EW607
TECHNICAL
GUIDE

Safety & Health of Welders

HOBART INSTITUTE
OF WELDING TECHNOLOGY

Covers hazards related to electric shock, arc radiation, air contamination, fire & explosion, compressed gases, weld cleaning, and more.

Safety and Health of Welders

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the Staff of Hobart Institute
of Welding Technology

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The Hobart Institute of Welding Technology presents this information as a guideline for good safety and health practices. It is information available at the time of production of this publication. Relevant standards may have been updated and should be reviewed together with this book for accuracy. It is not intended to be the only source of arc welding safety information. Federal or other laws and standards may govern different operations and facilities. Additional sources for arc welding safety are given in the references.

This document should be read and understood by all persons involved with welding and cutting. This includes welders, supervisors, management, contractors, educators, and others.

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1. Personal Protection and Safety Rules

Your safety and health is extremely important. All workers engaged in production and construction are continually exposed to potential hazards. There are a number of potential safety and health problems associated with welding, cutting, and allied processes. When correct precautionary measures are followed, welding is a safe occupation. Health officials state that welding, as an occupation, is no more hazardous or injurious to the health than other metal working occupations.[1]

Governments have become increasingly active concerning the safety and health of workers and have enacted laws prescribing safety regulations and the publication of safety information to insure the safety of workers. In the United States, the provisions of the Occupational Safety and Health Act (OSHA)[2] are the law. It makes many national consensus standards enforceable. The most important welding standard is the American National Standard "ANSI Z49.1, Safety in Welding,Cutting, and Allied Processes".[3] This standard states that welding and cutting operations pose potential hazards from fumes, gases, electric shock, heat radiation, and sometimes noise. All personnel shall be warned against these hazards where applicable by the use of adequate precautionary labeling. The minimum precautionary label for arc welding processes and equipment, which is recommended, is shown in Figure 1. There are other hazards which apply to all metal working occupations. These are accidents resulting from falling, being hit by moving objects, working around moving machinery, exposure to hot metal, etc. Normal precautions are required with regard to these hazards as well. Hazards that relate to welding are:

Electrical shock	Compressed gases
Arc radiation	Welding cleaning
Air contamination	Other hazards related to
Fire and explosion	specific occupations

Welders work under a variety of conditions including outdoors, indoors, in open areas, in confined spaces, high above the ground, and even under water. They utilize a large number of welding and cutting processes, however most of these have in common the exposure to fumes, gases, radiation and heat. Welders may be exposed to a number of factors simultaneously. The use of specific welding processes or welding on particular metals can present potential health risks, which will be covered later. Additional information is available in the American Welding Society publications listed in the references section of this book.

Welding Workplace Safety

The welding management and supervisors are responsible for assuring the workers are trained in the safe conduct of their day to day activities. Employees must be informed and trained so that they are able to detect when hazards are present and protect themselves from them.

The welders and other employees have an obligation to learn and use safe practices and to obey safety rules and regulations. They are responsible for the proper use of equipment. They have an obligation to learn safe practices, to obey safety rules and regulations and are expected to work in a safe manner. It is the responsibility of supervisors to assure safety rules and regulations are followed.

Combustible materials must not be allowed to collect in or near the welding workplace. Good housekeeping practices should always be employed. Adequate safety devices should be provided such as the proper fire extinguishers, life saving and support equipment, first aid kits, and so on. Train personnel to utilize this equipment properly. Only approved equipment should be used and it must be properly installed and maintained in good working order.

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs) and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American national Standard ANSI Z49.1: *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N. W. LeJeune Road, Miami, FL 33126; OSHA *Safety and Health Standards* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington, DC 20401.

DO NOT REMOVE THIS INFORMATION

Figure 1 - Precautionary Information for Arc Welding Processes and Equipment

Material Safety Data Sheets (MSDSs)

OSHA requires that employers must have a comprehensive hazard communication program to inform employees about hazardous substances that might be used in the workplace. The purpose of the MSDSs is to explain the hazards involved in handling/using products such as welding consumables and the precautionary measures which must be put in place for safe welding. The employer must maintain continuous training concerning such materials, and safety in general. Provisions to safeguard employees are included in Material Safety Data Sheets (MSDSs) as prescribed by the Hazard Communication Standard of the U.S. Department of Labor.[5] Information must be provided for all substances taken into the workplace except foods, drugs, cosmetics or tobacco products used for personal consumption. The use of these data sheets in all manufacturing workplaces has been mandated since 1985. Employees must be trained on the information in Material Safety Data Sheets and labels.

Each Material Safety Data Sheet for welding products includes information about every hazardous component comprising 1% or more of the contents, and for every potential carcinogen (cancer inciting or producing) comprising 0.1% or more. Many of the components are included in the listing by the American Conference of Governmental Industrial Hygienists with threshold limit values.[6]

Material Safety Data Sheets are required to be provided automatically by the suppliers of welding electrodes, fluxes, and gases. They should be kept on file in the personnel or welding departments and be readily available in the workplace. The training program must cover not only welders, but others working in the welding area such as service personnel, maintenance personnel, regular visitors to the welding shop, and others. A typical material safety data sheet for a tubular arc welding electrode is shown in Figures 2, 3, and 4. Particular points of interest are highlighted to provide more data for intelligent interpretation of this information.[7] Hazardous communication programs and welding safety training programs must be ongoing.

MSDS NO: TR-TW
REVISED: (date)
TW 2885

MATERIAL SAFETY DATA SHEET

For U.S. Manufactured or Distributed Welding Consumables and Related Products. May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910. 1200 and Superfund Amendments and Reauthorization Act (SARA) of 1986 Public Law 99-499. Standard must be consulted for specific requirements.

Hazards in the filler metal or flux itself

SECTION 1 – IDENTIFICATION

Manufacturer/Supplier Name: ABC COMPANY
Address: MAIN STREET, ANY CITY, ZIPCODE, USA
Telephone No: (000) 000-0000
Emergency No: (000) 000-0000

Products For: TUBULAR ARC WELDING ELECTRODES FOR FLUX CORED, METAL CORED AND COMPOSITE SUBMERGED ARC WELDING "GROUP A": Product Type: Gas Shielded Carbon and Low Alloy Steel"GROUP B": Product Type: Self-Shielded Carbon Steel
"GROUP C": Product Type: Carbon and Low Alloy Steel "GROUP D": Product Type: Corrosion Resisting Steel Metal Cored

Chemical Abstracts Service No. (safety information, immediately available by telephone to physicians and paramedics).

SECTION 2 - HAZARDOUS INGREDIENTS

IMPORTANT - This section covers the hazardous materials from which this product is manufactured. The fumes and gases produced during welding with normal use of this product are also addressed in Section 5. The term "hazardous" in this section should be interpreted as a term required and defined in OSHA Hazard Communication Standard (29 CFR Part 1910.1200).

PEL= Permissible Exposure Limit, mg/m^3.

American Conference of Governmental Industrial Hygienists Threshold Limit Value (mg/m^3). Time-weighted average.

HAZARDOUS% INGREDIENTS	WEIGHT Group A	Group B	Group C	Group D	CAS NO.	EXPOSURE LIMIT (mg/m^3) OSHA PEL	ACGIH TLV
IRON+	75-98	75-95	75-95	75-95	7439-89-6	5 R*	3 R*
IRON OXIDE	—	—	<2	—	1309-37-1	10 (Oxide Fume)	5 R*(Oxide {A4}
MANGANESE#	<4.5	<2	<4	<2	7439-96-5	5 CL** (Fume)	0.2
						1, 3 STEL*** (Fume)	(As inorganic Compounds of Mn)
TITANIUM DIOXIDE	<10	<4(4)	<10	<2	13463-67-7	15 (Dust)	10 {A4}
SILICON+	<4	<2(4)	<4	<2	7440-21-3	5 R*	3 R* ◆◆◆
FLUORSPAR	<5(5)	1-10	<5	—	7789-75-5	2.5 (as F)	2.5 (as F) {A4}
MOLYBDENUM	<1	—	<2	<2	7439-98-7	5 R*	3 R*; 10 I* (Elemental and Insoluble) 0.5 R*(Soluble Compounds) {A3}
CALCIUM CARBONATE	<2	<2(7)	—	—	1317-65-3	5 R* 5 (as CaO)	10 ◆◆◆◆◆ 2 (as CaO)
ALUMINUM###	<2	<5(6)	<3(6)	—	7429-90-5	5 R* (Dust)	10 (Dust) 2 (soluble salts, as Al)
MAGNESIUM+	—	<3	—	—	7439-95-4	5 R*	3 R*
MAGNESIUM OXIDE	—	<3	—	—	1309-48-4	15 (Fume, total particulate)	10 I* {A4}
BARIUM FLOURIDE#	—	5-15(1)	5-15(3)	—	7787-32-8	0.5 (as Ba)	0.5 (as Ba) {A4}
NICKEL#	—	—	<4	<1	7440-02-0	1 (Metal) 1 (Soluble Compounds) 1 (Insoluble Compounds)	1.5 I* (Elemental) {A5} 0.1 I* (Soluble Compounds) {A4} 0.2 I* (Insoluble Compounds) {A1}
CHROMIUM#	—-	—	<3	5 - 20	7440-47-3	1 (Metal) 0.5 (Cr II & Cr III Compounds) 0.005 (Cr VI Compounds)	0.5 (Metal) {A4} 0.5 (Cr III Compounds) {A4} 0.05 (Cr VI Soluble Compounds) {A1} 0.01 (Cr VI Insoluble Compounds) {A1}
COPPER#	<1(2)	—	<2(2)	—	7440-50-8	1 (Dust) 0.1 (Fume)	1 (Dust and Mists)◆, ◆◆ 0.2 (Fume)◆, ◆◆
TITANIUM+	—	—	<2	<2	7440-32-6	5 R*	3 R*
SILICA++	<2	—	<2	—	14808-60-7	0.1 R*	0.025 R* {A2}
(Amorphous Silica Fume)					69012-64-2	0.8	3 R* ◆◆◆
LITHIUM FLUORIDE	—	<2(9)	<2(9)	—	7789-24-4	2.5 (as F)	2.5 (as F) {A4}
STRONTIUM FLUORIDE	—	<2(8)	—	—	7783-48-4	2.5 (as F)	2.5 (as F) {A4}
COBALT	—-	—-	<1(10)	—-	7440-48-4	0.1 (Dust&Fume)	0.02 {A3}
CERIUM OXIDE	—-	—-	<2(11)	—	1306-38-3	15 (Dust) 5 R* (Dust)	10 (Dust) 3 R* (Dust)

(1) Present only in Group B Product Types (2) Present only in Group A and Group C Product Types (3) Present only in Group C Product Types (4) Present only in Group B Product Types (5) Present only in Group A Product Types (6) Present in All Group B Product Types (7) Present only in Group C Product Types (8) Present only in Group B Product Types (9) Present only in Group C Product Types (10) Present only in Group C Product Types (11) Present only in Group C Product Types
* - Respirable Fraction I* - Inhalable Fraction ** - Ceiling Limit *** - Short Term Exposure Limit. + - As a nuisance particulate covered under "Particulates Not Otherwise Regulated" by OSHA or "Particulates Not Otherwise Classified" by ACGIH. ++ - Crystalline silica is bound within the product as it exists in the package. However, research indicates silica is present in welding fume in the amorphous #- Reportable material under Section 313 of SARA. ### - Reportable material under Section 313 of SARA as dust or fume. {A1} - Confirmed Human Carcinogen per ACGIH {A2} - Suspected Human Carcinogen per ACGIH {A3} - Confirmed Animal Carcinogen with Unknown Relevance to Humans per ACGIH {A4} - Not Classifiable as a Human Carcinogen per ACGIH {A5} - Not Suspected as a Human Carcinogen per ACGIH (noncrystalline) form. ◆ - Listed under Notice of Intended Changes in 2006 per ACGIH ◆◆ - Limit of 0.1 mg/m^3 is proposed for Cu I* and 0.05 mg/m^3 is proposed for Cu R* of soluble compounds in 2006 by ACGIH ◆◆◆ - TLV withdrawn in 2006 ◆◆◆◆◆ - Intention to withdraw TLV in 2006 per ACGIH

The exposure limit for welding fume has been established at 5 mg/m^3 with OSHA's PEL and ACGIH's TLV. The individual complex compounds within the fume may have lower exposure limits than the general welding fume PEL/TLV. An Industrial Hygienist, the OSHA Permissible Exposure Limits For Air Contaminants (29 CFR 1910.1000), and the ACGIH Threshold Limit Values should be consulted to determine the specific fume constituents present and their respective exposure limits.

Figure 2 - Page 1 of 3 of Typical Material Safety Data Sheet

SECTION 3 - PHYSICAL/CHEMICAL CHARACTERISTICS
Welding consumables applicable to this sheet are solid and nonvolatile as shipped.

SECTION 4 - FIRE AND EXPLOSION HAZARD DATA
Welding consumables applicable to this sheet as shipped are nonreactive, nonflammable, nonexplosive and essentially nonhazardous until welded. Welding arcs and sparks can ignite combustibles and flammable products. See American National Standard Z49.1 referenced in Section 7.

SECTION 5 - REACTIVITY DATA - HAZARDOUS DECOMPOSITION PRODUCTS

Hazards created by the welding arc or torch.

Welding fumes and gases cannot be classified simply. The composition and quantity of both are dependent upon the metal being welded, the process, procedures and electrodes used. **Most fume ingredients are present as complex oxides and compounds and not as pure metals.**
Other conditions which also influence the composition and quantity of the fumes and gases to which workers may be exposed include: coatings on the metal being welded (such as paint, plating or galvanizing), the number of welders and the volume of the work area, the quality and amount of ventilation, the position of the welder's head with respect to the fume plume, as well as the presence of contaminants in the atmosphere (such as chlorinated hydrocarbon vapors from cleaning and degreasing activities).
When the electrode is consumed, the fume and gas decomposition products generated are different in percent and form from the ingredients listed in Section 2. Decomposition products of normal operation include those originating from the volatilization, reaction or oxidation of the materials shown in Section 2, plus those from the base metal and coating, etc., as noted above.

Typical fumes.

Reasonably expected constituents of the fume would include: Complex oxides of iron, manganese, silicon and titanium. Groups A and B may also contain calcium oxides. Groups A, B and C may have fluorides present. Groups A, C, and D may also contain molybdenum. Group B may also contain magnesium. Groups A, B, and C may also contain aluminum. Groups B and C may also contain barium. Groups A and C may also contain copper. Groups C and D may also contain chromium and nickel. Group B may also contain magnesium, lithium and strontium.
Monitor for the materials identified in Section 2. Fumes from the use of this product may contain barium, fluorides, manganese, calcium oxide, chromium and nickel compounds, copper, and amorphous silica fume whose exposure limits are lower than the 5 mg/m^3 PEL/TLV for general welding fume.

Gases

Gaseous reaction products may include carbon monoxide and carbon dioxide. Ozone and nitrogen oxides may be formed by the radiation from the arc.

How to sample actual fumes.

One recommended way to determine the composition and quantity of fumes and gases to which workers are exposed is to take an air sample inside the welder's helmet if worn or in the worker's breathing zone. [See ANSI/AWS F1.1, available from the "American Welding Society", P.O. Box 351040, Miami, FL 33135. Also, from AWS is F1.3 "Evaluating Contaminants in the Welding Environment - A Sampling Strategy Guide", which gives additional advice on sampling.]

SECTION 6 - HEALTH HAZARD DATA

Note effects of overexposure.

EFFECTS OF OVEREXPOSURE:
Electric arc welding may create one or more of the following health hazards:
ARC RAYS can injure eyes and burn skin.
ELECTRIC SHOCK can kill. See Section 7.
FUMES AND GASES can be dangerous to your health.
PRIMARY ROUTES OF ENTRY are the respiratory system, eyes and/or skin.
SHORT-TERM (ACUTE) OVEREXPOSURE EFFECTS:
WELDING FUMES - May result in discomfort such as dizziness, nausea or dryness or irritation of nose, throat or eyes.
IRON, IRON OXIDE - None are known. Treat as nuisance dust or fume.
MANGANESE - Metal fume fever characterized by chills, fever, upset stomach, vomiting, irritation of the throat and aching of body. Recovery is generally complete within 48 hours of the overexposure.
TITANIUM DIOXIDE - Irritation of respiratory system.
SILICA (AMORPHOUS) - Dust and fumes may cause irritation of the respiratory system, skin and eyes.
FLUORIDES - Fluoride compounds evolved may cause skin and eye burns, pulmonary edema and bronchitis.
MOLYBDENUM, CERIUM OXIDE - Irritation of the eyes, nose and throat.
CALCIUM OXIDE - Dust or fumes may cause irritation of the respiratory system, skin and eyes.
ALUMINUM OXIDE - Irritation of the respiratory system.
MAGNESIUM, MAGNESIUM OXIDE - Overexposure to the oxide may cause metal fume fever characterized by metallic taste, tightness of chest and fever. Symptoms may last 24 to 48 hours following overexposure.
BARIUM - Aching eyes, rhinitis, frontal headache, wheezing, laryngeal spasms, salivation or anorexia.
NICKEL, NICKEL COMPOUNDS - Metallic taste, nausea, tightness in chest, metal fume fever, allergic reaction.
CHROMIUM - Inhalation of fume with chromium (VI) compounds can cause irritation of the respiratory tract, lung damage and asthma-like symptoms. Swallowing chromium (VI) salts can cause severe injury or death. Dust on skin can form ulcers. Eyes may be burned by chromium (VI) compounds. Allergic reactions may occur in some people.
COPPER - Metal fume fever characterized by metallic taste, tightness of chest and fever. Symptoms may last 24 to 48 hours following overexposure.
STRONTIUM COMPOUNDS - Strontium salts are generally non-toxic and are normally present in the human body. In large oral doses, they may cause gastrointestinal disorders, vomiting and diarrhea.
LITHIUM COMPOUNDS - Overexposure may cause tremor and nausea.
COBALT – Pulmonary irritation, cough, dermatitis, weight loss.
LONG-TERM (CHRONIC) OVEREXPOSURE EFFECTS:
WELDING FUMES - Excess levels may cause bronchial asthma, lung fibrosis, pneumoconiosis or "siderosis."
IRON, IRON OXIDE FUMES - Can cause siderosis (deposits of iron in lungs) which some researchers believe may affect pulmonary function. Lungs will clear in time when exposure to iron and its compounds ceases. Iron and magnetite (Fe3O4) are not regarded as fibrogenic materials.
MANGANESE - Long-term overexposure to manganese compounds may affect the central nervous system. Symptoms may be similar to Parkinson's Disease and can include slowness, changes in handwriting, gait impairment, muscle spasms and cramps and less commonly, tremor and behavioral changes. Employees who are overexposed to manganese compounds should be seen by a physician for early detection of neurologic problems.
TITANIUM DIOXIDE - Pulmonary irritation and slight fibrosis.
SILICA (AMORPHOUS) - Research indicates that silica is present in welding fume in the amorphous form. Long term overexposure may cause pneumoconiosis. Noncrystalline forms of silica (amorphous silica) are considered to have little fibrotic potential.
FLUORIDES - Serious bone erosion (Osteoporosis) and mottling of teeth.
MOLYBDENUM - Prolonged overexposure may result in loss of appetite, weight loss, loss of muscle coordination, difficulty in breathing and anemia.
CALCIUM OXIDE - Prolonged overexposure may cause ulceration of the skin and perforation of the nasal septum, dermatitis and pneumonia.

Figure 3 - Page 2 of 3 of Typical Material Safety Data Sheet (see previous page)

ALUMINUM OXIDE - Pulmonary fibrosis and emphysema.
MAGNESIUM, MAGNESIUM OXIDE - No adverse long term health effects have been reported in the literature.
BARIUM - Long term overexposure to soluble barium compounds may cause nervous disorders and may have deleterious effects on the heart, circulatory system and musculature.
NICKEL, NICKEL COMPOUNDS - Lung fibrosis or pneumoconiosis. Studies of nickel refinery workers indicated a higher incidence of lung and nasal cancers.
CHROMIUM - Ulceration and perforation of nasal septum. Respiratory irritation may occur with symptoms resembling asthma. Studies have shown that chromate production workers exposed to hexavalent chromium compounds have an excess of lung cancers. Chromium (VI) compounds are more readily absorbed through the skin than chromium (III) compounds. Good practice requires the reduction of employee exposure to chromium (III) and (VI) compounds.
COPPER - Copper poisoning has been reported in the literature from exposure to high levels of copper. Liver damage can occur due to copper accumulating in the liver characterized by cell destruction and cirrhosis. High levels of copper may cause anemia and jaundice. High levels of copper may cause central nervous system damage characterized by nerve fiber separation and cerebral degeneration.
STRONTIUM COMPOUNDS - Strontium at high doses is known to concentrate in bone. Major signs of chronic toxicity, which involve the skeleton, have been labeled as "strontium rickets".
LITHIUM COMPOUNDS - May be considered as potentially teratogenic.
COBALT – Repeated overexposure to cobalt compounds can produce reduced pulmonary function, diffuse nodular fibrosis of lungs and respiratory hypersensitivity. IARC considers cobalt compounds as possibly carcinogenic to humans (GROUP 2B).
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
Persons with pre-existing impaired lung functions (asthma-like conditions).

Apply First Aid.

EMERGENCY AND FIRST AID PROCEDURES:
Call for medical aid. Employ first aid techniques recommended by the American Red Cross.
Eyes & Skin: If irritation or flash burns develop after exposure, consult a physician.

Beware! Carcinogenic means it may produce cancer.

CARCINOGENICITY:
Chromium VI and nickel compounds must be considered as carcinogens under OSHA (29 CFR 1910.1200). Chromium VI compounds are classified as IARC Group 1 and NTP Group 1 carcinogens. Nickel compounds are classified as IARC Group 1 and NTP Group 2 carcinogens. Welding fumes must be considered as possible carcinogens under OSHA (29 CFR 1910.1200).
CALIFORNIA PROPOSITION 65:
For Group C and D products: WARNING: This product contains or produces a chemical known to the State of California to cause cancer and birth defects (or other reproductive harm). (California Health & Safety Code Section 25249.5 et seq.)
For Group A and B products: WARNING: This product, when used for welding or cutting, produces fumes or gases which contain chemicals known to the State of California to cause birth defects and, in some cases, cancer. (California Health & Safety Code Section 25249.5 et seq.)

SECTION 7 - PRECAUTIONS FOR SAFE HANDLING & USE/APPLICABLE CONTROL MEASURES

Read and understand the manufacturer's instructions and the precautionary label on the product. See American National Standard Z49.1; Safety in Welding and Cutting published by the American Welding Society, P.O. Box 351040, Miami, FL 33135 and OSHA Publication 2206 (29 CFR 1910), U.S. Government Printing Office, Washington, DC 20402 for more detail on any of the following.

Ventilate weld area.

VENTILATION: Use enough ventilation, local exhaust at the arc or both to keep the fumes and gases below PEL/TLVs in the worker's breathing zone and the general area. Train the welder to keep his head out of the fumes.

Use respirator when necessary.

RESPIRATORY PROTECTION: Use NIOSH approved or equivalent fume respirator or air supplied respirator when welding in confined space or where local exhaust or ventilation does not keep exposure below PEL/TLVs.

Wear helmet, filter lens.

EYE PROTECTION: Wear helmet or use face shield with filter lens. As a rule of thumb begin with Shade Number 14. Adjust if needed by selecting the next lighter and/or darker shade number. Provide protective screens and flash goggles, if necessary, to shield others.

Protect from radiation, sparks electric shock, hot metal, sharp edges, pinch points, falls.

PROTECTIVE CLOTHING: Wear hand, head and body protection which help to prevent injury from radiation, sparks and electrical shock. See ANSI Z49.1. At a minimum this includes welder's gloves and a protective face shield, and may include arm protectors, aprons, hats, shoulder protection as well as dark nonsynthetic clothing. Train the welder not to touch live electrical parts and to insulate himself from work and ground.
PROCEDURE FOR CLEANUP OF SPILLS OR LEAKS: Not applicable
WASTE DISPOSAL: Prevent waste from contaminating surrounding environment. Discard any product, residue, disposable container or liner in an environmentally acceptable manner, in full compliance with Federal, State and Local regulations.

Never exceed permissible exposure limits.

SPECIAL PRECAUTIONS (IMPORTANT): Maintain exposure below the PEL/TLVs. Use industrial hygiene monitoring to ensure that your use of this material does not create exposures which exceed PEL/TLVs. Always use exhaust ventilation. Refer to the following sources for important additional information: ANSI Z49.1 from the American Welding Society, P.O. Box 351040, Miami, FL 33135 and OSHA (29 CFR 1910) from the U.S. Department of Labor, Washington, DC 20210.

Protect yourself. The manufacturer disclaims any responsibility.

ABC Company believes this data to be accurate and to reflect qualified expert opinion regarding current research. However, ABC Company cannot make any expressed or implied warranty as to this information.

Figure 4 - Page 3 of 3 of Typical Material Safety Data Sheet (see previous page)

Heat Exposure

In addition to working in hot climates, welders are sometimes required to weld on, or inside, preheated weldments. The preheat temperatures required for welding special materials can be quite high and the welder must be protected from coming into contact with the hot metal. They should be supplied with sufficient cool air to avoid breathing excessively hot air. Special precautions must be taken and special procedures must be adopted to protect the welder from the heat. Protective clothing should be worn which helps insulate the welder from excessive heat. Consultation with safety experts and just plain common sense is required in these situations.

Protective Clothing

Welders should wear work or shop clothes without openings or gaps to prevent the arc rays from injuring the skin. If the arc rays contact the skin for a period of time painful “sunburns” or “arc burns” will result. People working close to arc welding should also wear protective clothing.

For light-duty welding, normally 200 amperes or lower, the level of protection can be reduced. Figure 5 shows a welder dressed for light-duty work. Woolen clothing is more satisfactory than cotton since it will not disintegrate from arc radiation or catch on fire as quickly. Cloth or soft leather gloves can be used for light-duty work. For heavy-duty work, more thorough protective clothing is required. Figure 6 shows a welder dressed for heavy-duty welding work wearing leather gauntlet gloves, a leather cape, leather bib, and spats, which give additional protection against sparks and molten metal. When welding in the vertical and overhead position this type of clothing is required. In all cases a headcap should be used. Flame-retardant clothing should be worn. Clothing should always be kept dry, and this applies to gloves as well. High top shoes with safety toes are recommended. The leather clothes should be of the chrome-tanned type or its equivalent. Leather gloves should not be used to pick up hot items since this will cause the leather to become stiff and crack. Protective clothing must be kept in good repair. Check safety equipment regularly for damage. Replace faulty clothing and equipment. Gloves should be clean, without holes or tears, and dry. Welding helmets should be checked for cracks, and filter glasses should be replaced if damaged.

Signs should be posted in the welding area pointing out precautions that must be taken by employees and visitors. These signs should be in agreement with Z535 standards[8]. The welding area should also post signs alerting people with heart pace-makers that they should not enter and to check with their clinician.

Figure 5 - Welder dressed for light duty welding

Figure 6 - Welder dressed for heavy duty welding.

Safety Practices

The following, "Safety Precautions for Arc Welding and Cutting" and "Safety Precautions for Oxyacetylene Welding and Cutting" should be read and understood by all welders, cutters, and helpers.

Safety Precautions for Arc Welding and Cutting

1. Make sure your arc welding equipment is installed properly and grounded and is in good working condition. This will help prevent fatal electric shocks.
2. Always wear protective clothing suitable for the welding to be done. This will help prevent injuries and burns.
3. Always wear proper eye protection, when welding, cutting, or grinding. Do not look at the arc without proper eye protection. This will prevent eye injuries and "arc flash."
4. Avoid breathing the air in the fume plume directly above the arc. This will prevent illness due to overexposure to hazardous materials in the fume plume.
5. Keep your work area clean and free of hazards. Make sure that no flammable, volatile, or explosive materials are in or near the work area. Good housekeeping will help prevent accidents.
6. Handle all compressed gas cylinders with extreme care. Keep caps on when not in use. Damaged cylinders can rupture with explosive violence.
7. Make sure that compressed gas cylinders are secured to the wall or to other structural supports. The impact of a fall can cause cylinder rupture or valve failure.
8. When compressed gas cylinders are empty close the valve and mark the cylinder "empty". This will prevent contamination from entering the cylinder.
9. Do not weld in a confined space without special precautions. Poor ventilation can lead to asphyxiation. Accumulation of flammable gases can explode. Always practice "confined space" safety.
10. Do not weld on containers that have held combustibles with out taking special precautions. The heat of welding can ignite residual gases and cause an explosion. The heat can cause the release of hazardous fumes. Always assure a container is clean and safe for welding.
11. Do not weld on sealed containers or compartments without providing vents and taking special precautions. The heat of welding can cause gases to expand. The increased pressure can lead to an explosion.
12. Use mechanical exhaust at the point of welding when welding lead, cadmium, chromium, manganese, brass, bronze, zinc, or galvanized steel, and when welding in a confined space. These "low allowable-limit materials" cancause serious injury. Ventilation will prevent overexposure. (Refer to ref. 3)
13. When it is necessary to weld in a damp or wet area, wear rubber boots and stand on a dry insulated platform. This will minimize the chance of electric shocks.
14. Do not use cables with frayed, cracked, or bare spots in the insulation. This will prevent stray arcs between the bare cable and the ground. It will prevent electric shocks.
15. When the electrode holder is not in use, hang it on brackets provided. Never let it touch a compressed gas cylinder. This will help prevent damage to the holder. An energized holder can arc to a grounded cylinder and cause an explosion.
16. Dispose of electrode stubs in proper container since stubs on the floor are a safety hazard. Hot stubs can ignite fires or can cause trips and falls.
17. Shield others from the light rays produced by your welding arc. Ultraviolet arc rays can cause "arc flash" to the eyes of nearby people.
18. Do not weld near degreasing operations. Arc rays can inter-act with fumes of some cleaning agents and produce hazardous gases. Some of these gases can kill.
19. When working above ground make sure that scaffold, ladder, or work surface is solid. Falls from elevated positions can cause injury or even death.
20. When welding in high places, use safety belt or lifeline. Falls from high places are more likely to cause serious injury or death.

Safety Precautions for Oxyacetylene Welding and Cutting

1. Make sure that all gas apparatus shows UL or FM approval, is installed properly and is in good working condition. Make sure that all connections are tight before lighting the torch. Do not use a flame to inspect for tight joints. Use soap solution to detect leaks. This will minimize the chance of fuel gas leaks. Gas leaks can cause fires and explosions.
2. Always wear protective clothing suitable for welding or flame cutting. This will prevent injuries and burns.
3. Keep work area clean and free from hazardous materials. When flame cutting sparks can travel up to 35 feet (10.7 m). Do not allow flame cut sparks to hit hoses, regulators, or cylinders. Good housekeeping will help prevent fires and explosions.
4. Handle all compressed gas cylinders with extreme care. Keep cylinder caps on when not in use. Damaged cylinders can rupture with explosive violence.
5. Make sure that all compressed gas cylinders are secured to the wall or to other structural supports. Keep acetylene cylinders in the vertical position. The impact of a fall can cause cylinder rupture or valve failure. With horizontal acetylene cyllinders, acetone will be mixed in with the delivered gas.
6. Store compressed gas cylinders in a safe place with good ventilation. Acetylene cylinders and oxygen cylinders should be kept apart. This will prevent the accumulation of leaking gases and possible fires and explosions.
7. When compressed gas cylinders or fuel gas cylinders are empty, close the valve and mark the cylinder "empty". This will prevent contamination from entering the cylinder.
8. Use oxygen and acetylene or other fuel gases with the apropriate torches and only for the purpose intended. This will minimize the chance of sustained backfires and flash-backs.
9. Avoid breathing the air in the fume plume directly above the flame. This will prevent illness due to overexposure to hazardous materials in the fume plume.
10. Never use acetylene at a pressure in excess of 15 psi (103.4k Pa). Higher pressure can cause an explosion. The high pressure can cause acetylene to detonate spontaneously.
11. Never use oil, grease or any material on any apparatus or threaded fittings in the oxyacetylene or oxyfuel system. Oil and grease in contact with oxygen may cause spontaneous combustion.

12. Do not weld or flame cut in a confined space without taking special precautions. Poor ventilation can lead to asphyxiation. Accumulation of fuel gas can explode. Always practice "confined space" safety.
13. When assembling apparatus, crack gas cylinder valve before attaching regulators (cracking means opening the valve on a cylinder slightly, then closing). This blows out any accumulated foreign material. Make sure that all threaded fittings are clean and tight. The impact of foreign material can mcause regulators to explode, when they are pressurized upon opening of the cylinder valve.
14. Always follow the torch manufacturer's instructions when lighting the torch. This will prevent damage and the release of excess gases.
15. Always follow the torch manufacturer's instructions when shutting down a torch. This will prevent damage and re-verse gas flows in the hoses.
16. Use mechanical exhaust when welding or cutting lead, cadmium, chromium, manganese, brass, bronze, zinc, or galvanized steel. These "low allowable-limit materials" can cause serious injury. Ventilation will prevent overexposure (Refer to Ref. 3)
17. If you must weld or flame cut with combustible or volatile materials present, take extra precautions, make out a hot work permit, and provide for a lookout, etc. This will minimize the chance of fires. (Refer to Ref. 25.)
18. Do not weld or flame cut on containers that have held combustibles without taking special precautions. The heat of the flame can ignite residual gases and cause an explosion. The heat can cause the release of hazardous fumes. Always assure a container is clean and safe for welding or cutting.
19. Do not weld or flame cut into a sealed container or compartment without providing vents and taking special precautions. The heat of the flame can cause gases to expand. The increased pressure can lead to an explosion.
20. Do not repair damaged hoses with tape. Only trained persons should repair hoses. Gas leaks can cause fires and explosions and, in some cases, asphyxiation.

The Safety in Welding and Cutting standard also provides a precautionary label for oxy-fuel gas processes. This label is shown in Figure 7.

If the hazards mentioned in this chapter are properly and adequately handled, the welder is as safe as any other industrial worker. There must be continual vigilance over safety conditions and safety hazards. Safety meetings should be held regularly. The safety rules should be reissued annually and they must be completely understood and enforced.

WARNING:

PROTECT yourself and others. Read and understand this information.

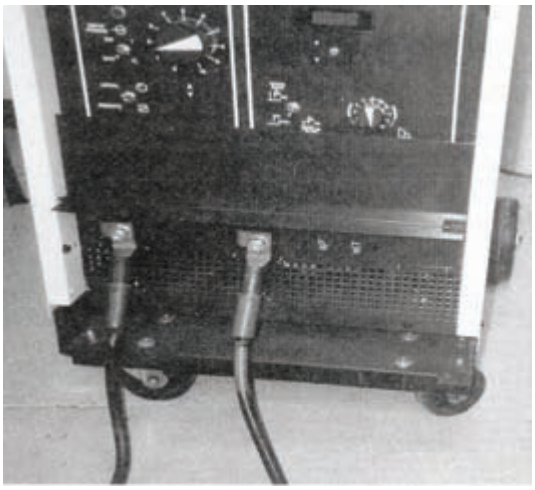
FUMES AND GASES can be hazardous to your health.

HEAT RAYS (INFRARED RADIATION) from flame or hot metal can injure eyes.

- **Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.**
- **Keep your head out of the fumes.**
- **Use enough ventilation, exhaust at the flame, or both, to keep fumes and gases from your breathing zone and the general area.**
- **Wear correct eye, ear, and body protection.**
- **See American National Standard ANSI Z49.1, *Safety In Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126; OSHA *Safety and Health Standards* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington, DC 20401.**

DO NOT REMOVE THIS INFORMATION

Figure 7 - Precautionary Information for Oxyfuel Gas Processes and Equipment



Terminal protection open

Terminal protection closed

Figure 8 - Insulating devices on terminals of a welding machine

2. Electrical Shock Hazard

A shock hazard is associated with all electrical equipment. This includes extension lights, electric hand tools, and all types of electrically powered machinery. Welding equipment operators should note that ordinary household voltage (115 v) is higher than the output voltage of a conventional arc welding machine.

Use only welding machines that meet recognized national standards. Most industrial welding machines meet the National Electrical Manufacturers Association (NEMA) standards for electric welding apparatus.[9] This is mentioned in the manufacturer's literature and is shown on the nameplate of the welding machine.

In Canada, approval by the Canadian Standards Association (CSA) is required for certain types of welding machines and this is also indicated on the nameplate.[10] In certain parts of the U.S., and for certain applications, the Underwriters Laboratory (UL) approval is required.[11] The NEMA specification provides classes of welding machines, duty cycle requirements, and no load voltage maximum requirements.

In order to comply with the OSHA requirements, manufacturers have made changes to improve the safety of the machines. This includes methods to protect the output terminals with insulating devices. A typical method is shown in Figure 8. Manufacturers have also made the ventilation slots smaller so that the fingers of the welder cannot come in contact with high voltage inside the case. They have also changed the cases of the welding machines so that "tools" are required to open the case where high voltage is exposed.

Only insulated type welding electrode holders should be used for shielded metal arc welding. Semiautomatic welding guns for continuous wire processes should utilize low voltage control circuits so that high voltage is not brought into the hands of the welder. In fully automatic equipment higher voltages are permitted, but are inaccessible to the operator during normal operation.

Installation

All electric arc welding machines must be installed in accordance with the National Electrical Code[12] and all local codes. Installation instructions are included in the manufacturer's manual that accompanies the welding machine. If applicable, follow lockout/tagout procedures[37]. The manual also gives the size of power cable that should be used to connect the machine to the main line. Motor generator welding machines feature com-plete separation of the primary input power and the welding circuit output power since the generator is mechanically connected to the electric motor.

However, the metal frame and case of the motor generator must be grounded since the high voltage input from the main lines come into the case. In transformer and transformer rectifier type machines, the primary and secondary transformer windings are electrically isolated from each other by insulation. This insulation may become defective if proper maintenance practices are not observed. The metal frames and cases of transformers and transformer rectifier machines must be grounded to earth. Normally, the work terminal of the welding machine should not be grounded to earth. However, it is possible to connect the work terminal to a grounded enclosure when ANSI Z49.1 Section II requirements are followed.

Disconnect switches should be employed with all power sources so that they can be disconnected from the main lines for maintenance and to prevent electrical shocks.

It is extremely important when paralleling transformer welding machines that the phases of the power line be accurately identified. Parallel machines must be on the same phase and "in phase" with one another. It is relatively easy to check this by connecting the work leads together and measuring the voltage between the electrode holders of the two machines. This voltage should be practically zero. If it is double the normal open circuit voltage, it means that either the primary or secondary connections are reversed. If the voltage is approximately 1-1/2 times the normal open circuit voltage it means that the machines are connected to different phases of the three phase power line. Corrections must be made before welding begins. Refer to ANSI Z49.1 for further information.

When large weldments, like ships, buildings, or other metal structures are involved, it is normal to have the work terminal of many welding machines connected to the metal structure. When welders are working on one structure sufficiently close to each other, and someone is likely to touch the exposed parts of more than one electrode holder simultaneously, machines must be connected to minimize the shock hazard. However, this must be done with care, by a qualified person, and according to the teachings of ANSI Z49.1 Section II. It is extremely important that the machines be connected to the proper phase and have the same polarity. This can be checked by measuring the voltage between the electrode holders of the different machines mentioned above. The situation can also occur with respect to direct current power

sources when they are connected to a common structure. If one machine is connected for straight polarity electrode negative and one for reverse polarity electrode positive, the voltage between the electrode holders will be double the normal open circuit voltage. Precautions should be taken to see that all machines are of the same polarity when connected to a common weldment. Simultaneous welding with AC and DC welding machines must not be permitted on the same weldment unless the teachings of ANSI Z49.1 Section II are followed.

The welding electrode holders must be connected to machines with flexible cables designed for welding application. There shall be no splices in the electrode cable within 10 feet (3 meters) of the electrode holder. Splices or connectors, if used in work or electrode leads, must be insulated to achieve the mechanical strength, quality, conductivity, and water tightness of the original cable.

Finally, it is important to locate welding machines where they have adequate ventilation and that ventilating ports are so located that they cannot be obstructed.

Use

Electrode leads and work leads should not be coiled around the welding machines, nor should they ever be coiled around the welder. Electrode holders should not be hung where they can accidentally come in contact with the other side of the circuit. Electrodes should be removed from holders whenever they are not in use. It is absolutely essential that power cables or primary power coming to a welding machine should not be intermixed or come in contact in any way with the welding cables. The welding machine must be kept dry and if it should become wet it should be properly dried by competent electrical maintenance personnel. In addition, the work area must be kept dry. Welders should never work in water or damp areas since this reduces the resistance to the welder and increases potential electrical hazard.

Unless they are trained and qualified, welders should not make repairs on welding machines or associated equipment. Welders should be instructed not to use tools to open cases of welding machines. They should be instructed not to perform maintenance on electrode holders, welding cables, welding guns, wire feeders, etc. Instead they should be advised to notify their supervisors of maintenance problems or potential hazards so that qualified maintenance personnel can make needed repairs.

Maintenance

Welding machines and auxiliary equipment must be periodically inspected and maintained by competent electricians. During maintenance, the equipment must be disconnected from main power lines so that there is no possibility of anyone coming in contact with the high input voltage. If applicable, follow lockout/tagout procedures.[37] Maintenance records should be kept on welding power supplies. Supervisors and maintenance personnel should make routine inspection of welding cables and electrode holders, guns, and work clamps. Welders should report defective equipment or problems to their supervisors. Electrode holders with worn or missing insulators, and worn and frayed cables, should be repaired or replaced. Wire feeding semiautomatic equipment and specialty equipment, designed for gas tungsten arc welding, normally utilize switch-controlled power contactors. This means that the electrode wire or torch is electrically “cold” except while welding unless the switch is operated. The trigger on the welding gun or foot switch or programmer closes the contactors which energize the welding circuit. Arc voltage is normally not as hazardous as ordinary household voltage.

3. Arc Radiation Hazard

The electric arc is a very powerful source of light–visible, ultraviolet, and infrared. It is necessary that welders and others close to the welding arc wear suitable protection from the arc radiation. The brightness and exact spectrum of a welding arc depend on the welding process, the metals in the arc, the arc atmosphere, the length of the arc, and the welding current. The higher the current and arc voltage the more intense the light from the arc. Arc light radiation like all radiation decreases with the square of the distance. Those processes that produce smoke surrounding the arc have a less bright arc since the smoke acts as a filter. The spectrum of the welding arc is similar to that of the sun. Exposure of the skin and eyes to the arc is the same as exposure to the sun. In spite of claims by some people, arcs do not emit x-radiation. However, during the grinding of the thoriated tungsten electrodes, radioactive dust is created. The thoria is slightly radioactive. It creates the potential hazard of internal radiation exposure by inhalation or ingestion. That is why it is necessary to control the dust.[13]

Heat is radiated from the arc in the form of infrared radiation. The infrared radiation is harmless provided that the proper eye protection and clothing are worn. To minimize light radiation, screens should be placed around the welding area so that the people working nearby are shielded from the arc. Welders should attempt to screen all people from their arc. Screens and surrounding areas, especially welding booths, should be painted with paints that absorb ultraviolet radiation. The paint finish should have a low reflectivity to ultraviolet radiation.

Eye Protection

Welders must use protective welding helmets with special filter plates or filter glasses. The welding helmets should be in good repair since openings or cracks can allow arc light to get through and create discomfort. The curved front welding helmet as shown in Figure 9 is preferred because it helps reduce the amount of welding fumes that come to the welder’s breathing zone. Fiberglass or light weight is recommended. Some welding helmets can be attached to safety hard hats for industrial and construction work. Welding helmets have lens holders for inserting the cover glass and filter glass or plate. The standard size filter plate is 2 x 4-1/4 in. (50 x 108 mm). In some helmets, the lens holders will open or flip upwards. Helmets which accommodate larger-size filter lenses are also available. The larger filter glasses are 4 1/2 x 5-1/4 in. (115 x 133 mm) and are more expensive.

The filter glasses or plates come in various optical densities to filter out a portion of the arc rays. The shade of the filter glass used is based on the welding process and the welding current. Figure 10 shows the suggested filter shades according to the American Welding Society F2.2 Lens Shade Selector.[14]. A cover plate should be placed on the outside of the filter glass to protect it from weld spatter. Plastic or glass plates are used. Some welders also use magnifier lenses behind the filter plate to provide clearer vision. The filter glass must be tempered so that it will not break if hit by flying objects. Filter glasses must be marked showing the manufacturer, the shade number, and letter “H” indicating that it has been treated for impact resistance.

Several new types of filter lens for welding helmets have been introduced. One type of filter glass utilizes a thin layer of liquid crystals sandwiched between two pieces of clear glass. The liquid crystals employed have the special properties so that when an electrical signal is placed across them they will change their ability to transmit light. When electrically changed, liquid crystals produce a screen with the same approximate density as the

Figure 9 - Curve type helmet offers best protection.

welding filter glass. A photosensor on the helmet is triggered by the light from the arc. Within a fraction of a second this signal is transmitted through the liquid crystals which change the density of the filter glass. Another type of filter becomes darker when exposed to the bright light of the arc. These filters are becoming more popular. They eliminate the need for opening and closing or repositioning the welding helmet by a rapid head nod.

Safety glasses should always be worn in an active work area underneath the welding helmet. These are required since the helmet is usually lifted when slag is chipped or welds are ground. Tinted safety glasses with side shields are recommended. People working around welders should also wear tinted safety glasses with side shields. Safety glasses should meet all the requirements of ANSI Z87.1 "Occupational and Educational Personal Eye and Face Protection Devices" standard.

Contact Lenses

The wearing of contact lenses by welders is the subject of erroneous and recurring rumors. Various authorities, including the National Society to Prevent Blindness, the Contact Lens Association of Ophthalmologists, and others, state that the normal eye protection required by OSHA for welding, brazing and soldering is the same with or without contacts, The American Optometric Association adopted a policy statement saying that contact lenses may be worn in hazardous environments but only with appropriate normal safety eye wear. Contact lenses themselves do not provide eye protection in the industrial sense. As a general rule, if an employee habitually wears contact lenses, they should be allowed to wear their lenses but only with the addition of normal safety equipment. It was further noted that the radiation from a welding arc or flash is not intense enough to affect the materials from which contact lenses are made. Welders or anyone who may be exposed to a welding flash or arc must always wear appropriate safety goggles over their contact lenses. Eye experts unanimously agree that it is impossible for an electric arc to weld contact lenses to the eye. The American Optometric Association says that reports of this hazard are based on rumor and have been thoroughly discredited.

On occasion, welders and others will have their eyes exposed to the arc for a short period of time. This can result in what is known as *arc burn*, *arc flash*, or *welding flash*, and is technically called *photokeratitis*. It is very similar to a sunburn of the eye. For a period of approximately 24 hours the welder will have the painful sensation of sand in the eyes. The condition is normally of temporary duration and should not last over 48 hours. People who receive an arc flash may not be aware of it at the time. The first indication of an arc burn may occur 6 to 12 hours later. Temporary relief can be obtained by using eyedrops and eye washes. If the painful sensation lasts beyond one day, a doctor should be consulted for treatment.

Transparent Welding Curtains

Transparent welding curtains or screens made of plastic film are sometimes used for screening welding operations. Figure 11 shows an application of these screens. The material is relatively tough, available in large sheets, and comes in blue, green, gray and yellow. Tests have been performed by the National Institute of Occupational Safety and Health[15], and it is concluded that these curtains provide protection in the ultraviolet range.

Courtesy of Wilson Industries, Inc.
and the Welding Journal, American Welding Society.

Figure 11 - Welding station using transparent welding screen.

The material is flame resistant. In no case can this curtain material be substituted for filter glass in helmets. It is intended to protect nearby workers from arc flash and improve communication with welders. In some applications it may be an improvement over opaque curtains or shields.

Welding operations should be isolated from metal-degreasing or solvent-cleaning operations. Chemical-degreasing tanks may use trichloloethylene or other chlorinated hydrocarbons which will decompose to poisonous phosgene gas when exposed to arc (ultraviolet) radiation. Poisonous phosgene gas can build up to dangerous concentrations which will be potentially harmful. Fortunately, the odor of phosgene gas is quickly recognized (it smells like new mown hay) and if it is detected, the area should be evacuated and ventilated.

Guide for Shade Numbers

(from AWS F2.2, *Lens Shade Selector*)

Shade numbers are given as a guide only and may be varied to suit individual needs.

Process	Electrode Size in. (mm)	Arc Current (Amperes)	Minimum Protective Shade	Suggested* Shade No. (Comfort)
Shielded Metal Arc Welding (SMAW)	Less than 3/32 (2.4)	Less than 60	7	—
	3/32–5/32 (2.4–4.0)	60–160	8	10
	5/32–1/4 (4.0–6.4)	160–250	10	12
	More than 1/4 (6.4)	250–550	11	14
Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)		Less than 60	7	—
		60–160	10	11
		160–250	10	12
		250–500	10	14
Gas Tungsten Arc Welding (GTAW)		Less than 50	8	10
		50–150	8	12
		150–500	10	14
Air Carbon Arc Cutting (CAC-A)	(Light)	Less than 500	10	12
	(Heavy)	500–1000	11	14
Plasma Arc Welding (PAW)		Less than 20	6	6 to 8
		20–100	8	10
		100–400	10	12
		400–800	11	14
Plasma Arc Cutting (PAC)		Less than 20	4	4
		20–40	5	5
		40–60	6	6
		60–80	8	8
		80–300	8	9
		300–400	9	12
		400–800	10	14
Torch Brazing (TB)		—	—	3 or 4
Torch Soldering (TS)		—	—	2
Carbon Arc Welding (CAW)		—	—	14

	Plate Thickness		Suggested* Shade No. (Comfort)
	in.	mm	
Oxyfuel Gas Welding (OFW)			
Light	Under 1/8	Under 3	4 or 5
Medium	1/8 to 1/2	3 to 13	5 or 6
Heavy	Over 1/2	Over 13	6 or 8
Oxygen Cutting (OC)			
Light	Under 1	Under 25	3 or 4
Medium	1 to 6	25 to 150	4 or 5
Heavy	Over 6	Over 150	5 or 6

*As a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding, cutting, or brazing where the torch and/or the flux produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line of the visible light spectrum.

Figure 10 - Eye protection filter shade selector

As a protective measure, degreasing operations should be at least 200 ft away from welding operations. If this is not possible adequate ventilation is required. Care should be taken when welding parts that have been cleaned with these solvents. The parts must be thoroughly dry before welding.

Ultraviolet rays from the arc, particularly the high-intensity gas tungsten arc on aluminum, react with the oxygen in the atmosphere to produce ozone. Ozone is an active form of oxygen which has a pungent characteristic smell. It is sometimes evident after a lightening strike or in the generating room of a power house. It is relatively unstable and quickly changes back to oxygen. Exposure to ozone will cause a burning sensation in the throat, coughing or chest pains or wheezing in the chest during breathing. Ventilation should be used so that ozone concentration will be below the threshold limit values.

Warning signs should be posted in welding areas advising visitors not to look at the arc since arc flash may injure eyes.

4. Air Contamination Hazard

Arc and flame, welding and cutting, produce air contamination. This is seen as smoke rising above the welding or flame operation. The smoke or plume appears similar to smoke rising from a wood fire. Normal ventilation practice reduces the hazards of smoke from welding, cutting, or from an open fire. The fumes contain two types of air contamination - particulate matter and gases.

The welding industry sponsored research to investigate the welding atmosphere and to recommend precautions to avoid potential hazards. This includes a series of reports entitled "Effects of Welding on Health"[4] mentioned previously, starting in 1979 and continuing. The American Welding Society's study entitled "The Welding Environment"[16], and several other studies indicate that there is no significant health difference between welders and nonwelders when proper ventilation is used.

A precautionary label which was introduced in 1967 stated "***Caution***: *Welding may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. Use adequate ventilation. See American National Standard Z49.1 Safety in Welding and Cutting" published by the American Welding Society".*

This precautionary label has been revised to be more encompassing and is shown in Figure 1. A similar precautionary label for oxy-fuel gas processes is shown in Figure 7. The purpose of these labels is to remind welders and others of the potential hazards. That way adequate steps can be taken to protect personnel from concentrations that might be harmful. The potential harm from fumes and gases depends upon many factors including:

- The chemical composition of the particular matter;
- The concentration at the welder's breathing zone;
- The length of time of exposure to these fumes and gases.

Particulate Matter

Particulate matter is extremely small solids suspended in the air. Smoke is an example of particulate matter. Particulate matter includes common house dust, powders, pollen, smog, flash, grinding dust, etc. These range in size from less than 0.1 micron to over 100 microns. The smaller diameter particulates can only be seen with the microscope, while the larger ones can be seen with the human eye. The type of particulate matter depends on the welding process, the type of welding electrode or filler metal, the welding current employed, the welding location, atmospheric conditions, wind and so on. It also depends on the compositionof the base metal being welded, and on any coating on the base metal near the arc. All welding smoke is not the same and the concentration can vary over a wide range.

Many investigations and tests have been made to determine the composition of fumes generated. This is presented in the AWS publication "The Welding Environment"[16] mentioned previously, and was based on using different welding and allied processes. Much data is presented in the document "Fumes and Gases in the Welding Environment".[17] Some research to determine fume generated by arc welding is given by the document "Characterization of Arc Welding Fume".[18] In general, welding with mild steel electrodes on clean steel produces fumes containing a high proportion of iron oxide and small amounts of calcium oxide, titanium oxide, and amorphous silica.

The fumes produced when welding with low hydrogen type electrodes contain the oxides mentioned above and fluorides. When welding with stainless steel electrodes, the iron oxide is lower but there are now oxides of chromium and nickel as well as fluorides. Electrode manufacturers supply Material Safety Data Sheets (MSDSs) for each container of filler metal, which show the composition of the coating on electrodes, fluxes or flux cores. MSDSs may also include the composition of particulate matter produced as these electrodes are consumed in the arc. Due to the high temperature of the arc, the composition of the particulate matter is different than that of the coating. Similar information is provided for oxyfuel gas materials.

The flux cored arc welding process can produce a great deal of particulate matter, or smoke. However, for a similar amount of weld metal deposited, the particulate matter of SMAW and FCAW is similar. The gas metal arc welding process produces much less particulate matter. The submerged arc process produces a very small amount of particulate matter as do the gas tungsten and plasma arc welding processes.

The base material is another source of particulate matter. The base metal, when melted by an arc, may volatilize and produce airborne contaminants. Chromium and nickel compounds are found in the fume when stainless steels are arc welded. The International Agency for Research on Cancer has determined chromium and nickel welding fumes *are possibly carcinogenic to humans* (Group 2B)[40]. The American Welding Society has developed a standardized method for measuring and determining the particulate matter produced by different welding processes. This method is outlined by the AWS document "Methods for Sampling Airborne Particulates Generated by Welding and Allied Processes".[19] By using this technique, measurements can be made to determine contamination.

Certain metals identified as "low allowable-limit materials" in ANSI Z49.1[3] should not be welded without the use of mechanical exhaust systems or respiratory protection. These low allowable-limit materials are antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, ozone, selenium, silver, and vanadium. Arc welding should not be done on any of these materials unless mechanical ventilation is employed or unless the welder uses respiratory protection.

Airborne contaminants are produced when welding or cutting on coated materials. Base metal coated with any of the above metals must be treated with caution and mechanical ventilation or respiratory protection must be provided. Other coatings such as paint, varnish, plastic, and oil can also generate contamination. The coatings must be removed from the welding area or else mechanical ventilation must be provided. A serious problem can be encountered when old steel work is flame cut or welded. Often older structural steel may be covered with many coats of lead bearing paint. The heat of the arc or flame will cause the coating to volatilize and produce smoke containing lead. New pipe is often coated with a plastic protective material. This must be removed from the arc area. In every case, adequate ventilation or respiratory protection for the welder must be employed.

Gases

Gases are produced or may be involved in many of the processes using flames. Gases are produced as products of combustion with the fuel gas processes. Gas is produced by some of the constituents of the coating on the shielded metal arc welding electrode or the material contained in the core of a flux cored electrode wire. These coatings and contained materials are designed as a part of the consumable filler metal to produce gases to help shield the arc area from the atmosphere. Packages of filler metals also carry a precautionary label.

Fluxes used for gas welding and brazing, and for submerged arc welding and electroslag welding will also produce gases. Brazing and gas welding fluxes sometimes contain fluoride which, upon heating or melting, produces small amounts of fluorine in the atmosphere. Packages containing these types of fluxes are labeled as shown in Figure 12. Brazing filler metals containing cadmium are labeled as shown in Figure 13. These products produce potentially harmful fumes and gases and proper ventilation should be employed.

Carbon dioxide is the most common gas produced by the disintegration of electrode coatings or materials in flux cored electrode wires. The CO_2 is used to help protect the arc area from the atmosphere. There is a possibility of carbon monoxide, a very hazardous gas, being produced in the arc. Carbon monoxide, however, readily recombines with available oxygen in the heated atmosphere to produce CO_2 gas. Carbon monoxide is rarely found beyond a short distance away from the arc area.

Ozone is sometimes produced by the ultraviolet light emitted by the arc. Ozone is a form of oxygen with a chemical formula of 0_3 and is over 1 1/2 times as dense as oxygen. Ozone is more often produced in the arc welding processes that do not employ fluxes or coatings. Ozone changes back to normal oxygen a short distance from the arc.

The gas shielded welding processes use various gases to shield the arc area from the atmosphere. Inert gases are used for gas tungsten arc welding and for plasma arc welding, but active gases or mixtures of active and inert gases are used for gas metal arc and flux cored arc welding. Adequate ventilation is required to remove these gases from the welders breathing zone.

WARNING: CONTAINS FLUORIDES:
Protect yourself and others. Read and understand this information.

FUMES AND GASES CAN BE HAZARDOUS TO YOUR HEALTH. BURNS EYES AND SKIN ON CONTACT. CAN BE FATAL IF SWALLOWED.

- **Before use, read and understand the manufacturer's Instructions, Material Safety Data Sheets (MSDSs) and your employer's safety practices.**
- **Keep your head out of the fume.**
- **Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area.**
- **Avoid contact of flux with eyes and skin.**
- **Do not take internally.**
- **Keep children away when using.**
- **See American National Standard ANSI Z49.1, *Safety In Welding, Cutting, and Allied Processes,* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; OSHA *Safety and Health Standards,* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington, DC 20401.**

First Aid: If contact in eyes, flush immediately with clean water for at least 15 minutes. If swallowed, induce vomiting. Never give anything by mouth to an unconscious person. Call a physician.

DO NOT REMOVE THIS INFORMATION

Figure 12 - Precautionary information for brazing and welding fluxes containing fluorides

DANGER: CONTAINS CADMIUM

Protect yourself and others. Read and understand this information.

FUMES ARE POISONOUS AND CAN KILL.

- **Before use, read and understnd the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.**
- **Do not breathe fumes. Even brief exposure to high concentrations should be avoided.**
- **Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area. If this cannot be done, use air supplied respirators.**
- **Keep children away when using.**
- **See American National Standard ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; OSHA *Safety and Health Standards* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington, DC 20401.**
- **First Aid: If chest pain, shortness of breath, cough, or fever develop after use, obtain medical help immediately.**

DO NOT REMOVE THIS INFORMATION

Figure 13 - Precautionary information for brazing filler metals containing cadmium

Confined or Enclosed Areas

All arc and flame operations and associated operations, carried out in confined or restricted spaces must be adequately ventilated to prevent the accumulation of toxic materials, combustible gases or oxygen deficiency.

Generally speaking, an enclosed area, also called a confined space, is a relatively small or restricted space such as a tank, vat, pressure vessel, boiler, compartment, small room, tunnel or any enclosure which may have poor ventilation. It may also have restricted entry and exit. Even a large room or enclosure without proper ventilation can be considered a confined space. The upper corner of a room can even be a confined space when lighter than air gases can accumulate. An open pit can be a confined space when heavier than air gases can accumulate. These types of areas pose problems not only for welders, but for anyone working inside them. The potential hazards range from deficiency of oxygen, too much oxygen, poisonous gases, flammable or explosive gases, as well as the accumulation of dense smoke or particulate matter. Welding, flame cutting or allied processes should never be started without taking special precautions. Only work in such areas after they have been declared safe for work by supervision or management.

Everyone knows the risk of remaining in a closed garage with an automobile engine running. This can also be a potential problem with an engine driven welding machine. The exhaust gas given off by the engine should always be channeled to the outside. In enclosed areas, even large rooms, an engine driven welding machine if not exhausted to the outside can produce a build-up of carbon monoxide and carbon dioxide gas hazardous for people working within the room.

The same problem can occur when preheating weldments using the combustion of fuel gases, coal or charcoal for heat. The burning of these fuels will produce carbon monoxide and carbon dioxide which must be exhausted to the outside.

A “lookout” or watcher or attendant must be assigned to continually watch the welders and other workers, and have voice contact to those in the enclosed area. One lookout or attendant should be assigned to a team of welders working in a specific enclosed area. In some hazardous cases, lifelines with harnesses should be employed. Lifelines should be attached so that workers can be removed through manholes with ease.

Prior to entering enclosed areas, special precautions should be taken to determine the atmosphere within the enclosed area. Explosive concentrations of gases sometimes build up in an enclosed area. This could occur if an acetylene torch is left inside the compartment, or fuel gas could leak into the compartment, or products of decomposition were enclosed. The atmosphere within the enclosed area must be tested prior to entering the area. Portable explosimeters are available for sampling the atmosphere to determine if an explosive mixture is present.

Another problem relating to confined or enclosed areas involves oxygen enriched atmospheres. Oxygen enriched atmospheres can result from a leak in the oxygen line of an oxy flame cutting torch. Normally the atmosphere contains approximately 21% oxygen. If the oxygen would increase 5% or more, the enriched atmosphere would support rapid combustion, or even an explosive mixture. Striking an arc or starting a flame could be extremely hazardous. Clothes, oily cloths, and other combustible items would burn with an almost explosive violence. Oxygen from a compressed gas cylinder should never be used to help ventilate an enclosed compartment. It should never be used in place of compressed air suitable for breathing. When in doubt, portable instruments indicating oxygen concentration are available and should be used to sample the atmosphere before entering an enclosed compartment.

Oxygen deficiency can be another potential hazard for workers in an enclosed area. When using the gas shielded metal arc process, the two most popular shielding gases are both heavier than air. Both argon and carbon dioxide weigh approximately 1-1/2 times the weight of air and will displace it. Without proper ventilation, the used shielding gas will, in time, displace the air so that the atmosphere at the welder’s breathing zone will become rich in the shielding gas atmosphere and there will be a deficiency of oxygen. If the oxygen content in the breathing zone is reduced by 5% or more, serious damage or death can be the result to the worker. Whenever there is doubt, the atmosphere in an enclosed area must be monitored with a portable oxygen indicator.

Mechanical ventilation must be used for ventilating enclosed areas. Preferably both air exhaust systems and fresh air supply systems should be employed. When welding or cutting in any area that cannot be adequately mechanically ventilated, positive pressure, self contained breathing apparatus, or air line respirators must be used.

If you have questions concerning monitoring atmospheres or monitoring instruments, or special breathing apparatus, contact your company’s safety department or your local fire department or State Industrial Commission representative. Never ever work in a confined or enclosed area unless it has been declared safe by a qualified person, supervision, or management.

Ventilation

Adequate ventilation must be provided for all welding, cutting, brazing and related operations. Adequate ventilation means sufficient ventilation so that hazardous concentrations of airborne contaminants are below the allowable levels specified by OSHA or the American Conference of Governmental Hygienists (ACGIH). Adequate ventilation depends on many factors including the following:

1. Volume and configuration of the space where welding occurs.
2. Number and type of operations generating contaminants.
3. Allowable levels of specific toxic or flammable contaminants being generated.
4. Natural air flow and general atmospheric conditions where work is being done.
5. Location of welders’ and other persons’ breathing zones in relation to the contamination, contaminants, or sources.

Adequate ventilation can be obtained by using the following, either singly or in combination:

1. Natural ventilation
2. General mechanical ventilation
3. Local exhaust ventilation

Natural ventilation occurs when the welding is done out of doors. Natural ventilation can occur indoors, but only if the welding shop is sufficiently large. This means a space of 10,000 cu. ft. (284 cu. meters) per welder, with a ceiling height of more than 16 ft. (5 meters), and does not contain partitions, balconies, or other structural barriers that obstruct ventilaton. Natural ventilation must be supplemented when welding on hazardous materials.

General mechanical ventilation using roof exhaust fans, wall exhaust fans, or similar air movers must be used if the space per welder is less than 10,000 cu ft. (284 cu meters), or if the ceiling height is less than 16 ft. (5 meters), or if the shop includes partitions, balconies, or other structural barriers that obstruct cross ventilation. General mechanical ventilation is recommended to maintain a low level of airborne contaminants, and to prevent

accumulation of explosive gas mixtures. General mechanical ventilation is used for individual welding booths as shown in Figure 14. If general mechanical ventilation is not sufficient to maintain the general background level of airborne contaminants below the recommended limits, then local exhaust ventilation or local forced ventilation is required.

Local exhaust ventilation requires the use of fixed or movable exhaust hoods placed as near as practical to the work and able to capture sufficient contaminants to keep the level below the requirements.

Local exhaust ventilation can be obtained by the following methods:

1. Use of freely movable hoods, shown in figure 15, placed near the arc.
2. A fixed enclosure with a top and not less than two sides surrounding the welder with a sufficient rate of air flow.
3. Tables with down draft ventilation.
4. A smoke exhaust nozzle is built into the welding gun such as shown in Figure 16. Similar suction devices are available for covered electrode welding.

Figure 14 - Welding booths with mechanical ventilation

Photo courtesy of Kemper America, Inc.

Figure 15 - Moveable hood for local exhaust

Photo courtesy of Bernard Welding Equipment

Figure 16 - OXO APX® Air-cooled MIG welding gun showing smoke exhaust nozzle

This smoke exhaust gun system is based on collecting the fumes as close as possible to the point of generation or at the arc. This method of fume exhaust works well with semi automatic and robotic welding, particularly when using flux cored welding electrodes. The operation of this exhausting system is shown in Figure 17, which shows the smoke exhaust gun on and off. This system has proven economical since much less air is exhausted. This reduces the need for massive air make-up units to provide heated or cooled air to replace the air exhausted.

In all cases where local exhaust ventilation is used, the exhaust air should be filtered before it is discharged into the atmosphere or returned to the welding shop.

The use of movable hoods for local exhaust systems is further illustrated in Figure 18, which provides some details concerning the nozzle pick-up design. It shows typical volumetric air flow velocities to meet exhaust requirements. This is based on the *Industrial Ventilation: Manual of Recommended Practice*.[20]

Local forced ventilation means a local air moving system such as a fan placed so that it moves the air at right angles to the welder across the welder's face. It should produce a velocity of approximately 100 ft. per minute (30 meters per minute), and be maintained for a distance of approximately 2 ft. (.6 meters) directly across the work area. Be careful of how the air is directed. Keep it away from the arc zone. Higher velocities than 100 fpm can disturb the arc shielding. This will result in a defective weld.

Air velocity is relatively easy to measure using a velometer or air flow meter, thus it is easy to check the efficiency of local forced ventilation. Down-draft welding work tables are popular in Europe but have not been used to a very large degree in the United States or other parts of the world.

There is one foolproof method to determine if proper ventilation is being provided. This is done by collecting samples of the atmosphere at the welder's breathing zone under the helmet. A special pick-up device is mounted inside the welding helmet and atmosphere samples are collected for a specific time period. The samples are then chemically analyzed in calibrated instruments which determine the value of all elements that are found in the welder's breathing zone.

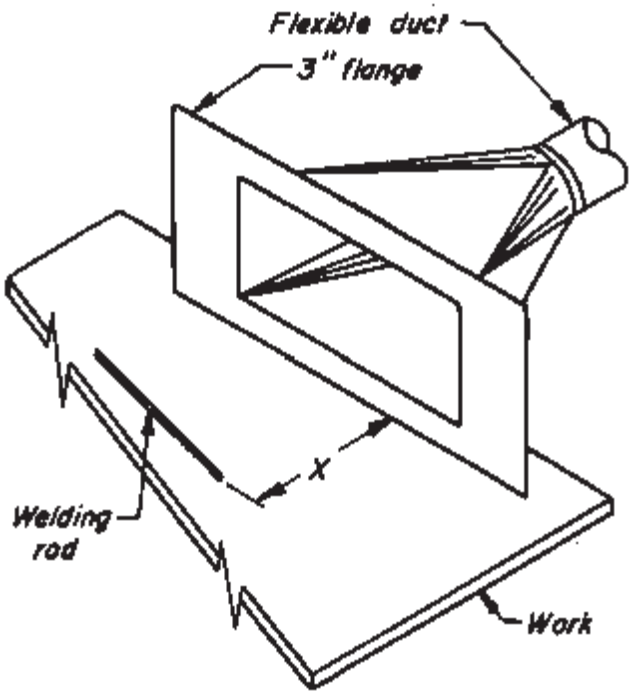


Figure 18 - Moveable hood for local exhaust

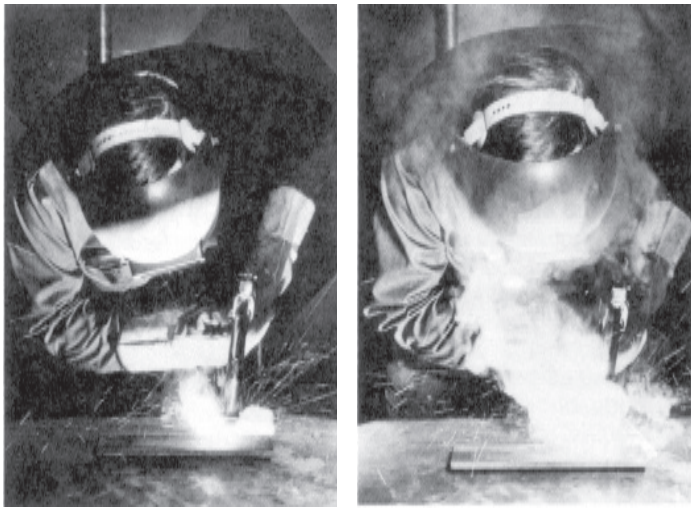


Figure 17 - Smoke exhaust gun on and off.

Two American Welding Society documents provide guidance in making these types of investigations—*Evaluating Contaminants in the Welding Environment, A Sampling Strategy Guide*[21], and *Laboratory Method for Measuring Fume Generation Rates and Total Fume Emission of Welding and Allied Processes*.[22] By following the teachings of these documents, it can be determined if the sample meets or exceeds the prescribed exposure limits. The threshold limit values (TLV®) of most hazardous materials are established by the American Conference of Governmental Industrial Hygienists, "Threshold Limit Values for Chemical Substances and Physical Agents in the Work Room Environment."[6] The determinations found in the welder's breathing zone should be below these TLV® limits. OSHA publishes permissible exposure limits (PELs). Analytical work of this type must only be done by highly qualified people who are familiar with welding operations, testing and sampling techniques, as well as the analytical methods to determine the amounts of contaminants found in the air samples taken from the welder's breathing zone. (*TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists.)*

PORTABLE EXHAUST

X INCHES	PLAIN DUCT CFM	FLANGE OR CONE CFM
up to 6	335	250
6 - 9	755	560
9 - 12	1335	1000

FACE VELOCITY = 1500 FPM
DUCT VELOCITY = 3000 FPM MINIMUM
PLAIN DUCT ENTRY LOSS = 0.93 DUCT VP
FLANGE OR CONE ENTRY LOSS = 0.25 DUCT VP

GENERAL VENTILATION, WHERE LOCAL EXHAUST CANNOT BE USED:

ROD, DIAM	CFM / WELDER
5/32	1000
3/16	1500
1/4	3500
3/8	4500

OR

A. For open areas where welding fume can rise away from the breathing zone: cfm required = 800 x lb/hour rod used

B. For enclosed areas or positions where fume does not readily escape breathing zone: cfm required = 1600 x lb/hour rod used.

For toxic materials, higher airflows are necessary and operator may require respiratory protection equipment.

5. Fire and Explosion Hazard

A large number of the fires are caused by cutting and welding in areas not specifically designated or approved for such work. The three elements of the fire triangle, fuel, heat, and oxygen are present in most welding operations. The heat is from the torch flame, the arc or from hot metal. The fuel is from the fuel gas employed, or from combustibles in the welding area. The oxygen is present in air but may be enriched by oxygen used with the fuel gas. Many of these fires have been caused by sparks and spatter. These are globules of oxidized molten metal which can travel up to 35 ft. (11 meters). Sparks may also fall through cracks, pipe holes, or other small openings in floors and partitions and start fires in other areas. That is why you should always be alert to fires in hidden areas.

Hot pieces of metal may come in contact with combustible materials and start fires. Fires and explosions have also been caused when this heat is transmitted through walls to flammable atmospheres or to combustibles on the other side. Anything that is combustible or flammable is susceptible to ignition by cutting and welding. Welding or cutting on metal which is in contact with foam insulation is especially hazardous. All insulating organic foams whether indicated fire retarded or not, should be considered combustible and handled accordingly.

Cutting and welding fires can be prevented by eliminating or protecting all combustibles in the welding area. Welding arcs or oxy fuel gas flames rarely cause fires when used in areas designed for welding and cutting. Fire and explosion hazards should be considered from two points of view: welding in designated areas and welding with portable equipment in all other areas.

Safe Work Areas

A workplace can be designed for safe welding and cutting operations. Floors, walls, ceilings, etc., must be constructed of noncombustible materials. The work area must be kept clean and free of combustible and flammable materials. All fuel gas lines, manifolds, branches, etc., must be installed in accordance with specifications and codes.

Fire-fighting equipment must be installed in the welding workshop areas. The types of extinguishers for the possible different types of fires should be available and identified for the type of fires that might occur. Management must assure that supervisors and workers are trained in safe work practices.

Fuel Gases

There are a number of different fuel gases used for welding and flame cutting. The most familiar is acetylene, but propane, natural gas, methylacetylene-propadiene stabilized, etc. are also used.

Acetylene is sometimes produced on the premises by an acetylene generator. An acetylene generator uses carbide and water to produce acetylene which is then piped through the plant to the welding and cutting departments. Acetylene generators must be installed properly, maintained properly, and operated only by trained and qualified people. Carbide must be stored properly and never exposed to moisture or water which creates more acetylene to feed fires and cause explosions.

Acetylene cylinders and other fuel gas cylinders should be stored in a specified well-ventilated area or outdoors away from oxygen and in the vertical position. This will avoid the accumulation of explosive gas mixtures. All cylinders in storage should have their caps on and cylinders, either filled or empty, should have the valve closed. In a fire situation there are special precautions that should be taken for acetylene cylinders.[23] All acetylene cylinders are equipped with one or more safety relief devices constructed with a low melting point metal. This fusible metal melts at about the boiling point of water (212°F or 100°C). If fire occurs on or near an acetylene cylinder the fuse plug will melt. The escaping acetylene may be ignited and will burn with a roaring sound. Immediately evacuate all people from the area. It is difficult to put out such a fire. The best action is to spray water on the cylinder to keep it cool and to keep all other acetylene cylinders in the area cool. Attempt to remove the burning cylinder from close proximity to other acetylene cylinders, from flammable or hazardous materials, or from combustible buildings. It is best to allow the gas to burn rather than to allow acetylene to escape, mix with air, and possibly violently explode.

If the fire on a cylinder is a small flame around the hose connection, the valve stem, or the fuse plug, try to put it out as quickly as possible. Immediately move the cylinder out-of-doors where the leak may be fixed. A wet glove, wet heavy cloth, or mud slapped on the flame will frequently extinguish it. Thoroughly wetting the gloves and clothing will help protect the person approaching the cylinder. Avoid getting in line with the fuse plug which might melt at any time.

Apparatus

Gas welding or cutting apparatus must be listed with a nationally recognized independent testing laboratory. When ordering gas welding or cutting apparatus specify that it must carry the Underwriters Laboratory (UL) or Factory Mutual Engineering Corporation (FM) or equivalent seal of approval.

Gas apparatus must be properly maintained and repaired by qualified people. All too often apparatus is allowed to deteriorate before maintenance is performed. Welding gauges, welding regulators, welding torches, welding tips, etc., should all be carefully inspected periodically and maintained at the first sign of deterioration. Oil or grease should never be used on any gas welding or cutting apparatus. These and the following steps will prevent leaks, as well as fires and explosions.

Only approved gas hoses should be used with oxy-fuel gas equipment. The size of hose should be matched to the connectors, the regulators and torches. In the United States the color green is used for oxygen, red for the acetylene or fuel gas and black for inert gas and compressed air. International standards use different colors. The thread connections on hoses are right-handed for inert gases and oxygen and left-handed for fuel gases. The nuts on fuel gas hoses are identified by a groove machined in the center of the nuts. Hoses should be periodically inspected for burns, worn places, or leaks at the connections. They must be kept in good repair and should be no longer than necessary. Remember, these steps will help prevent leaks, fires and explosions.

Hot Work Permits

To prevent fires and explosions, welding permits or, as they are sometimes called, “hot work permits”, are often required. These permits must be used when welding or flame cutting is done where fires and explosions may occur. Management and supervision must assure workers are trained to recognize the need for hot work permits.

One source of sample hot work permits is the National Safety Council. The National Fire Protection Association (NFPA)[25] Publication 51B, “Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,” requires the use of hot work permits in areas not designated for hot work. Their sample permit form is shown in Figure 19. Your casualty insurance company may have similar permits. The National Fire Protection Association also recommends the use of a fire watcher or person trained in fire safety procedures. Supervision must assure hot work permits and firewatchers are used when required. When using portable equipment, these are

invaluable and can avoid the headlines stating that the fire was caused by "a welder's torch."

Firewatchers are persons trained to understand the inherent hazards of the work site and the hot work. They must assure conditions are safe during the hot work; and they must have the authority to stop the work if unsafe conditions develop. They shall have fire extinguishing equipment readily available and be trained in its use. They must be familiar with procedures for sounding an alarm in the event of a fire. They must watch for fires in exposed areas and try to extinguish them only if it is obviously within the capacity of the extinguishers. Otherwise, they must sound the alarm immediately. More than one firewatcher may be needed when hidden hazards or multiple hazardous areas are present.

It may be necessary to extend the firewatch period at times. Supervision must be alert for conditions where smoldering fires can occur. Fires are known to have occurred many hours after the hot work has ceased.

HOT WORK PERMIT

Seek an alternative/safer method if possible!

Before initiating hot work, ensure precautions are in place as required by NFPA 51B and ANSI Z49.1.
Make sure an appropriate fire extinguisher is readily available.

This Hot Work Permit is required for any operation involving open flame or producing heat and/or sparks. This work includes, but is not limited to, welding, brazing, cutting, grinding, soldering, thawing pipe, torch-applied roofing, or chemical welding.

Date	Hot work by ❑ employee ❑ contractor
Location/Building and floor _____	Name (print) and signature of person doing hot work
Work to be done _____	I verify that the above location has been examined, the precautions marked on the checklist below have been taken, and permission is granted for this work.
Time started _____ Time completed _____	Name (print) and signature of permit-authorizing individual (PAI)
THIS PERMIT IS GOOD FOR ONE DAY ONLY	

❑ Available sprinklers, hose streams, and extinguishers are in service and operable.

❑ Hot work equipment is in good working condition in accordance with manufacturer's specfications.

❑ Special permission obtained to conduct hot work on metal vessels or piping lined with rubber or plastic.

Requirements within 35 ft (11 m) of hot work
- ❑ Flammable liquid, dust, lint, and oily deposits removed.
- ❑ Explosive atmosphere in area eliminated.
- ❑ Floors swept clean and trash removed.
- ❑ Combustible floors wet down or covered with damp sand or fire-resistive/noncombustible materials or equivalent.
- ❑ Personnel protected from electrical shock when floors are wet.
- ❑ Other combustible storage material removed or covered with listed or approved materials (welding pads, blankets, or curtains; fire-resisteive tarpaulins), metal shields, or noncombustible materials.
- ❑ All wall and floor openings covered.
- ❑ Ducts and conveyors that might carry sparks to distant combustible material covered, protected, or shut down.

Requirements for hot work on walls, ceilings, or roofs
- ❑ Construction is noncombustible and without combustible coverints or insulation.
- ❑ Combustible material on other side of walls, ceilings, or roofs is moved away.

Requirements for hot work on enclosed equipment
- ❑ Enclosed equipment is cleaned of all combustibles.
- ❑ Containers are purged of flammable liquid/vapor.
- ❑ Pressurized vessels, piping, and equipment removed from service, isolated, and vented.

Requirements for hot work fire watch and fire monitoring
- ❑ Fire watch is provided during and for a minimum of 30 min. after hot work, including any break activity.
- ❑ Fire watch is provided with suitable extinguishers and, where practical, a charged small hose.
- ❑ Fire watch is trained in use of equipment and in sounding alarm.
- ❑ Fire watch can be required in adjoining areas, above and below.
- ❑ Yes ❑ No Per the PAI/fire watch, monitoring of hot work area has been extended beyond the 30 min.

 NFPA 51B

Figure 19 - Hot work permit

Welding on Containers

Any container or hollow body such as a can, tank, hollow compartment in a weldment, or hollow area in a casting, even though it may contain only air, must be given special attention before welding. No container shall be presumed to be clean or safe, but containers can be made safe for hot work. The heat from welding can cause trapped gas to expand. The expansion can create dangerously high pressure so that the part or container may explode. Always vent containers before welding or cutting. Hollow areas may also contain gases that are extremely dangerous when heated or exposed to an arc or flame. Therefore, drill or pierce a path into the hollow space to provide pressure relief.

Explosions and fires may result if welding or cutting is done on empty containers that are not entirely free of combustible reactive or toxic solids, liquids, vapors, dust, and gases. Cracks and crevices, as well as hidden joints, can contain hazardous materials. Containers can be made safe for welding or cutting by following prescribed steps. Refer to the American Welding Society's *Safe Practices for the Preparation of Containers and Piping for Welding and Cutting.*[26] No container should be considered clean or safe until proven so by tests.

Cleaning the container, which is normally made of metal, is necessary in all cases before welding or cutting. Cleaning should be done by experienced personnel familiar with the characteristics of the contents. Cleaning should be done outdoors. If this is impractical, the inside work area should be well ventilated so that hazardous vapors will be quickly carried away. Identify the material that was in the container and match the cleaning method to the material previously contained. Only a qualified person should designate and manage the cleaning process. No cleaning method is perfect, and after cleaning, the container should be inspected to determine that it is thoroughly cleaned.

When it is determined that the container is safe the container should be so marked, signed, and dated. Even after tanks have been made safe they can be filled with water as an added precaution before welding or cutting. Place the container so that it can be kept filled with water to within a few inches of the point where welding and cutting are to be done. Make sure that the space above the water level is vented so that the heated air can escape, as shown in Figure 20.

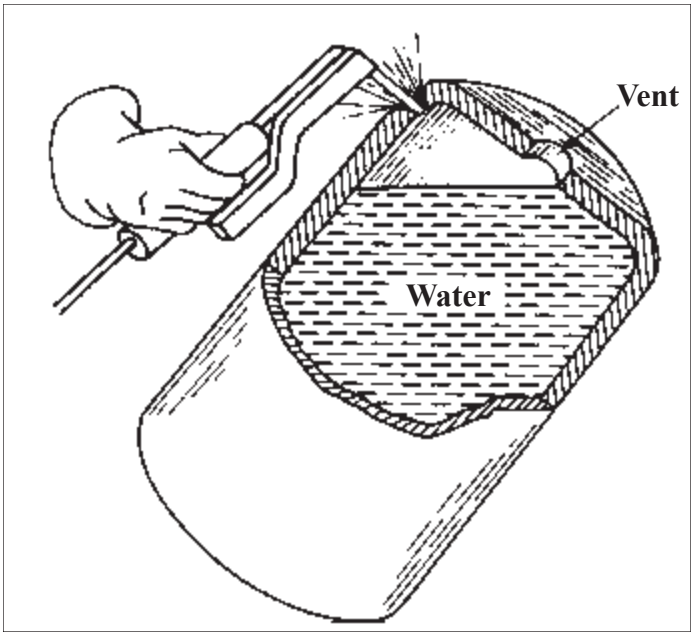


Figure 20 - Safe way to weld a container that held combustibles

As an alternate to the water-filling method fill the container with an inert gas. Flammable gases and vapors will be rendered nonflammable and nonexplosive if mixed with a sufficient amount of inert gas. Nitrogen or carbon dioxide is normally used. The concentration of flammable gases and vapors must be checked by testing. The inert gas concentration must be maintained during the entire welding and cutting operation. Hot work or welding permits should be utilized for all welding or cutting operations on containers that have held hazardous materials.

Hot Tapping

In pipe lines, welders sometimes do hot tapping. This is the welding of a special fitting to a line carrying a combustible liquid or gas and then cutting a hole in the pipe after the fitting has been welded to it. This must be done only by experienced people using special equipment with proper precautions. Refer to the American Petroleum Institute (API) publication, *Safe Hot Tapping Practices in the Petroleum and Petro-chemical Industries.*[27]

6. Compressed Gases

All compressed gas cylinders are potential hazards. One of the major hazards is the possibility of sudden release of the gas by removal or breaking off of the valve. The Compressed Gas Association (CGA) (Pamphlet V-1)has established a 0.300 inch (7.62 mm) maximum valve inlet diameter as a requirement to minimize the propulsion effect in case the valve is severed. Cylinders meeting the CGA requirements will rapidly release all of their gas which could be a health and/or a flammability concern. The gas release can cause a whistling sound and possibly spin the cylinder uncontrollably. Larger valve openings, such as those for propane, butane, or fire protection cylinders, may cause the cylinder to take off and become airborne.

Treatment of Gas Cylinders

Gases used for welding, fuel gases, oxygen, or shielding gases, are normally delivered in cylinders which are manufactured and maintained by the gas supplier in accordance with the regulations of the U.S. Department of Transportation (DOT). In Canada the Board of Transport Commissioners for Canada has this responsibility. In most countries there are laws and regulations concerning manufacturing, maintaining, and periodic inspection of portable cylinders for the storage and shipment of compressed gases. All compressed gas cylinders must be legibly marked to identify the gases contained by either the chemical or the trade name of the gas. There is no international uniform color coding for identification purposes, however some countries have standardized color marking systems. For additional information, refer to American Welding Society's Safety and Health Fact Sheet No. 30, "Cylinders: Safe Storage, Handling, and Use".[28] Always inspect cylinders for any damage and report this damage to your gas supplier.

Cylinder Storage

Oxygen cylinders should be stored separately from fuel gas cylinders and separate from combustible materials. Store cylinders in cool, well-ventilated areas. The temperature of the cylinder should never be allowed to exceed 125°F (52°C). Cylinders should be stored vertically and secured to prevent falling. The valve protection caps must be in place. When cylinders are empty they should be marked "Empty" and the valves must be closed to prevent contamination from entering. When the gas cylinders are in use, a regulator is attached and the cylinder should be secured by means of chains or clamps. Cylinders for portable apparatus should be securely mounted in specially designed cylinder trucks. Cylinders should be handled with respect. They should

not be dropped or struck. They should never be used as rollers. Hammers or wrenches should not be used to open cylinder valves that are fitted with hand wheels. They should never be moved by electromagnetic cranes. They should never be in an electric circuit so that the welding current could pass through them. An arc strike on a cylinder will damage the cylinder causing possible fracture, and requiring the cylinder to be condemned and taken out of service.

Oxygen

Oxygen is one of the most common gases carried in portable high-pressure cylinders. It should always be labelled "oxygen", never "air". Combustibles should be kept away from oxygen, including the cylinder, valves, regulators, and hose apparatus. Oxygen cylinders or oxygen apparatus should not be handled with oily hands or oily gloves. Oxygen does not burn, but will support and vigorously accelerate combustion of oil and grease and other flammable materials, causing them to burn with great intensity. Oil or grease in the presence of oxygen may spontaneously ignite and violently burn or explode. Oxygen should never be used in any air tools or for any of the purposes where compressed air is normally used. Escaping oxygen can enrich the work area, especially enclosed areas, and can create a fire or explosion hazard.

Fuel Gases

There are a number of fuel gases. All are compounds of carbon and hydrogen. All fuel gases are potentially hazardous and should be treated with respect.

When welding or cutting with oxygen and fuel gases the welder should be particularly alert to *backfires, sustained backfires,* and *flashbacks*. A *backfire* is a a momentary recession of the flame into the torch, potentially causing a flashback or sustained backfire. It is usually signaled by a popping sound, after which the flame may either extinguish or reignite at the end of the tip. This is caused by an obstruction of the gas flow or by an overheated or damaged tip. If this occurs the equipment should be shut down immediately and corrective action taken. A *sustained backfire* is the recession of the flame into the torch body with continued burning characterized by an initial popping sound followed by a squealing or hissing sound, potentially burning through the torch body. A *flashback* is the recession of the flame through the torch and into the hose, regulator, and/or cylinder, potentially causing an explosion. When this occurs, the equipment should be shut down immediately and corrective action should be taken. Some causes of flashback include improper pressures, distorted or loose tips, clogged or damaged tips, damaged seats and kinked hoses.

In extinguishing the oxygen fuel gas flame one recommended sequence is to first close the torch oxygen valve and then the torch acetylene or fuel gas valve. Some equipment manufacturers recommend closing the fuel gas valve first. In any case, follow the procedure recommended by the torch manufacturer. In starting a torch, it is usually recommended to first open the fuel gas valve slilghtly and, with a spark lighter, light the torch followed by opening the oxygen torch valve. Always read, understand and follow the recommendations of the equipment manufacturer.

Shielding Gases

Shielding gases are either inert or active. Typical inert gases are argon and helium and are stored in high-pressure cylinders. Nitrogen, considered inert in some cases, is also stored in high pressure cylinders. These cylinders must be treated with the same precautions as oxygen cylinders. The active gas normally used for weld shielding is carbon dioxide (CO_2).

7. Weld Cleaning and Other Hazards

The slag that often covers the deposited weld metal must usually be removed. Welds are often chipped and ground. Hand and power tools are employed and the materials removed are propelled through the air to become potential projectile or fire hazards. Safety glasses with side shields should be worn under the welding helmet.

Radioactive Hot Areas

Welders may be required to work in radioactive "hot" areas. This is due to repair and maintenance operations necessary in nuclear power plants. In such cases, extra special care and precaution must be taken to determine the radiation levels, time of exposure, radiation protection, and all other factors involved. The exposure time may be extremely short and welders may be used to set up automated welding devices and then leave the hot area to operate the devices remotely. Only qualified personnel with knowledge of working in and around radioactive areas should be permitted to make judgments of this type.

Noise

Weld chipping and weld peening produce excessive noise and should be controlled. Excessive noise can damage hearing and cause other injury. Noise exposure can cause either temporary or permanent hearing loss. OSHA regulations prescribe allowable noise exposure levels. Carbon arc gouging at high currents produces high noise levels and ear protection is required. Plasma arc cutting with high current also creates excessive noise and ear protection is required. Figure 21 shows a worker wearing suitable protection for noisy work. Noise measurement instruments are available and should be used to check noise in the work area so that precautionary measures can be taken. Normal arc weld operations do not exceed noise level requirements as specified by OSHA. In combination with other noise producing machinery, noise levels may be excessive. Noise levels can be measured and monitored by means of specialized instruments. The American Welding Society's *Arc Welding and Cutting Noise* (AWN)[29] should be consulted. It is necessary that trained personnel be used to measure noise. You can request help from your company's safety department or from the State Industrial Commission representatives. Noise levels are reduced fairly rapidly as the worker moves further away from the source of the noise.

Courtesy of Occupational Safety and Health Administration, Washington, DC.

Figure 21 - Worker wearing suitable ear protection for noisy work.

Other Hazards

Falling items create hazards. Hard hats should be worn in connection with welding helmets on construction sites and in some plants. Other hazards such as falling from high places, working with heavy objects, and working around heated metals are similar to the hazards encountered by all employees in plants, forging shops, structural shops, and so on. Welding electrode stubs act as rollers when stepped on at the wrong angle. Electrode stubs should be placed in containers and not thrown on the floor or working surface where others can step on them.

8. Safety for Specific Welding Processes and Occupations

The previous sections dealt primarily with arc welding and oxy-fuel gas welding, cutting and torch brazing. The other welding and allied processes can be hazardous if safety precautions are ignored. The potential hazards mentioned previously apply to most welding and allied processes since electricity, compressed gases, flames, heated metals or fumes are usually involved. Specific process applications or welding occupations involve other hazards. The following is an overview of some safety situations.

Underwater welding is one of the most hazardous welding occupations. Underwater work of any type is hazardous at any working depth. Welding in the dry, underwater, is welding in an atmosphere which is under pressure that is greater than sea level atmosphere pressure. Higher operating pressures create special hazards. The hazards of underwater welding in the wet in contact with the water or in a habitat are very complex and are only briefly mentioned here. More complete information concerning aspects of underwater welding are provided in the U.S. Navy's "Underwater Cutting and Welding" technical manual.[38] Also refer to American Welding Society's D3.6M "Specification for Underwater Welding." [41]

Robotic and automated welding are becoming more popular. Robot welding combines the potential hazards of welding with the hazards of moving metal working machinery. Robots operate outside their machine base area. They involve unanticipated motion, may start unexpectedly, and operate at relatively high rates of speed. Robots are normally safe since operators work outside the operating envelope of the robot. However, when programming robots or maintaining equipment, or troubleshooting welding problems, people work in close proximity to the robot's welding torch and are thus exposed to potential hazards.

The American Welding Society has several documents related to robotic welding. For safety information, refer to D 16.1, "Specification for Robotic Arc Welding Safety," [42] and D16.3, "Risk Assessment Guide for Robotic Arc Welding." [43]

Automated brazing and soldering involves moving equipment with the associated hazards. However fluxes and filler metals employed may give off noxious fumes when heated, especially when heated to temperatures normally above operating temperatures.

Adequate mechanical ventilation should be provided for all automated brazing and soldering operations to remove explosive or toxic gases. In addition, large quantities of liquid heated flux or filler metal creates hazards. Guards on motion devices must be properly designed and always in place.

The American Welding Society has many documents related to brazing and soldering. For some safety information, refer to "Braze Safely" [44] (BRS) and the "Brazing Handbook [45] (BRH). Also refer to the "Soldering Handbook" [46] (SHB).

Resistance welding operations involve some potential hazards. These are largely involved with motion since it is present with resistance welding equipment. Dual palm buttons are normally used to provide operator safety. Operators should wear face shields, safety glasses or goggles to protect the face and eyes from flying sparks that may be ejected from the weld area.

For further reference, consult the "Resistance Welding Manual,"[47] (RWM) and "Recommended Practices for Resistance Welding,"[48] C1.1, available from the American Welding Society.

Arc air cutting and gouging and plasma arc cutting at high currents creates noise of a level that may be harmful. Ear protection should be worn. Refer to American Welding Society's "Recommended Practices for Air Carbon Arc Gouging and Cutting,"[49] (C5.3) and "Recommended Practices fo Plasma Arc Cutting and Gouging,"[50] (C5.2).

Electron beam welding is an automated process but the motion is normally enclosed. In most cases a vacuum is involved with the welding chamber and normal precautions are required. In the high-voltage electron beam systems, x-rays are generated as electron beam strikes the work piece. Adequate shielding must be provided to protect the operator from x-rays. Refer to American Welding Society's "Recommended Practices for Electron Beam Welding,"[51] (C7.1).

Thermal spraying involves potential hazards in addition to those involved with arc welding and oxy-fuel gas welding. These involve the use of powders or wires which are atomized and sprayed on the workpiece. Large amounts of particulate matter are produced, which can create problems. For further reference, see American Welding Society's "Thermal Spray Manual,"[52] (TSM) and "Thermal Spraying Practice, Theory and Application,"[53] (TSS).

Laser welding is usually an automated operation. Lasers are used not only for welding but also for cutting and surface metal treatment. The equipment must definitely be installed in accordance with the manufacturer's recommendations. Certain classes of lasers generate radiation which can produce eye damage. This also relates to reflected laser light. Safety precautions require the use of special glasses and other protective materials. Helpful information can be found in American Welding Society's "Recommended Practices for Laser Beam Welding, Cutting, and Drilling,"[54] (C7.2).

Allied Processes

Continued attention to safe practice is required for all welding, cutting and allied processes. Common sense and the adoption of practices recommended in this book will help provide a safe workplace.

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Individual Hobart Technical Guides are available on these subjects:

Gas Tungsten Arc Welding (EW-470)

Shielded Metal Arc Welding (EW-472)

Gas Metal Arc Welding (EW-473)

Flux-Cored Arc Welding (EW-492)

Electroslag Arc Welding (EW-493)

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