a very high rate of heat release. Causes of hydraulic oil release can be deteriorated flexible hoses; failure of pipe joints, especially if threaded connections are utilized; or failure of valve packing or gaskets. **One of the easiest ways to dramatically reduce the intensity of a hydraulic oil leak fire is simply to shut off the oil supply.**

However, experience has shown that if there is a failure in a pressurized oil system, especially one that results in an intense fire, personnel in the area are likely to run for safety without shutting down the pump. For this reason, remotely located emergency shutoff switches should be provided, or, as a more positive step, *automatic shutoff should be provided*.

Automatic shutdown can be provided by low-level switches in the main oil reservoir; an excess flow switch; a flame-actuated detector; a fixed-temperature release, such as a fusible link or thermostat provided in the vicinity of the equipment; or through interconnection to a sprinkler water flow switch. In most cases where significant hydraulic oil systems are utilized, automatic sprinkler protection should be provided. If the building is not sprinklered completely, the system should extend for at least 20 ft (6 m) beyond all areas of hydraulic usage. Suitable Class BC portable extinguishers are also necessary throughout these areas.

Welded connections should be used wherever possible to eliminate the possibility of leaks from threaded joints. Tubing should be used in preference to pipe. Piping or tubing should be securely fastened in place, and flexible hoses should be kept clear of all objects and not allowed to bend in excessively tight turns. Routine maintenance checks of all hydraulic system components should be made and necessary repairs or corrective action taken on a timely basis. Leaks should not be allowed to continue, and good housekeeping should be maintained around all equipment.

Machine-Cuttings

All machining operations result in the creation of chips, which will vary widely in character, size, and configuration, depending on the operation being performed, the feed and speed of cutting, and the intrinsic characteristics of the metal being cut. Frequently, cuttings and chips appear to be quite large and heavy, and, for this reason, it is often an erroneous assumption that they do not constitute a fire hazard or an explosion hazard.

Combustibility depends on the combustible character of the metal and on the ratio of the exposed surface of the cutting or chip to its mass. The thinner the cutting and the smaller the particles, the greater the likelihood of fire. Table 6.11.1 indicates that relatively small amounts of energy are needed to initiate combustion in some fine metal powders.

TABLE 6.11.1 *Ignition and Explosibility of Metal Powders*[1]

	Ignition Temperature Cloud Layer		Minimum Explosive Concentration		Minimum Ignition Energy Dust Cloud	Maximum Pressure		Maximum Rate of Pressure Rise		Explosibility[a] Index
Metal	°F	°C	oz/ft³	g/m³	(mJ)	psig	kPa	psi/sec	Pa/s	
Aluminum	650	343	0.045	45	50	73	503	20000	508	>10.0
Magnesium	620	327	0.040	40	40	90	620	9000	228	>10.0
Zirconium	20	−7	0.045	45	15[b]	55	379	6500	146	>10.0
Titanium	330	165	0.045	45	25	70	462	5500	140	>10.0
Uranium	20	−7	0.060	60	45[b]	53	365	3400	86	>10.0
Iron	440	227	0.200	200	72,305	45	310	600	15	0.1
Zinc	680	360	0.500	500	960	48	331	1800	45	<0.1
Bronze	370	188	1.000	1,000	—	44	303	1300	33	—
Copper	700	371	—	—	—	—	—	—	—	<0.1

[a]Index of Explosibility: none: 0; weak: 0.1; moderate: 0.1 to 1.0; strong: 1.010; severe: 10.
[b]In this test, 1 g of powder was used. Larger quantities ignited spontaneously.

Table 6.11.1

The accumulation of chips, cuttings, or fine particles should never be permitted at the machine. They should be removed and placed in a noncombustible container and suitably stored. In small, single-machine operations, the removal of chips is often done manually. In the larger integrated and automated operations, central collection systems are often used.

Where heavy chips and cuttings are generated, they are often mechanically separated from the cutting fluids and stored in some suitable container until disposed. Heavy chips represent the hazard attributable to the particular metal involved.

FIRE HAZARDS

The principal hazards encountered in a machining operation are

- Chip fires at the machine, where ignition is caused by the heat of metalworking, friction of the chip against the tool, or both.
- Spontaneous combustion of cuttings.
- Combustion of coolant/lubricants.
- Fine particles that are either combustible or explosible.
- Reaction of certain metals with water or other agents.
- Combustion of pressurized hydraulic fluids used for the actuation of machine tools and/or their accessories.
- Combustion of oil vapors deposited on building structures.
- Combustion of oil-saturated floors.

The principal sources of ignition are

- Smoking materials.
- Heat of cutting.
- Spontaneous oxidation.
- Hot particles from grinding, dressing of grinding wheels, and welding and cutting.
- Hot surfaces, such as furnaces and torches.
- Electrical sparking or arcing.
- Impact ignition of certain pyrophoric surface compounds, which sometimes form during the earlier stages of fabrication (e.g., magnesium nitride, which sometimes appears on the surface of castings and can explode under the impulse of a very minor impact)

SAFEGUARDS

Building Construction

Buildings that house metalworking processes should be of fire resistive or noncombustible construction with a noncombustible roof deck. If the building is large, it should be subdivided by fire walls to limit the spread of fire. Buildings in which machining operations are performed should be regularly inspected for the accumulation of oily deposits and/or fine combustible metal particles.

Fire Protection

The need for sprinkler protection should be carefully considered. It will depend largely on the combustible characteristics of the building structure, especially the floors and roof deck, and the extent of the hazard posed by the metalworking machine or raw material as previously discussed. Small fires at machines can be best controlled with portable extinguishers of the correct classification. If proper housekeeping is practiced, the fire hazard from cuttings and turnings can be minimized.

Welding, Cutting and other Hot Work

In its largest sense, hot work includes most materials fabrication processes. As used in this chapter, welding means only fusion welding, that is, melting together. Similarly, melting is the significant feature in reference to thermal cutting. Both welding and thermal cutting require high-intensity energy sources-usually an electric arc or the heat of combustion of a fuel gas.

Torch fires accounted for **2.2** % of reported 1994-1998 **structure fires** in the United States, including **1.3** % of residential structure fires and 4.8 % of nonresidential structure fires. For industrial and manufacturing properties, the torch share of 1994-1998 reported structure fires was more than 8 percent. Of the torch fires coded by type of torch from 1994 to 1998, 0.75 of the nonresidential structure fires but only 0.4 of the residential structure fires were due to cutting or welding torches. An average of 12,600 reported structure fires per year were attributed to torches from 1994 to 1998. However, education, training, and on-the-job practice can significantly reduce the potential for welding, cutting and other hot work fires.

Four factors must be kept in mind:

1. Two sides of the fire triangle are always present, that is, a source(s) of ignition and air to support combustion. The other controllable element is the combustible material.
2. Familiarity with hot work as an activity. A shop that performs welding or cutting operations on a routine basis in a fixed location can develop confidence and reinforce safe habits more than a shop that performs welding or cutting only occasionally and in a variety of different temporary locations.

3. The kind of process and equipment used and their potential fire effect. Cutting, as well as certain arc welding operations, produces literally thousands of ignition sources in the form of sparks and hot slag. Other types of hot work torches, such as arcs and oxy-fuel gas flames, have only themselves as ignition sources.
4. The supervision and training of the operator. Is the operator trained in the proper use of the equipment and mindful of the exposure? Who has knowledge of and has assessed the risks involved in bringing a torch into the work area and has authorized its use there?

PROCESSES USING ELECTRICITY

Arc Welding (AW)

Arc welding (AW) applies to a number of processes that use an *electric arc as the heat source* for melting and joining metals. The arc is a useful tool because its heat can be concentrated and controlled quite effectively. Frequently, but not always, a *filler metal* must be used to obtain a good joint. The *arc is struck between the metals to be welded and an electrode*, which is maneuvered along the joint or remains stationary while the work is moved beneath it. The electrode may be *consumable or non-consumable.* If the latter, a separate rod or wire may be used as the filler metal. Consumable electrodes supply their own filler metal by melting. The molten metal and weld zone can be protected from atmospheric contamination by use of a supplementary shielding gas or a shielding atmosphere produced by decomposition of a flux, which is used with certain types of electrodes and wires.

Shielded Metal Arc Welding (SMAW). This simple well known process is widely used with ferrous-based metals (Figure 6.14.1).

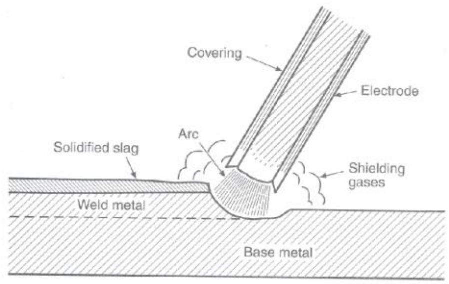

FIGURE 6.14.1 Typical Shielded Metal Arc Welding Operation

It produces coalescence of metals by heating them with an arc between a covered metal electrode and the weld pool. The process is used with shielding gases from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode. The process requires an alternating or direct current power supply, power cables, and an electrode holder. Shielded metal arc welding can be performed readily in remote, unusual, or confined locations. Consequently, this process is widely used in such industrial applications as construction, shipbuilding, and pipeline erection. Fairly simple, portable units are frequently used in maintenance and field construction work. It is also commonly known as "stick welding," "covered electrode welding," and sometimes simply as "arc welding."

Gas Metal Arc Welding (GMAW). This process uses a continuous filler metal electrode, which functions as one terminal of the arc, and a gas to shield the arc and the weld metal. The shielding gas depends on the base metal and process variations. It can be an inert gas, such as argon or helium; an active gas, such as carbon dioxide; or mixtures involving these gases with additions of hydrogen, nitrogen, or oxygen. Over all, this process can be used to join just about any metal in any configuration of joint. Gas metal arc welding is commonly referred to as MIG welding, an acronym for metal inert gas welding, even though active gases are also employed.

OXYFUEL GAS PROCESSES

Oxyfuel gas welding (OFW) uses the heat of combustion of a fuel gas and oxygen flame at high temperatures to melt the work piece base metal and filler metal, if these are used.

Acetylene remains the preeminent welding fuel because it has the highest flame temperature of all the fuel gases. Other fuel gases or mixtures, such as methyl acetylene-propadiene (stabilized), have found acceptance. Other hydrocarbons (propane, propylene, butane, natural gas-methane) are not suitable for

welding ferrous metals. Hydrogen has a low flame temperature and heat content, and its flame, which is colorless, is difficult to adjust for oxygen-fuel gas ratio.

Table 6.14.1 shows neutral flame temperatures of some fuel gases. With the exception of acetylene, neutral flame temperatures are significantly lower than the maximums, so it is not possible to melt and control the weld, except perhaps for thin sheet metal.

At maximum temperatures, the flames are strongly oxidizing and not usable because of deleterious metal oxide formation in the weld metal. Use of methyl acetylene-propadiene (stabilized) requires special procedures.

TABLE 6.14.1 *Flame Temperatures of Fuel Gases with Oxygen*

Gas	Neutral Flame Temperature	
	°F	°C
Acetylene	5589	3087
Methyl acetylene-propadiene (stabilized)	5301	2927
Propylene	5250	2900
Hydrogen	4820	2660
Natural gas-methane	4600	2538
Propane	4579	2526

TABLE 6.14.1 Flame Temperatures of Fuel Gases with Oxygen

Oxyfuel Gas Cutting (OFC)

The term oxyfuel gas cutting (OFC) describes a group of oxygen cutting processes named by the specific fuel gas used [e.g., oxyacetylene cutting (OFC-A), oxy-natural gas cutting (OFC-N)] for severing metals by the reaction of high-purity oxygen with the metal at elevated temperatures. Burning iron in oxygen produces iron oxide, normally a solid, but the oxide melts at a temperature below the melting point of iron or steel and runs off as slag. A variation in the process is oxyfuel gas gouging, wherein a relatively low-velocity oxygen jet permits gouging or grooving of a metal surface in a reasonably smooth, well-defined manner.

Oxyfuel Gas Welding and Cutting Equipment

Basic elements are fuel gas and oxygen supplies, pressure regulators, conduits (hoses or piping) to convey the gases, and a torch to mix and burn the gases in controlled fashion and provide the oxygen jet used in cutting operations.

In its simplest form, the equipment comprises a cylinder each of fuel gas and oxygen, a pressure regulator on each cylinder, hoses, and a torch (Figure 6.14.2).

FIGURE 6.14.2 *Portable Welding Outfit with Oxygen and Acetylene Outfits Chained to an Easy-Rolling Cylinder Truck (cutting attachments not shown) (Source: ESAB Welding and Cutting)*

FIGURE 6.14.2 Portable Welding Outfit with Oxygen and Acetylene Outfits Chained to an Easy-Rolling Cylinder Truck (cutting attachments not shown) (Source: ESAB Welding and Cutting)

A steel mill, however, might have a major installation for cutting and welding operations (Figure 6.14.3). Fuel gas might be supplied from large multi-cylinder manifolds (possibly truck mounted and replaceable), from storage tanks for liquefied fuel, or from a public utility natural gas main. Oxygen might be supplied from the mill's own on-site oxygen-generating plant, from storage tanks for liquid oxygen or high-pressure gas or both, or from multi-cylinder manifolds. A major installation might also have an extensive fixed-piping distribution network and consuming devices running the gamut from simple hand torches to sophisticated steel conditioning machines.

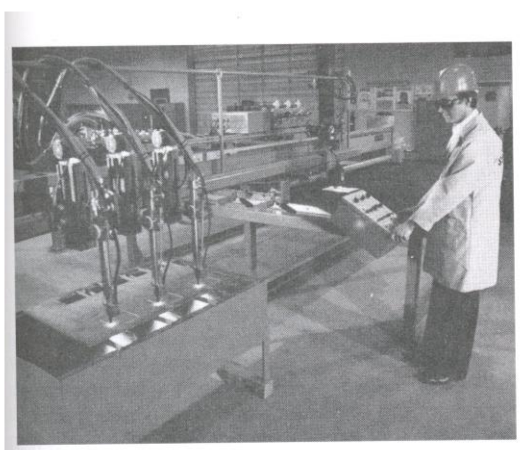

FIGURE 6.14.3 Large Stationary Oxyfuel Gas Cutting Machine in Operation (Source: ESAB Welding and Cutting)

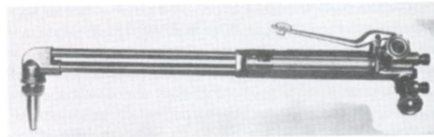

FIGURE 6.14.4 *Typical Cutting Torch. All control valves are located at the rear of the body. (Source: ESAB Welding and Cutting)*

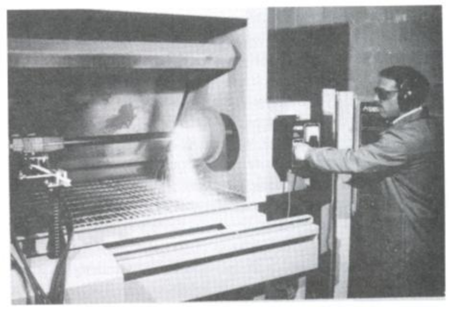

FIGURE 6.14.5 Thermal Spray Gun (Source: American Welding Society)

Welding torches have inlet connections and valves for each gas at the rear of the handle (Figure 6.14.4). The gases are controlled by inlet valves and thoroughly mixed before issuing from the torch tip. Cutting torches are similar but provide passageways and separate valving for supplying and controlling the cutting oxygen jet at the center of the tip.

Mechanized cutting is common. Equipment varies from relatively simple, portable machines, used for straight line work and perhaps circles and some irregular shapes, to highly sophisticated multi-torch machines that can trace (by photocell, laser beams, or other electronic means) intricate shapes and accurately and simultaneously produce a number of parts of the same shape.

SAFEGUARDS

Equipment Preparation and Condition

Although it is beyond the scope of this chapter to describe all the fire prevention considerations that are tied into proper equipment design, installation, and maintenance, some significant items have been selected for specific attention.

Oxyfuel Gas Equipment

Equipment meeting recognized standards (e.g., torches, cylinder manifolds, pressure regulators, pipeline protective devices, etc.) should be used.

Since oxygen is a far more powerful oxidizer than air, oxygen equipment must be kept clean (i.e., free of oil, grease, and other combustible contaminants). Materials that burn in air will burn violently in pure oxygen at normal pressure and explosively in pressurized oxygen. Also, many materials that do not burn in air will do so in pure oxygen, particularly under pressure.

Consequently, it is widely recognized good practice to reserve equipment for oxygen service only.

Proper storage of gas cylinders is important. Cylinders should be moved and handled in accordance with recognized practices, for example, those of the American National Standards Institute (ANSI) and the Compressed Gas Association (CGA). Cylinders should always be supported or located in such a way that they cannot be knocked over. Ruptured cylinders can explode.

Oxyfuel gas cutting and welding equipment should be tested periodically for leaks (Figure 6.14.6). Testing frequency depends on the specific kind of equipment involved and how often it is used. Hose connections are known possible trouble spots. Also, experience has shown that fires can occur at fuel gas cylinder-to-regulator connections simply because someone failed to tighten the joint properly. The ignition of leaking gas at this point can in turn cause the release of cylinder safety devices, especially-with acetylene cylinders fitted with fusible plugs, thereby releasing more gas and increasing the size of the fire.

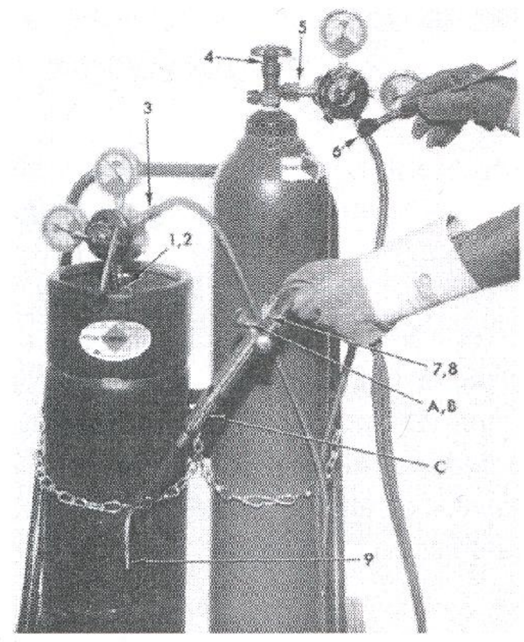

FIGURE 6.14.6 Checking Equipment for Leaks before Operating an Oxyfuel Gas Outfit. After pressurizing both hose lines (with torch valves tightly closed), test for leakage at the following points, using an approved leak-test solution: (1,2) **acetylene cylinder connection** and **acetylene cylinder valve spindle**, (3) **acetylene regulator-to-hose connection**, (4) **oxygen valve spindle**, (5) **oxygen cylinder connection**, (6) **oxygen regulator-to-hose connection**, (7,8) **hose connections at the torch**, and (9) **torch tip** (for leakage past the torch valves). Later, after lighting the torch, check for leakage at the throttle valve stems (A,B) and at the welding head-to-torch handle connection (G). (Source: ESAB Welding and Gutting)

Only standard welding hose should be used. It should be frequently inspected for burns, cuts, **worn places**; **abrasions**, and similar defects. Taped repairs are unacceptable. Replace the damaged hose, or, if feasible, cut out the affected area and insert a proper splice. When repairs to equipment, such as torches and regulators, are required, they should be carried out by trained, skilled mechanics.

Arc Welding Equipment

When using arc welding equipment, the following should be addressed to avoid accidents, electric shock, or equipment damage:

1. Use equipment meeting recognized criteria, such as that provided by the American National Standards Institute, National Electrical Manufacturers Association (NEMA), and Underwriters Laboratories Inc. (UL). Installation, including incoming power lines and grounding of the machine

frame or case, should comply with NFPA 70, National Electrical Code, with particular attention to Article 630, "Electric Welders"; and with ANSI/AWS Z49.1, Standard for Safety in Welding, Cutting, and Allied Processes.

2. Proper storage and handling procedures for cylinders of shielding gases should be observed.

3. At each work location, cylinders should be supported or located in such a way that they cannot be knocked over accidentally. Precautions must be taken that the cylinders are not grounded.

4. Cable sizes should be adequate for current and anticipated duty cycles. Sustained overloading of inadequate cables can burn away insulation. Cables should be inspected frequently for wear and damage and properly repaired or replaced when necessary.

Precautions for the Work Area

Hazardous sparks, such as globules of molten, burning metal or hot slag, are produced by welding, cutting, and other hot work operations. Sparks from cutting, particularly oxyfuel gas cutting, are generally more hazardous than those from welding, because the sparks are more numerous and travel greater distances. In a sense, they are jet propelled by the oxygen or airstreams used in cutting processes. Oxyfuel gas flames and electric arcs are inherent and obvious ignition sources, as are hot workpieces or sections cut from the base workpiece.

Either isolation or protection of combustibles is essential, for they may be exposed to sparks that fall through cracks or other openings in floors and partitions. If those sparks are of sufficient mass to retain heat for a time, they may ignite combustibles. The recommended requirements for combustible control in the cutting or welding work area are:

1. *Move all combustibles a safe distance* away at least 10 m- and be sure that there are no openings in walls or floors within 35 ft (10 m) radius.

2. *Be alert for cutting conditions that could propel sparks overhead or downward,* where combustibles are within a l0 m sphere of the point of operation.

3. *Move the work to a safe location*.

4. If none of the foregoing steps is possible, *protect the exposed combustibles with suitable fire-resistant guards* and provide a trained fire watcher with extinguishing equipment readily available.

These steps are only a partial solution to the problem of preventing cutting, welding, and other hot work fires. **There are other important factors to consider.**

- Are there any combustibles in an area proposed for cutting and welding operations?
- What conditions must be met before cutting and welding operations can take place?
- Who has the responsibility for authorizing the work to proceed?
- Are cutters, welders, and their supervisors properly trained in the use of their equipment and in emergency procedures should a fire occur?
- If an outside firm is engaged to do de cutting and welding work, chances are that its employees will be of unfamiliar with the premises and its contents.
- Have they been briefed on the conditions in the areas where they will work?

Based on the fundamental but necessary understanding that workers, their supervisors or permit-authorizing individuals, and facility management share the responsibility for fire safety, the following paraphrased version of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work* should be helpful. It is adapted here for convenience, and should not be used in place of NFPA 5IB.

1. Management must establish areas designed and authorized for hot work and/or designate a permit-authorizing individual (PAl) to authorize hot work in areas not specifically designed for such processes. This management designee must require trained fire-watchers where the potential exists for a significant fire to develop. Fire watchers must also be required where appreciable quantities of shielded combustibles are less than 11 m away; where wall or floor openings within 11 m expose combustibles in adjacent areas.

2. The PAl of hot work (e.g., the plant manager, plant maintenance foreman, contractor, or contractor's foreman) in areas at the not designed for such processes **must be assigned the following responsibilities:**

(a) Determine what combustible materials are present at the work site.

(b) If necessary, have the work or the combustibles moved, or have the combustibles shielded.

(c) Issue authorization in the form of a written hot work permit.

(d) See that the worker is aware of the authorization and conditions.

(e) See that fire watchers are available when required.

(f) Make a final check for fires one-half hour after completion of welding or cutting operations in cases where a fire watcher was not required.

3. Workers must have the PAl's approval before starting hot work, must handle their equipment safely, and must continue to work only so long as approval conditions do not change.

4. There are a number of precautions to be observed during hot work:

(a) Hot work must not be permitted in flammable (explosive) atmospheres; near large quantities of exposed, readily ignitable materials; in areas not authorized by management; or on metal partitions, walls, or roofs with combustible covering.

(b) Floors must be free of combustibles, such as wood shavings. If the floor is of combustible material, it must be kept wet or otherwise protected.

(c) If combustibles are closer than 11 m to the welding or cutting process and the work cannot be moved or the combustibles relocated at least 11 m away, they must be protected with flame resistant covers or metal guards or curtains. This also applies to walls, partitions, ceilings, or roofs of combustible construction (Figure 6.14.7).

FIGURE 6.14.7 Safe Work Procedures

(d) Openings in walls, floors, or ducts must be covered if within 11 m of the work.

(e) Cutting or welding on pipes or other metal in contact with combustible walls, partitions, ceilings, or roofs must not be performed if close enough to cause ignition by heat conduction.

(f) Charged and operable fire extinguishers must be readily available. Trained fire watchers must be posted. In the absence of fire watchers, an important minimum step is to check the work area and adjacent areas carefully for at least one-half hour after completion of welding or cutting to detect possible smoldering fires.

SPECIAL SITUATIONS AND ADDITIONAL PRECAUTIONS

Containers

Welding or cutting on containers can cause-and has caused explosions or fires with potential for deaths or serious injuries.

Any container can contain or might have contained a combustible. Therefore, all containers must be considered hazardous unless they have been tested and found safe, cleaned, or rendered inert. Therefore, it is essential that flammable liquids, solids, or vapors be removed from containers by some type of adequate cleaning procedure before welding or cutting.

Depending on the application, it might be necessary or desirable to supplement the cleaning with inerting, water flooding, or periodic testing (for flammables) of the atmosphere within the container. For details concerning these hazards, see AWS F4.1, “Recommended Safe practices for the Preparation for Welding and Cutting of Containers and Piping."

Hot Tapping

Occasionally, there are situations in which emergency repair or the complete impracticality of emptying and cleaning demands welding or cutting on a container while it holds flammable gas or liquid (e.g., a natural gas transmission pipeline or utility distribution system). Schemes to accomplish such hot tapping with relative safety have been developed. (See ANSI B31.8, *Gas Transmission and Distribution Piping Systems;* and API Publ. 2201, "Procedures for Welding or Hot Tapping on Equipment Containing Flammables.") Needless to say, any such work must be performed only by specially trained and qualified staff, using recognized and authorized methods.

Personnel Protection and Ventilation

One aspect of welding and cutting fire protection that is sometimes overlooked or inadequately considered is the safety of the operator, helpers, or nearby workers. Flame-resistant gloves, wool clothing, aprons of leather or other durable flame-resistant material, cape sleeves or shoulder covers with skull caps under helmets or with goggles for overhead work, leggings for heavy work, and high-top safety shoes are generally recommended.

Trousers should not be turned up or cuffed on the outside, front pockets on clothing should be eliminated, and sleeves and collars kept buttoned to prevent sparks from entering and lodging in such places. Outer clothing should be free of oil and grease.

Cotton instead of wool clothing may be worn if the cotton is chemically treated to reduce its combustibility (Figure 6.14.9).

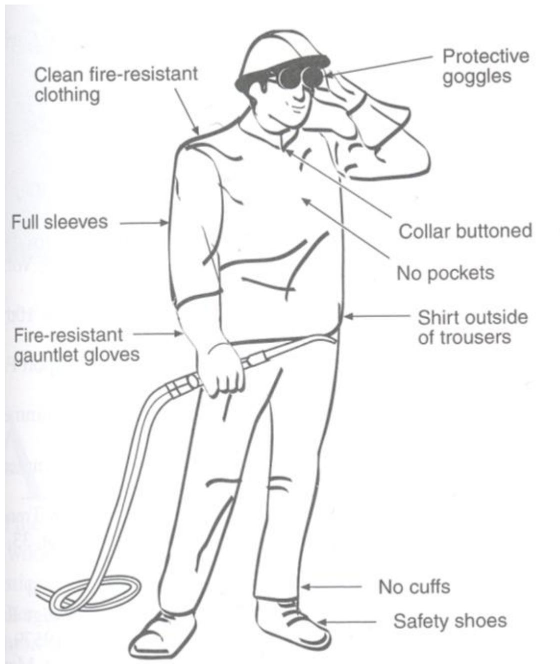

Figure 6.14.9 Welder Protection

Adequate ventilation must be provided wherever welding, cutting, and other hot work are performed to protect the operator from inhaling noxious gases and fumes. Potentially hazardous materials might exist in certain fluxes, coatings, and filler metals. In some cases, general natural draft ventilation is adequate. Other operations require forced-draft ventilation, local exhaust hoods or booths, or personal respirators or air-supplied masks. A good reference for additional information on personal protective equipment (PPE) and ventilation is ANSI Standard Z49.1.