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Welding Inspection Technology

WELDING INSPECTION TECHNOLOGY

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American Welding Society
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Welding Inspection and Certification

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Chapter 1—Welding Inspection and Certification

Introduction

In today's world there is increasing emphasis placed on the need for quality, and weld quality is an important part of the overall quality effort. This concern for product quality is due to several factors, including economics, safety, government regulations, global competition, and the use of less conservative designs. While not singularly responsible for the attainment of weld quality, the welding inspector plays a large role in any successful welding quality control program. In reality, many people participate in the creation of a quality welded product. However, the welding inspector is one of the "front line" individuals who must check to see if all of the required manufacturing steps have been completed properly.

To do this job effectively, the welding inspector must have a wide range of knowledge and skills, because it involves more than simply looking at welds. Consequently, this course is specifically designed to provide both experienced and novice welding inspectors a basic background in the more critical job aspects. This does not imply, however, that each welding inspector will use all of this information while working for a particular company. Nor does it mean that the material presented will include all of the information for every welding inspector's situation. Selection of these various topics is based on the general knowledge desirable for an individual to do general welding inspection.

The important thing to realize is that effective welding inspection involves much more than just looking at finished welds. Section 4 of AWS QC1, *Standard for AWS Certification of Welding Inspectors*, outlines the various functions of the welding inspectors. You should become familiar with these various responsibilities because the welding inspector's job is an ongoing process. A successful quality control program begins well before the first arc is struck. Therefore, the welding inspector must be familiar with many facets of the fabrication process. Before welding, the inspector will check drawings and specifications to determine such information as the configuration of the component, its specific weld quality requirements, and what degree of inspection is required. This review will also show the need for any special processing during manufacturing. Once welding begins, the welding inspector may observe various processing steps to assure that they are done properly. If all these subsequent steps have been completed satisfactorily, then final inspection should simply confirm the success of those operations.

Another benefit of this course is that it has been designed to provide the welding inspector with the necessary information for the successful completion of the American Welding Society's Certified Welding Inspector (CWI) examination. The ten chapters listed below are sources for examination information. The welding inspector must have at least some knowledge in each of these areas. Typically, the information presented will simply be a review, while sometimes it may represent an introduction to a new topic.

Chapter 1:	**Welding Inspection and Certification**
Chapter 2:	**Safe Practices for Welding Inspectors**
Chapter 3:	**Metal Joining and Cutting Processes**
Chapter 4:	**Weld Joint Geometry and Welding Symbols**
Chapter 5:	**Documents Governing Welding Inspection and Qualification**
Chapter 6:	**Metal Properties and Destructive Testing**
Chapter 7:	**Metric Practice for Welding Inspection**
Chapter 8:	**Welding Metallurgy for the Welding Inspector**
Chapter 9:	**Weld and Base Metal Discontinuities**
Chapter 10:	**Visual Inspection and Other NDE Methods and Symbols**

Additionally, selected technical references are included in the "Body of Knowledge" required. These include:

- A Selected Code (AWS D1.1, API 1104, etc.)
- AWS CM, Certification Manual for Welding Inspectors
- AWS A1.1, *Metric Practice Guide for the Welding Industry*
- AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*
- AWS A3.0, *Standard Welding Terms and Definitions*
- AWS B1.10, *Guide for the Nondestructive Examination of Welds*
- AWS B1.11, *Guide for the Visual Inspection of Welds*
- ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- AWS QC1, *Standard for AWS Certification of Welding Inspectors*
- AWS B5.1, *Specification for the Qualification of Welding Inspectors*

Who is the Welding Inspector?

Before turning our discussion to the technical subjects, let us talk about the welding inspector as an individual and the typical responsibilities that accompany the position. The welding inspector is a responsible person, involved in the determination of weld quality **according to applicable codes and/or specifications**. In the performance of inspection tasks, welding inspectors operate in many different circumstances, depending primarily for whom they are working. Thus, there is a special need for job specifications due to the complexity of some components and structures.

The inspection workforce may include destructive testing specialists, nondestructive examination (NDE) specialists, code inspectors, military or government inspectors, owner representatives, in-house inspectors, and others. These individuals may, at times, consider themselves "welding inspectors," since they inspect welds as part of their job responsibility. The three general categories into which the welding inspectors' work-functions can be grouped are:

- Overseer
- Specialist
- Combination Overseer—Specialist

The Overseer is usually one who oversees the duties of several inspectors.The specialist, on the other hand, is an individual who does some specific task(s) in the inspection process. A specialist may or may not act independently of an overseer. The nondestructive examination (NDE) specialist is an example of this category of inspector.

It is common to see inspectors serving as both overseer and specialist. Such an individual may be responsible for general weld quality judgments in each of the various fabrication steps, and be required to perform any nondestructive testing that is necessary. Fabricators may employ several overseer type inspectors, each having their own area of general weld inspection responsibility. Because inspection responsibility is divided in these cases, inspectors may have to rely on others for specific aspects of the total inspection program.

For the purposes of this course, we will refer to the welding inspector in general, without regard to how each individual will be used by an employer. It is impractical to address each individual's situation in the scope of this discussion.

To emphasize the differences in job requirements, let's look at some industries using welding inspectors. We see welding inspection being done in the construction of buildings, bridges and other structural units. Energy related applications include power generation facilities, pressure vessels and pipelines, and other distribution equipment requiring pressure containment. The chemical industry also uses welding extensively in the fabrication of pressure-containing processing facilities and equipment. The transportation industry requires assurance of accurate weld quality in such areas as aerospace, automotive, shipbuilding, railroad apparatus and off-road equipment. Finally, the manufacturing of consumer goods often requires specific weld quality requirements. With the diversity shown by this listing, various situations will clearly require different types and degrees of inspection.

Important Qualities of the Welding Inspector

The first, and perhaps the most important quality, is a professional attitude. Professional attitude is often the key factor for welding inspector success. Inspector attitude often determines the degree of respect and cooperation received from others during the performance of inspection duties. Included in this category is the ability of the welding inspector to make decisions based on facts so that inspections are fair, impartial and consistent. A welding inspector must be completely familiar with the job requirements. Inspection decisions must be based on facts; the condition of the weld and the acceptance criteria specified in the applicable specification must be the determining factors. Inspectors will often find themselves being "tested" by other personnel on the job, especially when newly assigned to some task. Maintaining a professional attitude helps overcome obstacles to successful job performance.

The individual who does welding inspection should possess certain qualities to assure that the job will be done most effectively. Figure 1.1 illustrates these qualities.

Next, the welding inspector should be in good physical condition. Since the primary job involves visual inspection, obviously the welding inspector should have good vision, whether natural or corrected. The AWS CWI program requires the inspector to pass an eye examination, with or without corrective lenses, to prove near vision acuity on Jaeger J2 at not less than 12 in, and complete a color perception test. Another aspect of physical condition involves the size of some welded structures. Welds can be located anywhere on very large structures, and inspectors must often go to those areas and make evaluations. Inspectors should be in good enough physical condition to go to any location where the welder has

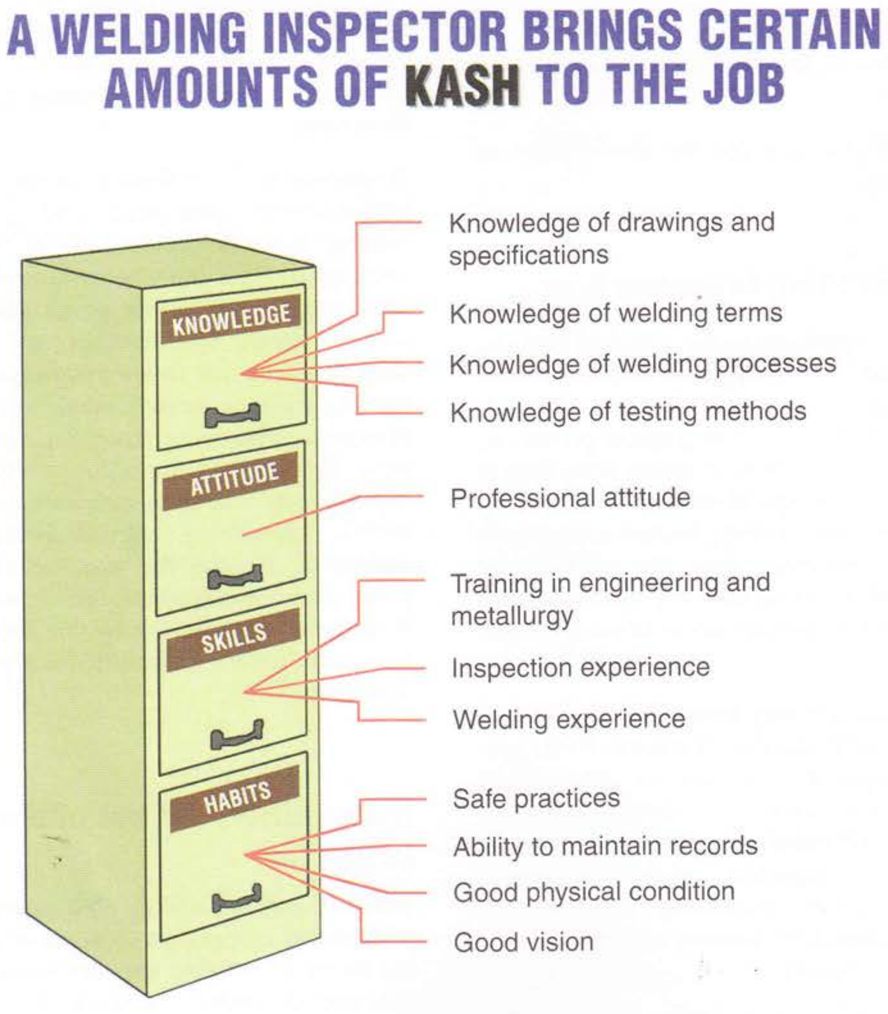

Figure 1.1—The Inspector Possesses a Great Amount of Knowledge, Attitudes, Skills, and Habits (KASH)

been. This does not imply that inspectors must violate safety regulations just to do their duties. Inspection can often be hampered if not done immediately after welding, because access aids for the welder such as ladders and scaffolding may be removed, making inspection impossible or dangerous. Within safety guidelines, welding inspectors should not let their physical condition prevent them from doing the inspection properly.

Another quality the welding inspector should develop is an ability to understand and apply the various documents describing weld requirements. These can include drawings, codes, standards and specifications. Documents provide most of the information regarding what, when, where and how the welding and subsequent inspections are to be done. Therefore, the rules or guidelines under which the welding inspector does the job can be found in these documents. They also state the acceptable quality requirements against which the welding inspector will judge the weld quality. It is important that these documents are reviewed before the start of any work or production because the welding inspector must be aware of the job requirements. Often this pre-job review will reveal required "hold points" for inspections, procedure and welder qualification requirements, special processing steps or design deficiencies such as weld inaccessibility during fabrication. Although welding inspectors should be thorough in their review, this does not mean that the requirements should be memorized. These are reference documents and should be readily available for detailed information any time in the fabrication process. Generally, inspectors are the individuals most familiar with all these documents so they may be called upon by others for information and interpretation regarding the welding.

Most people associated with welding inspection will agree that having inspection experience is very important. Textbooks and classroom learning cannot teach an inspector all of the things needed to inspect effectively. Experience will aid the welding inspector in becoming more efficient. Better ways of thinking and working will develop with time. Experience will also help the inspector develop the proper attitude and point of view regarding the job. Experience gained working with various codes and specifications improves an inspector's understanding of welding requirements and generally improves job effectiveness. To emphasize the need for inspection experience, we often see a novice inspector paired with an experienced one so the proper techniques can be passed along. Finally, we see that inspector certification programs require some minimum level of experience for qualification.

Another desirable quality of the welding inspector is a basic knowledge of welding and the various welding processes. Because of this, former welders are sometimes selected to be converted into welding inspectors. With a basic knowledge of welding, the inspector is better prepared to understand certain problems that a welder encounters. This aids in gaining respect and cooperation from the welders. Further, this understanding helps the welding inspector to predict what weld discontinuities may be encountered in a specific situation. The welding inspector can then monitor critical welding variables to aid in the prevention of these welding problems. Inspectors experienced in several welding processes, who understand the advantages and limitations of each process, can probably identify potential problems before they occur.

Knowledge of various destructive and nondestructive test methods are also very helpful to the welding inspector. Although inspectors may not necessarily perform these tests, they may from time to time witness the testing or review the test results as they apply to the inspection. Just as with welding processes, the welding inspector is aided by a basic understanding of testing processes. It is important for the inspector to be aware of alternate methods that could be applied to enhance visual inspection. Welding inspectors may not actually perform a given test but they may still be called upon to decide if the results comply with the job requirements.

The ability to be trained is a necessity for the job of welding inspector. Often, an individual is selected for this position based primarily on this attribute. Inspectors do their job most effectively when they receive training in a variety of subjects. By gaining additional knowledge, inspectors become more valuable to their employers.

Another very important responsibility of the welding inspector is safe work habits; good safety habits play a significant role in avoiding injury. Working safely requires a thorough knowledge of the safety hazards, an attitude that all accidents can be avoided, and learning the necessary steps to avoid unsafe exposure. Safety training should be a part of each inspector's training program.

A final attribute, which is not to be taken lightly, is the welding inspector's ability to complete and maintain inspection records. The welding inspector must accurately communicate all aspects of the various inspections, including the results. All records developed should be understandable to anyone familiar with the work. Neatness is important as well. The welding inspector should look at these reports as his or her permanent records should a question arise later. When reports are generated, they should contain information regarding how the inspection was done so, if necessary, it can be duplicated later by someone else with similar results. Once records have been developed, the welding inspector should facilitate easy reference later.

There are a few "rules of etiquette" relating to inspection reports. First, they should be completed in ink, or typewritten. (In today's "age of computers," typing of inspection reports into a computer system is a very effective way of making legible reports, easily retrieved when needed.) If an error is made in a handwritten report, it can be single-lined out in ink and corrected (the error should **not** be totally obliterated). This corrective action should then be initialed and dated. A similar approach is used when the reports are computer generated. The report should also accurately and completely state the job name and inspection location as well as specific test information. The use of sketches and pictures may also help to convey information regarding the inspection results. Then the completed report should be signed and dated by the inspector who did the work.

Ethical Requirements for the Welding Inspector

We have described some of the qualities which are desired of a welding inspector. In addition to those listed above, there are ethical requirements which are dictated by the position. Ethics simply detail what is considered to be common sense and honesty. The position of welding inspector can be very visible to the public if some critical dispute arises and is publicized. Therefore, welding inspectors should live by the rules and report to their supervisors whenever some questionable situation occurs. Simply stated, the welding inspector should act with complete honesty and integrity while doing the job since the inspection function is one of responsibility and importance. A welding inspector's decisions should be based totally on available facts without regard to who did the work in question.

The welding inspector's position also carries with it a certain responsibility to the public. The component and/or structure being inspected may be used by others who could be injured should some failure occur. While inspectors may be incapable of discovering every problem, it is their responsibility to report any condition that could result in a safety hazard. When performing an inspection, inspectors should only do those jobs for which they are properly qualified. This reduces the possibility of errors in judgment.

There are situations that occur that may be reported to the public. If the inspector is involved in a dispute regarding the inspection, he or she may be asked to publicly express an opinion. If stated, the opinion should be based totally on facts that the inspector believes to be valid. Probably the best way to deal with public statements, however, is simply to avoid them whenever possible. The inspector should not volunteer information just to gain publicity. However, in situations where a public statement is required, the welding inspector may wish to solicit the advice of a legal representative before speaking.

The ethical requirements of the job carry with them a great deal of responsibility. However, the welding inspector who understands the difference between ethical and unethical behavior should have little difficulty in performing the job with everyone's best interests in mind.

The Welding Inspector as a Communicator

An important aspect of the welding inspector's job is that of communication. The day-to-day inspection effort requires effective communication with many people involved in the fabrication or construction of some item. What must be realized, however, is that communication is not a one way street. The inspector should be able to express thoughts to others, and be ready to listen to a reply. To be effective, this communication sequence must be a continuous loop so that both parties have an opportunity to express their thoughts or interpretations (see Figure 1.2). It is wrong for any individual to think that their ideas will always prevail. Inspectors must be receptive to opinions to which a further response can be made. Often, the best inspector is one who listens well.

As mentioned, the welding inspector has to communicate with several different people involved in the fabrication sequence (see Figure 1.3). In fact, many situations occur where welding inspectors are the central figure of the communication network, since they will constantly be dealing with most of the people involved. Some people that the inspector may communicate with are welders, welding engineers, inspection supervisors, welding supervisors, welding foremen, design engineers, and production supervisors. Each company will dictate exactly how its welding inspectors function.

The communication between the welder and inspector is important to the attainment of quality work. If there is good communication, each individual can do a better job. Welders can discuss problems they encounter, or ask about specific quality requirements. For example, suppose the welders are asked to weld a joint having a root opening which is so tight that a satisfactory weld cannot be accomplished. They may contact the inspector to pass judgment and get the situation corrected right then rather than after the weld is rejected for being made improp-

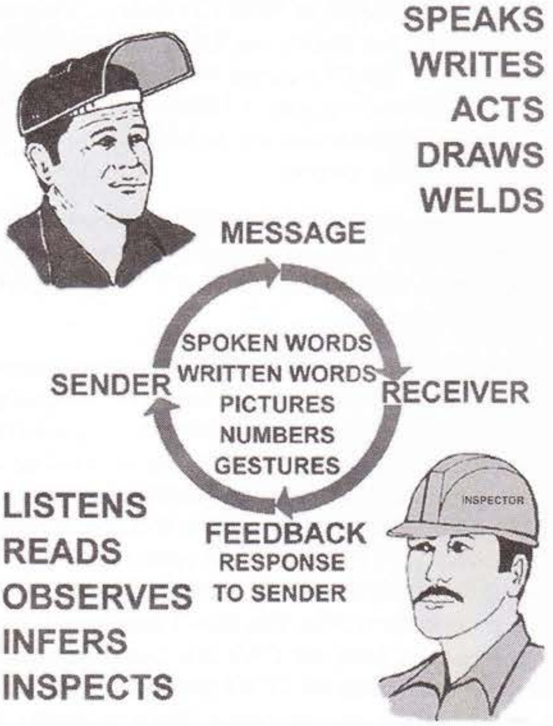

Figure 1.2—The Welding Inspector—A Communicator

erly. When effective communication occurs, the welding inspector has the opportunity to supply answers and/or begin corrective action to prevent the occurrence of some problem. The communication between the welder and an inspector is usually improved if the welding inspector has some welding experience. Then the welder has more confidence in the inspector's decisions. If there is poor communication between these two parties, quality can suffer.

Welding engineers rely heavily on welding inspectors to be their "eyes" on the shop floor or construction site. Engineers count on the inspector to spot problems relating to the techniques and processes specified. The welding inspector can also confirm whether specified procedures are being followed. The welding inspector, in turn, can ask the welding engineer about certain aspects of those procedures as well. Often, if a welding procedure is not producing consistent, reliable results, the welding inspector may be the first person to spot the problem. At that point, the welding engineer is notified so that adjustments can be made to alleviate the problem.

The welding inspector will probably work under the direction of some supervisor. This individual is responsible for verifying a welding inspector's qualifications to perform the work. The supervisor should also answer the

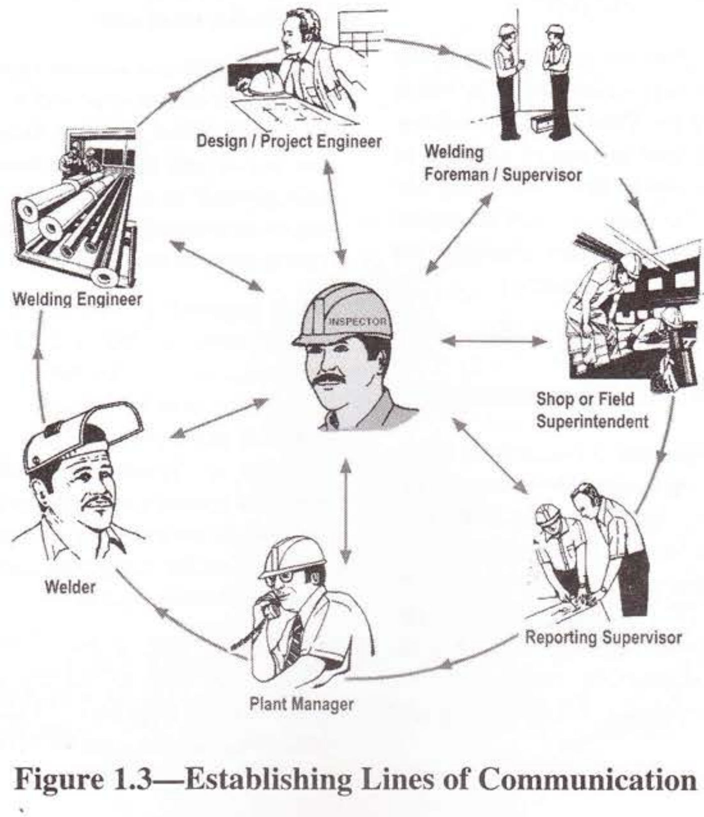

Figure 1.3—Establishing Lines of Communication

inspector's questions and aid in the interpretation of quality requirements. In some industry situations, the welding inspector must bring all questions to the supervisor. In turn the supervisor takes that question to someone in engineering, purchasing, etc. The welding inspector must convey a question clearly so it can be described properly by the inspection supervisor to the other party.

During the actual fabrication process, the welding inspector will have opportunities to speak with many other personnel. In some situations, instead of communicating directly with the welders, the welding inspector will deal with the welding supervisor or foreman. This usually involves specific quality requirements or explanations why some aspect of the welding is rejected.

The welding inspector may also have to gain information from design engineers about the actual weld requirements. During fabrication, other problems may arise which can only be answered by the person who actually designed the structure or component. Another way in which this aspect of communication takes place is through drawings and welding symbols. Although a powerful communication tool, welding and NDE symbols may require clarification by the symbol creator.

Finally, the welding inspector will have some occasion to discuss job scheduling with production personnel. This occurs especially when rejections have been noted which could alter the production schedule. It is important for the welding inspector to keep the production personnel aware of the status of the welding inspection.

When we talk of communication, we are not limiting our attention to speaking. There are several ways in which people effectively communicate. They include speaking, writing, drawing, gesturing, and the use of pictures or photographs. Each situation may be dealt with using one or more of these methods. The method is not as important as the fact that communication occurs; messages are sent, received and understood by all concerned.

Personnel Certification Programs

There are several programs presently available to determine whether an individual possesses the necessary experience and knowledge to perform welding inspection effectively. The American Society for Nondestructive Testing has issued guidelines for certification of NDE personnel in ASNT SNT-TC-1A. This document describes the recommended procedures for certifying inspectors performing nondestructive testing. ASNT recognizes three levels of certification: Levels I, II, and III.

AWS has also initiated an NDE Certification Program. Presently, AWS can certify one Level of Radiographic Interpreter (RI). The RI program certifies inspectors for interpreting weld radiographs. Additional NDE methods' certification is available through the joint efforts of AWS and outside training agencies.

For visual inspection of welds, AWS has developed the Certified Welding Inspector program. The front page of the Application form for the Certified Welding Inspector is shown in Figure 1.4.

AWS QC1, *Standard for AWS Certification of Welding Inspectors*, and AWS B5.1, *Specification for the Qualification of Welding Inspectors*, establish the requirements for AWS qualification and certification of welding inspection personnel. There are three levels of certification in AWS QC1. The Senior Certified Welding Inspector (SCWI) is a person with at least 15 years experience, including 6 years experience while certified as a Certified Welding Inspector (CWI). The SCWI must pass a separate examination from the CWI examination explained below. Information on the SCWI program and examination are found in a separate course, *Welding Quality Assurance and Inspection Manual—A Guide for the Senior Certified Welding Inspector*. The next certification level is the CWI and the third level is the Certified Associate Welding Inspector (CAWI). Both of these certifications are covered in this course. AWS QC1 and AWS B5.1 describe how personnel are qualified and certified, lists the principles of conduct, and notes the practice by which certification may be maintained. Those major elements will be discussed here.

The first step toward certification is the documentation of relevant educational and work experience. To qualify for the Certified Welding Inspector (CWI) examination, the individual must document his or her educational background. In addition, the candidate's years of welding-related experience according to some code or specification must be documented.

With supporting documentation (e.g., copies of transcripts, reference letters, credited hours of training, quarter hours or semester hours), up to two years of work experience may be substituted by post high school educational experience. Substituted educational experience includes an Associate or higher degree in engineering, physical sciences or engineering technology. Trade and vocational courses can be applied to work experience substitution for completed courses related to welding (up to one year maximum).

Candidates with a high school education, either by diploma or state or military equivalence, must have at least 5 years experience. Individuals with eighth grade schooling are required to have not less than 9 years job

American Welding Society

550 N.W. LeJeune Road, Miami, Florida 33126

APPLICATION FOR AWS WELDING INSPECTOR EXAMINATION

Please PRINT or TYPE

AWS USE ONLY

SITE CODE__________
1. Check #__________
2. Date Rec'd__________
3. Amount__________
4. Account #__________

SAMPLE

1a. CHECK THE EXAMINATION LEVEL YOU DESIRE

- ☐ A. Certified Welding Inspector **(CWI)**
- ☐ B. Certified Associate Welding Inspector **(CAWI)**

1b. Choose ONE of the following for the CODE BOOK test

- ☐ C-1 AWS D1.1
- ☐ C-2 API 1104
- ☐ C-3 ASME B31.1 & ASME Sec IX
- ☐ C-4 ASME Sec VIII & Sec IX

CHARGE MY: VISA AMEX MC DIN

CARD #__________
EXP. DATE__________

2. PERSONAL

LAST NAME FIRST MIDDLE INITIAL

STREET APT #

CITY STATE ZIP

LIST COMPANY NAME ONLY IF ADDRESS ABOVE IS COMPANY ADDRESS

TELEPHONE: AREA CODE AND NUMBER SOCIAL SECURITY NO. BIRTH DATE

3. AWS CERTIFICATION STATUS

a. Have you taken a previous AWS QC1 certification examination? ☐ YES ☐ NO

a.1. If Yes, give date and location__________

b. Have you ever been certified as an AWS QC1 ? ☐ YES ☐ NO

b.1. If Yes, print your certification no.__________

4. SIC CODES

SOURCE CODE: QC1

Type of Business (Check ONE only)

- A ☐ Contract construction
- B ☐ Chemicals & allied products
- C ☐ Petroleum & coal industries
- D ☐ Primary metal industries
- E ☐ Fabricated metal products
- F ☐ Machinery except elect. (incl. gas welding)
- G ☐ Electrical equip. supplies, electrodes
- H ☐ Transportation equip. - air, aerospace
- I ☐ Transportation equip. - automotive
- J ☐ Transportation equip. - boats, ships
- K ☐ Transportation equip. - railroad
- L ☐ Utilities
- M ☐ Welding distributors & retail trade
- N ☐ Misc. repair services (incl. welding shops)
- O ☐ Educational services (univ. libraries, schools)
- P ☐ Engr. & architectural services (incl. assns.)
- Q ☐ Misc. business services (incl. commercial labs)
- R ☐ Governments (federal, state, local)
- S ☐ other__________

Job Classification (Check ONE only)

- 01 ☐ President, owner, partner, officer
- 02 ☐ Manager, director, superintendent (or assistant)
- 03 ☐ Sales
- 04 ☐ Purchasing
- 05 ☐ Engineer — welding
- 06 ☐ Engineer — other
- 07 ☐ Inspector, tester
- 08 ☐ Supervisor, foreman
- 09 ☐ Welder, welding or cutting operator
- 10 ☐ Architect, designer
- 11 ☐ Consultant
- 12 ☐ Metallurgist
- 13 ☐ Research & development
- 14 ☐ Technician
- 15 ☐ Educator
- 16 ☐ Student
- 17 ☐ Librarian
- 18 ☐ Customer service
- 19 ☐ Other__________

Your Technical Interests (Place a number on line in choice order — 1-2-3, etc.)

- A ____ Ferrous metals
- B ____ Aluminum
- C ____ Non-fer. except aluminum
- D ____ Advanced mat'l/intermetalics
- ____ Ceramics
- F ____ High energy Processes
- G ____ Arc Welding
- H ____ Brazing & Soldering
- I ____ Resistance Welding
- J ____ Thermal Spray
- K ____ Cutting
- L ____ NDT
- M ____ Safety & Health
- N ____ Pipe & Tubing
- O ____ Pressure Vessels & Tanks
- P ____ Structures
- Q ____ Roll Forming
- R ____ Sheet metal
- S ____ Stamping & punching
- T ____ Bending & shearing
- U ____ Aerospace
- V ____ Automotive
- W ____ Machinery
- X ____ Marine
- Y ____ Other

Major product or service of your company__________

Figure 1.4—AWS Certified Welding Inspector Application Form

experience to qualify for the examination. For individuals with less than eighth grade schooling, not less than 12 years is required.

A subordinate level of qualification is the Certified Associate Welding Inspector (CAWI), which requires fewer years of experience for each educational level. All of the experience noted for both the CWI and CAWI must be work associated with some code or specification to be considered valid.

Individuals who qualify for the Certified Welding Inspector Examination take a three-part examination:

Part A—Fundamentals. The Fundamental examination is a closed book test consisting of 150 multiple choice questions. The topics covered in this portion of the exam include reports and records, destructive tests, welding performance, duties and responsibilities, weld examination, definitions and terminology, safety, welding and nondestructive examination symbols, nondestructive examination methods, welding processes, heat control, metallurgy, mathematical conversions and calculations.

Part B—Practical. The Practical examination consists of 46 questions. It requires measurement of weld replicas with provided measuring tools, and evaluation in accordance with a supplied "Book of Specifications." Not all questions require the use of the Book of Specifications; some require the individual to answer from practical knowledge. The Practical Test covers welding procedures, welder qualification, mechanical tests and properties, welding inspection and flaws, and nondestructive tests. Test candidates should be familiar with fillet and groove weld gauges, micrometers, dial calipers, and machinist's scales.

Part C—Open Book Code. This portion consists of questions on the code the individual has selected for this part of the examination. The following codes are applicable to this portion of the examination:

- **AWS D1.1.** The AWS D1.1, *Structural Welding Code—Steel*, examination covers the following subject areas: general requirements, design of welded connections, prequalification of WPSs, qualification, fabrication, inspection, stud welding and the annexes.
- **API 1104.** The API 1104, *Welding of Pipelines and Related Facilities*, examination covers the following subject areas: general, qualification of welding procedures, welder qualification, design and preparation of a joint for production welding, inspection and testing of production welds, standards of acceptability—NDT, repair or removal of defects, radiographic procedure, and automatic welding.
- **AWS D1.5.** The AWS D1.5, *Bridge Welding Code*, examination covers the following subject areas: general provisions, design of welded connections, workmanship, technique, qualification, inspection, stud welding, welded steel bridges, fracture control plan for nonredundant members and the annexes.
- **AWS D15.1.** The AWS D15.1, *Railroad Welding Specification for Cars and Locomotives*, examination covers welding of metal at least 1/8 in thick, specific requirements for welding railroad cars, and the requirements for the manufacturing and reconditioning of locomotives and passenger train vehicles.
- **ASME Section VIII and ASME Section IX, ASME B31.1, ASME B31.3.** ASME Section IX covers the qualification of Welding and Brazing Procedures, and Welders/Brazers. ASME B31.1 is the Power Piping code and ASME B31.3 the process piping code. The examination for ASME Section VIII and ASME Section IX covers the material, design, fabrication, inspection and qualification requirements for pressure vessel construction and welding and brazing qualifications. ASME Section IX, and ASME B31.1, ASME B31.3 covers the material, design, fabrication, inspection and qualification requirements and welding and brazing qualifications for power and process piping.

To successfully complete the examination, individuals must pass all three parts of the test. The passing score in each part for the CWI is 72%; the passing for CAWI is 60%. Beyond completion of the examination, the test candidate must undergo an eye examination to assure that the individual possesses adequate vision, whether natural or corrected. After all test results are successfully completed, the individual is considered qualified to perform visual inspection of welds. When AWS says that this individual is a Certified Welding Inspector, this simply implies that the person's qualifications are documented with an appropriate certificate. The CWI certificate does not state what code the inspector used on the examination, rather the CWI is qualified to use any code.

Welding inspectors are a very important part of any effective quality control program. While there are various categories of welding inspectors, in general they are considered to be those individuals responsible for evaluation of the resulting welding. These individuals must possess physical, mental and ethical qualities in order to be effective. The remaining chapters will detail those aspects of welding considered important for the welding inspector. In addition, these topics are also considered relevant to the AWS Certified Welding Inspector Examination. Therefore, this text is an appropriate guide for individuals to use in preparation for that series of examinations.

In preparation for that portion of the CWI examination covering welding inspector certification requirements, you are encouraged to read and become familiar with AWS QC1, *Standard for AWS Certification of Welding Inspectors*, and AWS B5.1, *Specification for AWS Qualification of Welding Inspectors*. Part of the welding inspector's job is the review and interpretation of various documents relating to the welded fabrication. This requires that the individual have a full understanding of the proper terms and definitions that are used. For this reason, included at the end of each chapter the reader will find, "Key Terms and Definitions" applicable to a chapter's topic. AWS realizes the need for standardized terms and definitions for use by those involved in the fabrication of welded products. In answer to this need, AWS A3.0, *Standard Welding Terms and Definitions*, was published.

AWS A3.0 was developed by the Committee on Definitions and Symbols to aid in welding information communication. Standard terms and definitions published in A3.0 are those that should be used in the oral and written language of welding. While these are the standard, or preferred, terms, they are not the only terms used to describe various situations. The purpose here is to educate, and it is often important to mention some of these common terms, even though they are not preferred terminology. When nonstandard terms are mentioned, they appear in parentheses after the preferred words.

While most of the terms used apply to the actual welding operation, it is important for the welding inspector to understand other definitions which apply to other related operations. Welding inspectors should understand how to describe weld joint configurations and fit up process elements requiring comment. After welding, the inspector may need to describe the location of a weld discontinuity that has been discovered. If a discontinuity requires further attention, it is important that the inspector accurately describe the location of the problem so that the welder will know where the repair is to be made. AWS recommends that standard terminology be used wherever possible, but the inspector must be familiar with nonstandard terms as well.

Key Terms and Definitions

API—American Petroleum Institute. The technical society which provides technical guidance for the petroleum industry.

API 1104—The API Standard, *Welding of Pipelines and Related Facilities*. This standard is often used in construction of cross-country pipelines.

ASME—American Society of Mechanical Engineers. The technical society which provides technical guidance for pressure containing vessels and equipment.

ASNT—American Society for Nondestructive Testing. The technical society which provides technical guidance for NDE.

AWS—American Welding Society. The technical society which provides technical guidance and leadership in all phases of welding.

AWS A3.0—The AWS *Standard Welding Terms and Definitions*. This standard defines welding-related terms with standard definitions.

AWS B5.1—The AWS *Specification for the Qualification of Welding Inspectors*.

AWS B5.11—The AWS *Specification for the Qualification of Radiographic Interpreters*.

AWS D1.1—The AWS *Structural Welding Code—Steel*. Used worldwide for construction of buildings and structures.

AWS D1.5—The AWS *Bridge Welding Code* used in the U.S. for construction of bridges.

AWS D15.1—The AWS *Railroad Welding Specification for Cars and Locomotives*. This specification covers welding of railroad cars and locomotives.

AWS QC1—The AWS *Standard for AWS Certification of Welding Inspectors*. Defines the requirements and program for AWS to certify welding inspectors.

CAWI—Certified Associate Welding Inspector.

CWI—Certified Welding Inspector.

KASH—An acronym for Knowledge, Attitude, Skills, and Habits, the basic tools of a welding inspector.

NDE—Nondestructive Examination. The act of determining the suitability of some material or component for its intended purpose using techniques that do not affect its serviceability. NDE is the preferred term per ANSI/AWS.

NDI—Nondestructive Inspection. A nonstandard term for **nondestructive examination** (see NDE).

NDT—Nondestructive Testing. A nonstandard term for **nondestructive examination** (see NDE).

SCWI—Senior Certified Welding Inspector.

SNT-TC-1A—This ASNT Recommended Practice, *Personnel Qualification and Certification in Nondestructive Testing*, outlines the certification program for NDT technicians.

CHAPTER 2

Safe Practices for Welding Inspectors

Contents

Chapter 2—Safe Practices for Welding Inspectors

Introduction

Welding inspectors often work in the same environment as the welder, so they can be exposed to many potential safety hazards. These include electric shock, falling, radiation, eye hazards such as ultraviolet light and particulate matter in the air, smoke and fumes, and falling objects. Safety is not to be taken lightly; even though the welding inspector may only be exposed to these conditions momentarily. The welding inspector should observe all safety precautions such as use of safety glasses, hard hats, protective clothing or any other appropriate apparatus for a given situation. For a more detailed look at recommended safety precautions refer to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

Safety is an important consideration in all welding, cutting, and related work. No activity is satisfactorily completed if someone is injured. The hazards that may be encountered, and the practices that will reduce personal injury and property damage, are discussed here.

The most important component of an effective safety and health program is leadership support and direction. Management must clearly state objectives and show its commitment to safety and health by consistent support of safe practices. Management must designate approved safe areas for conducting welding and cutting operations. When these operations are done in other than designated areas, management must assure that proper procedures are established and followed to protect personnel and property.

Management must also be certain that only approved welding, cutting, and allied equipment are used. Such equipment includes torches, regulators, welding machines, electrode holders, and personal protection devices (see Figure 2.1). Adequate supervision must be provided to assure that all equipment is properly used and maintained.

Thorough and effective training is a key aspect of a safety program. Adequate training is mandated under provisions of the *U.S. Occupational Safety and Health Act (OSHA)*, especially those of the *Hazard Communication Standard (29 CFR 1910.1200)*. Welders and other equipment operators work most safely when they are properly trained in the subject.

Figure 2.1—Personal Protective Equipment (PPE)

Proper training includes instruction in the safe use of equipment and processes, and the safety rules that must be followed. Personnel need to know and understand the rules and the consequences of disobeying them. For example, welders must be trained to position themselves while welding or cutting so that their heads are not in the gases or fume plume. A fume plume is a smoke-like cloud containing minute solid particles arising directly from the area of melting metal. The fumes are metallic vapors that have condensed into particulates.

Before work begins, users must always read and understand the manufacturers' instructions on safe practices for the materials and equipment, and the Material Safety Data Sheets (MSDSs). Certain AWS specifications call for precautionary labels on consumables and equipment. These labels concerning the safe use of the products should be read and followed (see Figure 2.2).

Manufacturers of welding consumables must, upon request, furnish a Material Safety Data Sheet that identifies materials present in their products that have hazardous properties. The MSDS provides OSHA permissible exposure limits, known as the Threshold Limit Value (TLV), and any other exposure limit used or recommended by the manufacturer. TLV is a registered trademark of the American Conference of Governmental and Industrial Hygienists (ACGIH).

WARNING:

PROTECT yourself and others. Read and understand this label.

FUMES AND GASES can be dangerous to your health.

ARC RAYS can injure your eyes and burn your skin.

ELECTRIC SHOCK can KILL.

- Before use, read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of 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 Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA *Safety and Health Standards*, available from U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE LABEL

Figure 2.2—Typical Warning Label for Arc Welding Processes and Equipment

Employers that use consumables must make all applicable MSDS data available to their employees, and also train them to read and understand the contents. The MSDS contain important information about the ingredients contained in welding electrodes, rods, and fluxes. These sheets also show the composition of fumes generated and other hazards that may be caused during use. They also provide methods to be followed to protect the welder and others who might be involved.

Under the OSHA *Hazard Communication Standard, 29 CFR 1910.1200*, employers are responsible for employee hazardous material training in the workplace. Many welding consumables are included in the definition of hazardous materials according to this standard. Welding employers must comply with the communication and training requirements of this standard.

Proper use and maintenance of the equipment must also be taught. For example, defective or worn electrical insulation in arc welding or cutting should not be used. Also, defective or worn hoses used in oxyfuel gas welding and cutting, brazing, or soldering should not be used. Training in equipment operation is fundamental to safe operation.

Personnel must also be trained to recognize safety hazards. If they are to work in an unfamiliar situation or environment, they must be thoroughly briefed on the potential hazards involved. For example, consider a person who must work in confined spaces. If the ventilation is poor and an air-supplied helmet is required, the need and instructions for its proper use must be thoroughly explained to the employee. The consequences of improperly using the equipment must be covered. When employees believe that the safety precautions for a given task are not adequate, or not understood, they should question their supervisor before proceeding.

Good housekeeping is also essential to avoid injuries. A welder's vision is often restricted by necessary eye protection, and personnel passing a welding station must often shield their eyes from the flame or arc radiation. This limited vision makes both the welder and passersby vulnerable to tripping over objects on the floor. Therefore, welders and supervisors must always make sure that the area is clear of tripping hazards. A shop production area should be designed so that gas hoses, cables, mechanical assemblies, and other equipment do not cross walkways or interfere with routine tasks (see Figure 2.3).

Figure 2.3—Designated Welding Area

Figure 2.4—Protective Screening Between Workstations

When work is above ground or floor level, safety rails or lines must be provided to prevent falls because of restricted vision from eye protection devices. Safety lines and harnesses can be helpful to restrict workers to safe areas, and to restrain them in case of a fall. Unexpected events, such as fume releases, fire and explosions do occur in industrial environments. All escape routes should be identified and kept clear so that orderly, rapid, and safe evacuation of an area can take place. Employees must be trained in evacuation procedures. Storage of goods and equipment in evacuation routes must be avoided. If an evacuation route must be temporarily blocked, employees who would normally use that route must be trained to use an alternate route.

Equipment, machines, cables, hoses, and other apparatus should always be placed so that they do not present a hazard to personnel in passageways, on ladders, or on stairways. Warning signs should be posted to identify welding areas, and to specify that eye protection must be worn. Occasionally, a "fire watch" person must be assigned to maintain safety during welding or cutting operations.

Personnel in areas next to welding and cutting must also be protected from radiant energy and hot spatter. This is accomplished with flame-resistant screens or shields, or suitable eye and face protection and protective clothing. Appropriate radiation-protective, semi-transparent materials are permissible. Where operations allow, work stations should be separated by noncombustible screens or shields (see Figure 2.4). Booths and screens should allow circulation of air at floor level and above the screen.

Where arc welding or cutting is regularly performed next to painted walls, the walls should be painted with a finish having low reflectivity of ultraviolet radiation. Paint finish formulated with certain pigments, such as titanium dioxide or zinc oxide, have low reflectivity to ultraviolet radiation. Color pigments may be added if they do not increase reflectivity. Pigments based on powdered or flaked metals are not recommended because they reflect ultraviolet radiation.

In most welding, cutting, and allied processes, a high-temperature heat source is present. Open flames, electric arcs, hot metal, sparks, and spatter are ready sources of ignition. Many fires are started by sparks, which can travel horizontally up to 35 ft from their source. Sparks can pass through or lodge in cracks, holes, and other small openings in floors and walls.

The risk of fire is increased by combustibles in the work area, or by welding or cutting too close to combustibles that have not been shielded. Materials most commonly ignited are combustible floors, roofs, partitions, and building contents including trash, wood, paper, textiles, plastics, chemicals, and flammable liquids and gases. Outdoors, the most common combustibles are dry grass and brush.

The best protection against fire is to do welding and cutting in specially designated areas or enclosures of noncombustible construction kept free of combustibles. Combustibles should always be removed from the work area or shielded from the operation.

Common combustibles found in welding manufacturing include fuels for both equipment engines and welding or cutting operations. These fuels should be stored and used with care. Equipment manufacturers' instructions should be followed because fuels and their vapors are combustible and can be explosive under some conditions. Acetylene, propane and other flammable gases used in cutting and welding areas require careful handling. Special attention should be given to fuel gas cylinders, hoses, and apparatus to prevent gas leakage.

Combustibles that cannot be removed from the area should be covered with tight fitting, flame-resistant material. These include combustible walls and ceilings. Floors around the work area should be free of combustible materials for a radius of 35 ft. All doorways, windows, cracks, and other openings should be covered with a flame-resistant material. If possible, the work area should be enclosed with portable flame-resistant screens.

Combustibles on the other side of metal walls, ceilings or partitions must be moved to safe locations when welding or cutting is done on or next to the location. If this cannot be done, a fire watch should be stationed near the combustibles. Welding heat can conduct through metal partitions and ignite combustibles on the opposite side. A thorough examination for evidence of fire should be made before leaving the work area. Fire inspection should be continued for at least 30 minutes after the operation is completed.

Welding or cutting should not be done on material having a combustible coating or internal structure, as in walls or ceilings. Hot scrap or slag must not be placed in containers holding combustible materials. Suitable fire extinguishers should always be available nearby, and the fire watch trained in their use.

Welding, brazing, or cutting should not be done on combustible floors or platforms that may readily be ignited by heat from the operation. Welders and inspectors must be alert for traveling vapors from flammable liquids. Vapors are often heavier than air. Vapors from flammable liquid storage areas can travel several hundred feet along floors and in depressions. Light vapors can travel along ceilings to adjacent rooms.

When welding, cutting or similar hot working operations are to be performed in areas not normally assigned for such operations, a "hot work permit" system should be used (see Figure 2.5). The purpose of the hot work permit system is to alert area supervisors to an extraordinary danger of fire that will exist at a particular time. The permit system should include a checklist of safety precautions. A checklist often includes fire extinguisher inspection, establishes the fire watches if necessary, a flammable material search, and area safety instructions for personnel not involved in the hot work. When a hot work permit is issued, the welding inspector must be aware of and adhere to all its requirements.

Flammable gases, vapors, and dust mixed with certain proportions of air or oxygen present explosion and fire dangers. To prevent explosions, avoid all sources of ignition. Welding, brazing, soldering, cutting, or operating equipment that can produce heat or sparks must not be done in atmospheres containing flammable gases, vapors, or dusts. Such flammables must be kept in leak-tight containers or be well removed from the work area. Heat or sparks may cause otherwise low-volatility materials to produce flammable vapors.

Hollow containers must be vented before, and during, any application of heat. Heat must not be applied to a container that has held an unknown material, a combustible substance or a substance that may form flammable vapors without considering the potential hazards. Such containers must first be thoroughly cleaned or filled with an inert gas. Adequate eye and body protection must be worn if the operation involves explosion risks. Burns of the eye or body are serious hazards in the welding industry. Eye, face, and body protection for the operator and others in the work area are required to prevent burns from ultraviolet and infrared radiation, sparks, and spatter.

Eye and Face Protection

Arc Welding and Cutting

Welding helmets or handshields containing appropriate filter plates and cover plates must be used by welders and welding operators and nearby personnel when viewing an arc. Standards for welding helmets, handshields, face shields, goggles, and spectacles are given in ANSI publication Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, latest edition.

Safety spectacles, goggles, or other suitable eye protection must also be worn during other welding and cutting operations (see Figure 2.6). Such devices must have full conforming side shields when there is danger of exposure to injurious rays or flying particles from grinding or chipping operations. Spectacles and goggles may have clear or colored lenses. Shading depends on the intensity of the radiation that comes from adjacent welding or cutting operations when the welding helmet is raised or removed. Number-2 filter plates are recommended for general purpose protection (see Table 2.1).

Oxyfuel Gas Welding and Cutting, Submerged Arc Welding

Safety goggles with filter plates and full conforming side shields must be worn while performing oxyfuel gas welding and cutting (see Table 2.1). During submerged arc welding, the arc is covered by flux and is not readily

PERMIT NO. ________

For electric and acetylene burning and welding with portable equipment in all locations outside of shop.

Date ________

Time Started ________ Finished ________

Building ________

Dept. ________ Floor ________

Location on Floor ________

Nature of job ________

____

Operator ________

Clock No. ________

All precautions have been taken to avoid any possible fire hazard, and permission is given for this work.

Signed ________
Foreman

Signed ________
Safety supervisor or plant superintendent

PERMIT NO. OU812

Date ________

Bldg ________ Floor ________

Nature of Job ________

Operator ________

INSTRUCTIONS TO OPERATORS

This permit is good only for the location and time shown. Return the permit when work is completed.

PRECAUTIONS AGAINST FIRE

1. Permits should be signed by the foreman of the welder or cutter and by the safety supervisor or plant superintendent.
2. Obtain a written permit before using portable cutting or welding equipment anywhere in the plant except in permanent safe-guarded locations.
3. Make sure sprinkler system is in service.
4. Before starting, sweep floor clean, wet down wooden floors, or cover them with sheet metal or equivalent. In outside work, don't let sparks enter doors or windows.
5. Move combustible material 25 feet away. Cover what can't be moved with asbestos curtain or sheet metal, carefully and completely.
6. Obtain standby fire extinguishers and locate at work site. Instruct helper or fire watcher to extinguish small fires.
7. After completion, watch scene of work a half hour for smoldering fires, and inspect adjoining rooms and floors above and below.
8. Don't use the equipment near flammable liquids, or on closed tanks which have held flammable liquids or other combustibles. Remove inside deposits before working on ducts.
9. Keep cutting and welding equipment in good condition. Carefully follow manufacturer's instructions for its use and maintenance.

Figure 2.5—National Safety Council "Hot Work Permit"

Figure 2.6—Eye, Ear, and Face Protective Equipment

Key Words—Eye protection and lens shade **AWS F2.2:2001**

Table 2.1
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) 3/32–5/32 (2.4–4.0) 5/32–1/4 (4.0–6.4) More than 1/4 (6.4)	Less than 60 60–160 160–250 250–550	7 8 10 11	— 10 12 14
Gas Metal Arc Welding (GMAW) and **Flux Cored Arc Welding (FCAW)**		Less than 60 60–160 160–250 250–500	7 10 10 10	— 11 12 14
Gas Tungsten Arc Welding (GTAW)		Less than 50 50–150 150–500	8 8 10	10 12 14
Air Carbon Arc Cutting (CAC-A) (Light) (Heavy)		 Less than 500 500–1000	 10 11	 12 14
Plasma Arc Welding (PAW)		Less than 20 20–100 100–400 400–800	6 8 10 11	6–8 10 12 14
Plasma Arc Cutting (PAC)		Less than 20 20–40 40–60 60–80 80–300 300–400 400–800	4 5 6 8 8 9 10	4 5 6 8 9 12 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 Medium Heavy	 Under 1/8 1/8 to 1/2 Over 1/2	 Under 3 3 to 13 Over 13		 4 or 5 5 or 6 6 or 8
Oxygen Cutting (OC) Light Medium Heavy	 Under 1 1 to 6 Over 6	 Under 25 25 to 150 Over 150		 3 or 4 4 or 5 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.

visible; therefore, an arc welding helmet is not needed. However, because the arc occasionally flashes through the flux burden, the operator should wear tinted safety glasses.

Torch Brazing and Soldering

Safety spectacles with side shields and appropriate filter plates are recommended for torch brazing and soldering. As with oxyfuel gas welding and cutting, a bright yellow flame may be visible during torch brazing. A filter similar to that used with those processes should be used for torch brazing (see Table 2.1).

Other Brazing Processes and Resistance Welding

Operators and helpers engaged in these processes must wear safety spectacles, goggles, and a face shield to protect their eyes and face from spatter. Filter plates are not necessary but may be used for comfort (refer to Table 2.1).

Protective Clothing

Sturdy shoes or boots, and heavy clothing should be worn to protect the whole body from flying sparks, spatter, and radiation burns. Woolen clothing is preferable to cotton because it is not so readily ignited. Cotton clothing, if used, should be chemically treated to reduce its combustibility. Clothing treated with nondurable flame retardants must be treated again after each washing or cleaning. Clothing or shoes of synthetic or plastic materials, which can melt and cause severe burns, should not be worn. Outer clothing should be kept free of oil and grease, especially in an oxygen-rich atmosphere.

Cuffless pants and covered pockets are recommended to avoid spatter or spark entrapment. Pockets should be emptied of flammable or readily ignitable material before welding because they may be ignited by sparks or weld spatter and result in severe burns. Pants should be worn outside shoes. Protection of the hair with a cap is recommended, especially if a hairpiece is worn. Flammable hair preparations should not be used.

Durable gloves of leather or other suitable material should always be worn. Gloves not only protect the hands from burns and abrasion, but also provide insulation from electrical shock. A variety of special protective clothing is also available for welders. Aprons, leggings, suits, capes, sleeves, and caps, all of durable materials, should be worn when welding overhead or when special circumstances warrant additional protection of the body.

Sparks or hot spatter in the ears can be particularly painful and serious. Properly fitted, flame-resistant ear plugs should be worn whenever operations pose such risks.

Noise

Excessive noise, particularly continuous noise at high levels, can severely damage hearing. It may cause either temporary or permanent hearing loss. U.S. Department of Labor Occupational Safety and Health Administration regulations describe allowable noise exposure levels. Requirements of these regulations may be found in *General Industry Standards, 29 CFR 1910.95.*

In welding, cutting, and allied operations, noise may be generated by the process or the equipment, or both. Hearing protection devices are required for some operations (see Figure 2.6). Additional information is presented in *Arc Welding and Cutting Noise*, American Welding Society, 1979. Air Carbon Arc and Plasma Arc Cutting are processes that have very high noise levels. Engine-driven generators sometimes emit a high noise level, as do some high-frequency, and induction welding power sources.

Machinery Guards

Welders and other workers must also be protected from injury by machinery and equipment they are operating or by other machinery operating in the work area. Moving components and drive belts must be covered by guards to prevent physical contact (see Figure 2.7).

Figure 2.7—Machinery Guard

Because welding helmets and dark filter plates restrict the visibility of welders, these people may be even more susceptible than ordinary workers to injury from unseen, unguarded machinery. Therefore, special attention to this hazard is required.

When repairing machinery by welding or brazing, the power to the machinery must be disconnected, locked out, tried, and tagged to prevent inadvertent operation and injury. Welders assigned to work on equipment with safety devices removed should fully understand the hazards involved, and the steps to be taken to avoid injury. When the work is completed, the safety devices must be replaced. Rotating and automatic welding machines, fixtures, and welding robots must be equipped with appropriate guards or sensing devices to prevent operation when someone is in the danger area.

Pinch points on welding and other mechanical equipment can also result in serious injury. Examples include resistance welding machines, robots, automatic arc welding machines, jigs, and fixtures. To avoid injury with such equipment, the machine should be equipped so that both of the operator's hands must be at safe locations when the machine is actuated. Otherwise, the pinch points must be suitably guarded mechanically. Metalworking equipment should not be located where a welder could accidentally fall into or against it while welding. During maintenance of the equipment, pinch points should be blocked to prevent them from closing in case of equipment failure. In very hazardous situations, an observer should be stationed to prevent someone from turning the power on until the repair is completed.

Fumes and Gases

Welders, welding operators, and other persons in the area must be protected from over-exposure to fumes and gases produced during welding, brazing, soldering, and cutting. Overexposure is exposure that is hazardous to health, or exceeds the permissible limits specified by a government agency. The *U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Regulations 29 CFR 1910.1000*, covers this topic. Also, the American Conference of Governmental Industrial Hygienists (ACGIH) lists guidelines in their publication, *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*. Persons with special health problems may have unusual sensitivity that requires even more stringent protection.

Fumes and gases are usually a greater concern in arc welding than in oxyfuel gas welding, cutting, or brazing. A welding arc may generate a larger volume of fume and gas, and a greater variety of materials are usually involved. Protection from excess exposure is usually accomplished by ventilation. Where exposure would exceed permissible limits with available ventilation, suitable respiratory protection must be used. Protection must be provided for welding, cutting, and other personnel in the area.

Exposure Factors

Position of the Head

The single most important factor influencing exposure to fumes is the position of the welder's head with respect to the fumes plume. When the head is in such a position that the fumes envelop the face or helmet, exposure levels can be very high. Therefore, welders must be trained to keep their head to one side of the fume plume. Sometimes, the work can be positioned so the fume plume rises to one side.

Types of Ventilation

Ventilation has a significant influence on fume amounts in the work area, and the welder's exposure to them. Ventilation may be local, where the fumes are extracted near the point of welding (see Figure 2.8), or general, where the shop air is changed or filtered. The appropriate type will depend on the welding process, the material being welded, and other shop conditions. Adequate ventilation is necessary to keep the welder's exposure to fumes and gases within safe limits.

Work Area

The size of the welding or cutting enclosure is important. It affects the background fume level. Fume exposure inside a tank, pressure vessel, or other confined space will be higher than in a high-bay fabrication area.

Background Fume Level

Background fume levels depend on the number and type of welding stations and the duty cycle for each power source.

Design of Welding Helmet

The extent a helmet curves under the chin toward the chest affects the amount of fume exposure. Close-fitting helmets can be effective in reducing exposure.

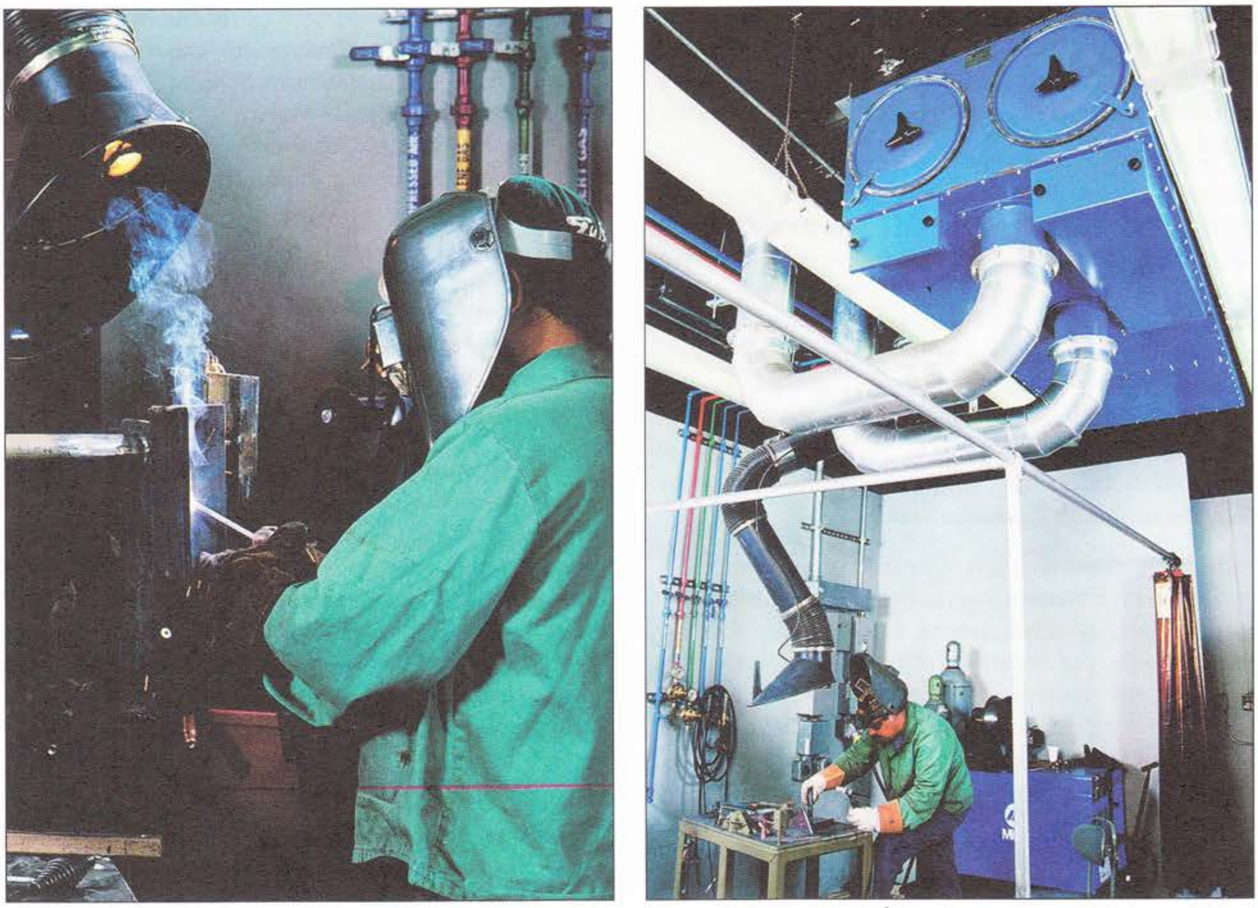

Figure 2.8—Movable Fume Extractor Positioned Near the Welding Arc

Base Metal and Surface Condition

The type of base metal being welded influences fume components and the amount generated. Surface contaminants or coatings may contribute significantly to the hazard potential of the fume. Paints containing lead or cadmium generate dangerous fumes during welding and cutting. Galvanized material creates zinc fumes which are harmful.

Ventilation

The bulk of fumes generated during welding and cutting consists of small particles that remain suspended in the atmosphere for a considerable time. As a result, fume concentration in a closed area can build up over time, as can the concentration of any gases evolved or used in the process. Particles eventually settle on the walls and floor, but the settling rate is low compared to the generation rate of the welding or cutting processes. Therefore, fume concentration must be controlled by ventilation.

Adequate ventilation is the key to control of fumes and gases in the welding environment. Natural, mechanical, or respirator ventilation must be provided for all welding, cutting, brazing, and related operations. The ventilation must ensure that concentrations of hazardous airborne contaminants are maintained below recommended levels.

Many ventilation methods are available. They range from natural drafts to localized devices, such as air-ventilated welding helmets. Examples of ventilation include:

1. Natural
2. General area mechanical ventilation
3. Overhead exhaust hoods
4. Portable local exhaust devices

5. Downdraft tables
6. Crossdraft tables
7. Extractors built into the welding equipment
8. Air-ventilated helmets

Welding in Confined Spaces

Special consideration must be given to the safety and health of welders and other workers in confined spaces. See ANSI publication Z117.1, *Safety Requirements for Working in Tanks and Other Confined Spaces*, latest edition, for further precautions. Gas cylinders must be located outside the confined space to avoid possible contamination of the space with leaking gases or volatiles. Welding power sources should also be located outside to reduce danger of engine exhaust and electric shock. Lighting inside the work area should be low voltage, 12 V, or if 110 V is required, the circuit must be protected by an approved Ground-Fault Circuit-Interrupter (GFCI).

A means for removing persons quickly in case of emergency has to be provided. Safety belts and lifelines, when used, should be attached to the worker's body in a way that avoids the possibility of the person becoming jammed in the exit. A trained helper, a "standby," should be stationed outside the confined space with a preplanned rescue procedure in case of an emergency (including not entering the confined space to aid the first worker without proper breathing apparatus).

Besides keeping airborne contaminants in breathing atmospheres at or below recommended limits, ventilation in confined spaces must also (1) assure adequate oxygen for life support (at least 19.5% by volume); (2) prevent accumulation of an oxygen-enriched atmosphere, (i.e., not over 23.5% by volume); and (3) prevent accumulation of flammable mixtures (see Figure 2.9). Asphyxiation can quickly result in unconsciousness and death without warning if oxygen is not present in sufficient concentration to support life. Air contains approximately 21% oxygen by volume. Confined spaces must not be entered unless well ventilated, or the inspector is wearing an approved air supplied breathing apparatus and has proper training to work in such spaces. A similarly equipped second person must be present as a standby.

Before entering confined spaces, the space should be tested for toxic or flammable gases and vapors, and adequate or excess oxygen. The tests should be made with instruments approved by the U.S. Bureau of Mines.

Heavier-than-air gases, such as argon, methylacetylene-propadiene, propane, and carbon dioxide, may accumulate in pits, tank bottoms, low areas, and near floors.

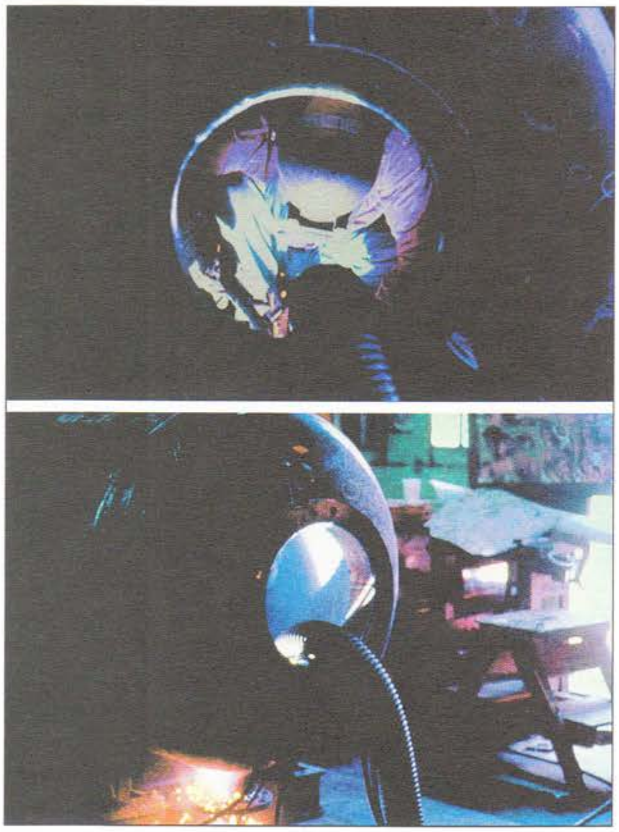

Figure 2.9—Welding in Confined Spaces

Lighter-than-air gases, such as helium and hydrogen, may accumulate in tank tops, high areas, and near ceilings. The precautions for confined spaces also apply to those areas. If practical, a continuous monitoring system with audible alarms should be used for work in a confined space.

Oxygen-enriched atmospheres pose great danger to occupants of confined areas. They are especially hazardous at oxygen concentrations above 25%. Materials that burn normally in air may flare up violently in an oxygen-enriched atmosphere. Clothing may burn fiercely; oil or grease soaked clothing or rags may catch fire spontaneously; paper may flare into flame. Very severe and fatal burns can result.

Protection in confined spaces must be provided welders and other personnel in the enclosure. Only clean, respirable air must be used for ventilation. Oxygen, other gases, or mixtures of gases must never be used for ventilation.

Positive pressure self-contained breathing apparatus must be used when welding or cutting related processes are done in confined areas where proper ventilation cannot be provided and there is immediate danger to life and health. It must have an emergency air supply of at least five minutes duration in the event that the main source fails.

Welding of Containers

Welding or cutting outside or inside containers and vessels that have held dangerous substances presents special hazards. Flammable or toxic vapors may be present, or may be generated by the applied heat. The immediate area outside and inside the container should be cleared of all obstacles and hazardous materials. If repairing a container in place, entry of hazardous substances into the container from the outside must be avoided. The required personal and fire protection equipment must be available, serviceable, and in position for immediate use.

When welding or cutting inside vessels that have held dangerous materials, the precautions for confined spaces must also be observed. Gases generated during welding should be discharged in a safe and environmentally acceptable manner according to government rules and regulations. Provisions must be made to prevent pressure buildup inside containers. Testing for gases, fumes, and vapors should be conducted periodically to ensure that recommended limits are maintained during welding.

An alternative method of providing safe welding of containers is to fill them with an inert medium such as water, inert gas, or sand. When using water, the level should be kept to within a few inches of the point where the welding is to be done. The space above the water should be vented to allow the heated air to escape. With inert gas, the percentage of inert gas that must be present in the tank to prevent fire or explosion must be known. How to safely produce and maintain a safe atmosphere during welding must also be known.

Highly Toxic Materials

Certain materials, which are sometimes present in consumables, base metals, coatings, or atmospheres for welding or cutting operations, have permissible exposure limits of 1.0 mg/m^3 or less. Among these materials are the metals noted in Table 2.2.

Manufacturer's Material Safety Data Sheets should be consulted to find out if any of these materials are present in welding filler metals and fluxes being used. Material Safety Data Sheets should be requested from suppliers. However, welding filler metals and fluxes are not the only source of these materials. They may also be present in base metals, coatings, or other sources in the work area. Radioactive materials under Nuclear Regulatory Commission jurisdiction require special considerations and may also require compliance with state and local regulations. These materials also include X-ray machines and radiographic isotopes.

Table 2.2
Toxic Metals

1. Antimony	9. Lead
2. Arsenic	10. Manganese
3. Barium	11. Mercury
4. Beryllium	12. Nickel
5. Cadmium	13. Selenium
6. Chromium	14. Silver
7. Cobalt	15. Vanadium
8. Copper	

When toxic materials are encountered as designated constituents in welding, brazing, or cutting operations, special ventilation precautions must be taken. The precautions assure that the levels of these contaminants in the atmosphere are at or below the limits allowed for human exposure. All persons in the immediate vicinity of welding or cutting operations involving these materials must be similarly protected.

Handling of Compressed Gases

Gases used in welding and cutting operations are packaged in containers called cylinders. Only cylinders designed and maintained in accordance with U.S. Department of Transportation (DOT) specifications may be used in the United States. The use of other cylinders may be extremely dangerous and is illegal. Cylinders requiring periodic retest under DOT regulations may not be filled unless the retest is current.

Cylinders may be filled only with the permission of the owner, and should be filled only by recognized gas suppliers or those with the proper training and facilities to do so. Filling one cylinder from another is dangerous and should not be attempted by anyone not qualified to do so. Combustible or incompatible combinations of gases must never be mixed in cylinders.

Welding must not be performed on gas cylinders. Cylinders must not be allowed to become part of an electrical circuit because arcing may result. Cylinders containing shielding gases used in conjunction with arc welding must not be grounded. Electrode holders, welding torches, cables, hoses, and tools should not be stored on gas cylinders to avoid arcing or interference with valve operation. Arc-damaged gas cylinders may rupture and result in injury or death.

Cylinders must not be used as work rests or rollers. They should be protected from bumps, falling objects, weather, and should not be dropped. Cylinders should not be kept in passageways where they might be struck by vehicles. They should be kept in areas where temperatures do not fall below –20°F or exceed 130°F. Any of these exposures, misuses, or abuses could damage them to the extent that they might fail with serious consequences.

Cylinders must not be hoisted using ordinary slings or chains. A proper cradle or cradle sling that securely retains the cylinder should be used. Electromagnets should not be used to handle cylinders.

Cylinders must always be secured by the user against falling during either use or storage (see Figure 2.10). Acetylene and liquefied gas cylinders (dewars) should always be stored and used in the upright position. Other cylinders are preferably stored and used in the upright position, but this is not essential in all circumstances.

Before using gas from a cylinder, the contents should be identified by the label thereon. Contents should not be identified by any other means such as cylinder color, banding, or shape. These may vary among manufacturers, geographical area, or product line and could be completely misleading. The label on the cylinder is the only proper notice of the contents. If a label is not on a cylinder, the contents should not be used and the cylinder should be returned to the supplier.

A valve protection cap is provided on many cylinders to protect the safety device and the cylinder valve. This cap should always be in place unless the cylinder is in use. The cylinder should never be lifted manually or hoisted by the valve protection cap. The threads that secure these valve protection caps are intended only for that purpose, and may not support full cylinder weight. The caps should always be threaded completely onto the cylinders and hand tightened.

Gas cylinders and other containers must be stored in accordance with all state and local regulations and the appropriate standards of OSHA and the National Fire Protection Association. Safe handling and storage procedures are discussed in the *Handbook of Compressed Gases*, published by the Compressed Gas Association.

Many gases in high-pressure cylinders are filled to pressures of 2000 psi or more. Unless the equipment to be used with a gas is designed to operate at full cylinder pressure, an approved pressure-reducing regulator must be used to withdraw gas from a cylinder or manifold. Simple needle valves should never be used. A pressure-relief or safety valve, rated to function at less than the maximum allowable pressure of the welding equipment, should also be employed. Valve functions prevent equipment failure at pressures over working limits if the regulator should fail in service.

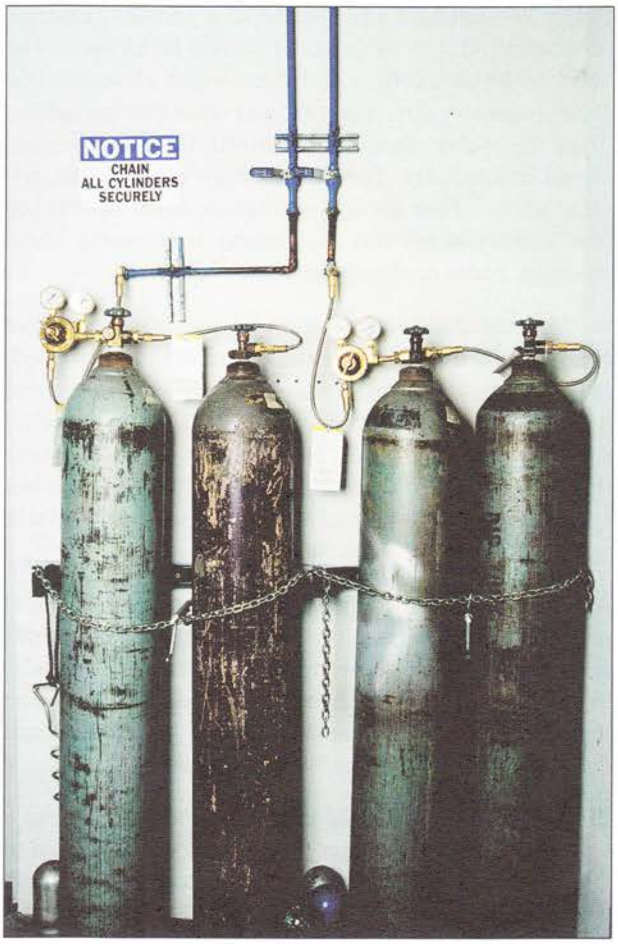

Figure 2.10—Inert Gas Cylinders Attached to Manifold System

Valves on cylinders containing high pressure gas, particularly oxygen, should always be opened slowly to avoid the high temperature of adiabatic recompression. Adiabatic recompression can occur if the valves are opened rapidly. With oxygen, the heat can ignite the valve seat that, in turn, may cause the metal to melt or burn. The cylinder valve outlet should point away from the operator and other persons when opening the valve to avoid injury should a fire occur. The operator should never stand in front of the regulator when opening a cylinder to avoid injury from high pressure release if the regulator fails.

Before connecting a gas cylinder to a pressure regulator or a manifold, the valve outlet should be cleaned. The valve outlet should be wiped clean with a clean, oil-free cloth to remove dirt, moisture, and other foreign matter. Then the valve should be opened momentarily and closed immediately. This is known as "cracking the cylinder valve." Fuel gas cylinders must never be cracked near sources of ignition (i.e., sparks and flames), while smoking, nor in confined spaces.

A regulator should be relieved of gas pressure before connecting it to a cylinder, and also after closing the cylinder valve upon shutdown of operation. The outlet threads on cylinder valves are standardized for specific gases so that only regulators or manifolds with similar threads can be attached (e.g., flammable gas cylinders typically have a left-hand thread while nonflammable gas cylinders have a right-hand thread).

It is preferable not to open valves on low pressure, fuel gas cylinders more than one turn. This usually provides adequate flow and allows rapid closure of the cylinder valve in an emergency. High pressure cylinder valves, on the other hand, usually must be opened fully to backseat (seal) the valve to prevent leaks during use.

The cylinder valve should be closed after each use of a cylinder and when an empty cylinder is to be returned to the supplier. This prevents loss of product through leaks that might develop and go undetected while the cylinder is unattended, and avoids hazards that might be caused by leaks. It also prevents backflow of contaminants into the cylinder. It is advisable to return cylinders to the supplier with about 25 psi of contents remaining. This prevents possible contamination by the atmosphere during shipment.

Pressure Relief Devices

Only trained personnel should be allowed to adjust pressure relief devices on cylinders. These devices are intended to provide protection in the event the cylinder is subjected to a hostile environment, usually fire or other source of heat. Such environments may raise the pressure within cylinders. To prevent cylinder pressures from exceeding safe limits, the safety devices are designed to relieve the contents.

A pressure reducing regulator should always be used when withdrawing gas from gas cylinders for welding or cutting operations. Pressure reducing regulators must be used only for the gas and pressure given on the label. They should not be used with other gases or at other pressures although the cylinder valve outlet threads may be the same. The threaded connections to the regulator must not be forced. Improper fit of threads between a gas cylinder and regulator, or between the regulator and hose suggests an improper combination of devices being used.

Use of adapters to change the cylinder connection thread is not recommended because of the danger of using an incorrect regulator or of contaminating the regulator. For example, gases that are oil-contaminated can deposit an oily film on the internal parts of the regulator. This film can contaminate oil-free gas and result in fire or explosion when exposed to pure oxygen.

The threads and connection glands of regulators should be inspected before use for dirt and damage. If a hose or cylinder connection leaks, it should not be forced with excessive torque. Damaged regulators and components should be repaired by properly trained mechanics or returned to the manufacturer for repair.

A suitable valve or flowmeter should be used to control gas flow from a regulator (see Figure 2.11). The internal pressure in a regulator should be released before it is connected to or removed from a gas cylinder or manifold.

Manifolds

A manifold is used when gas is needed without interruption or at a higher delivery rate than can be supplied from a single cylinder. A manifold must be designed for the specific gas and operating pressure, and be leak tight (see Figures 2.12 and 2.13). The manifold components should be approved for such purpose, and should be used only for the gas and pressure for which they are approved. Oxygen and fuel gas manifolds must meet specific design and safety requirements.

Piping and fittings for acetylene and methylacetylene-propadiene (MPS) manifolds must not be unalloyed copper or alloys containing 70% or more copper. These fuel gases react with copper under certain conditions to form unstable copper acetylide. This compound may detonate under shock or heat.

Manifold piping systems must contain an appropriate overpressure relief valve. Each fuel gas cylinder branch line should incorporate a backflow check valve and flash arrester. Backflow check valves must also be installed in each line at each station outlet where both fuel gas and oxygen are provided for a welding, cutting, or preheating torch. These check valves must be checked periodically for safe operation.

Unless it is known that a piping system is specifically designed and constructed to withstand full cylinder pressure or tank pressure of the compressed gas source supplying it, the piping system must be protected with safety pressure relief devices. The devices must be sufficient to

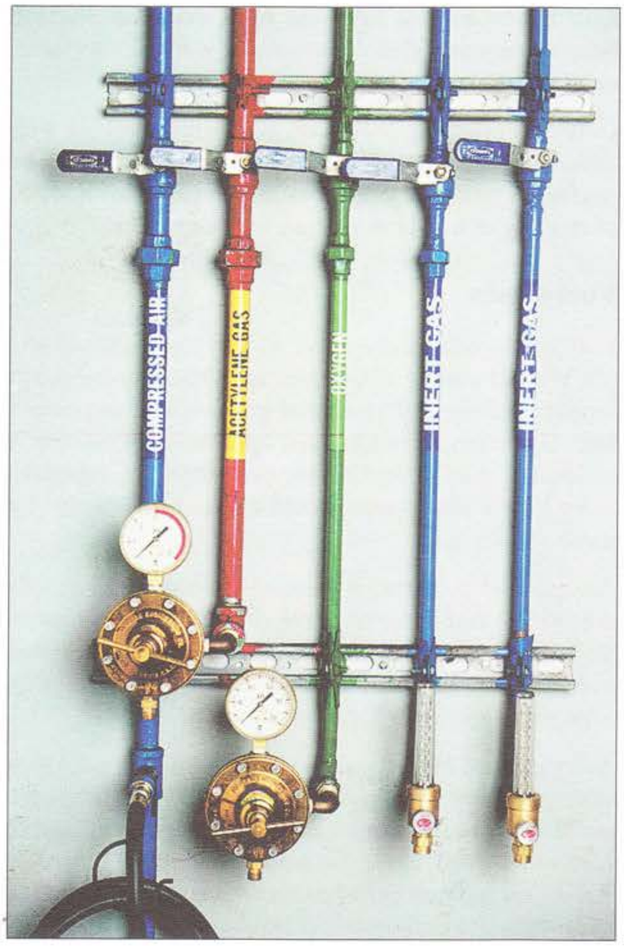

Figure 2.11—Acetylene and Oxygen Regulators and Inert Gas Flowmeters

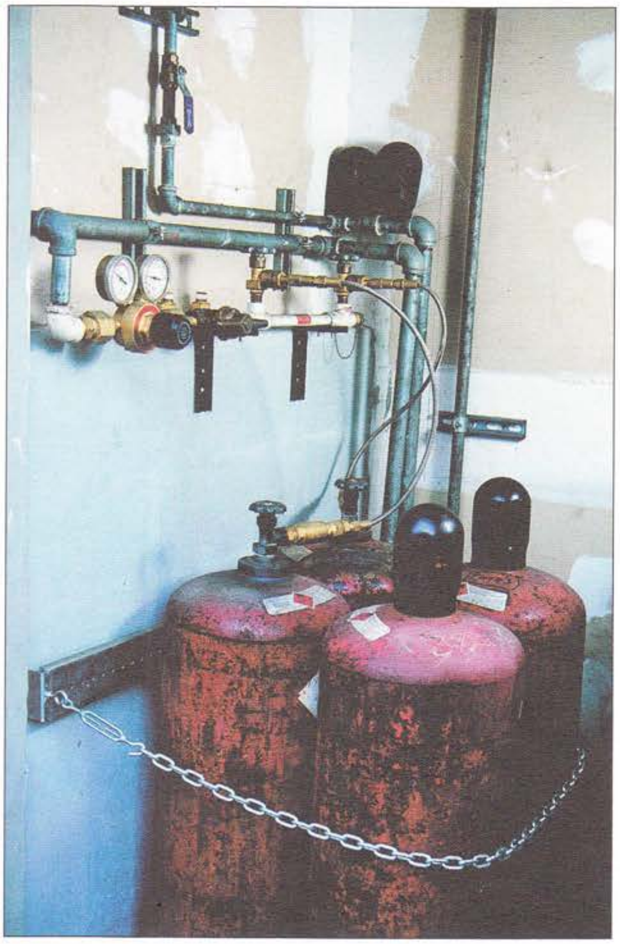

Figure 2.12—Acetylene Manifold System

prevent development of pressure in the system beyond the capacity of the weakest element.

Such pressure relief devices may be relief valves or bursting discs. A pressure reducing regulator must never be solely relied upon to prevent over pressurization of the system. A pressure relief device must be located in every section of the system that could be exposed to the full source supply pressure while isolated from other protective relief devices (such as by a closed valve). Some pressure regulators have integral safety relief valves. These valves are designed for the protection of the regulator only, and should not be relied upon to protect the downstream system.

In cryogenic piping systems, relief devices should be located in every section of the system where liquefied gas may become trapped. Upon warming, such liquids vaporize to gas, and in a confined space, the gas pressure can increase dramatically. Pressure relief devices protecting fuel gas piping systems or other hazardous gas systems should be vented to safe locations.

Gases

Oxygen

Oxygen is nonflammable but it supports the combustion of flammable materials. It can initiate combustion and vigorously accelerate it. Therefore, oxygen cylinders and liquid oxygen containers should not be stored near combustibles or with cylinders of fuel gas. Oxygen should never be used as a substitute for compressed air. Pure oxygen supports combustion more vigorously than air, which contains only 21% oxygen. Therefore, the identification of the oxygen and air should be differentiated.

Figure 2.13—Oxygen Manifold System

Oil, grease, and combustible dusts may spontaneously ignite on contact with oxygen. All systems and apparatus for oxygen service must be kept free of any combustibles. Valves, piping, or system components that have not been expressly manufactured for oxygen service must be cleaned and approved for this service before use.

Apparatus expressly manufactured for oxygen service, and so labeled, must be kept in the clean condition as originally received. Oxygen valves, regulators, and apparatus should never be lubricated with oil. If lubrication is required, the type of lubricant and the method of applying the lubricant should be specified in the manufacturer's literature. If it is not, then the device should be returned to the manufacturer or authorized representative for service.

Oxygen must never be used to power compressed air tools. These are usually oil lubricated. Similarly, oxygen must not be used to blow dirt from work and clothing because they are often contaminated with oil, or grease, or combustible dust.

Only clean clothing should be worn when working with oxygen systems. Oxygen must not be used to ventilate confined spaces. Severe burns may result from ignition of clothing or hair in an oxygen-rich atmosphere.

Fuel Gases

Fuel gases commonly used in oxyfuel gas welding (OFW) and cutting (OFC) are acetylene, methylacetylene-propadiene (MPS), natural gas, propane, and propylene. Hydrogen is used in a few applications. Gasoline is sometimes used as fuel for oxygen cutting (it vaporizes in the torch). These gases should always be referred to by name.

Acetylene in cylinders is dissolved in a solvent (such as acetone) so that it can be safely stored under pressure. In the free state, acetylene should never be used at pressures over 15 psi [103 kPa] because it can dissociate with explosive violence at higher pressures.

Acetylene and MPS should never be used in contact with silver, mercury, or alloys containing 70% or more copper. These gases react with these metals to form unstable compounds that may detonate under shock or heat. Valves on fuel gas cylinders should never be opened to clean the valve outlet near possible sources of flame ignition, or in confined spaces.

When fuel gases are used for a brazing furnace atmosphere, they must be vented to a safe location. Before filling a furnace with fuel gas, the equipment must first be purged with a nonflammable gas. Nitrogen or argon can be used to prevent formation of an explosive air-fuel mixture.

Special attention must be given when using hydrogen. Flames of hydrogen may be difficult to see and parts of the body, clothes, or combustibles may, therefore, unknowingly come in contact with hydrogen flames.

Fuel Gas Fires

The best procedure for avoiding fire from a fuel gas or liquid is to keep it contained within the system, that is, prevent leaks. All fuel systems should be checked carefully for leaks upon assembly and at frequent intervals after that. Fuel gas cylinders should be examined for leaks, especially at fuse plugs, safety devices, and valve packing. One common source of fire in welding and cutting is ignition of leaking fuel by flying sparks or spatter.

In case of a fuel fire, an effective means for controlling the fire is to shut off the fuel valve, if accessible. A fuel gas valve should not be opened beyond the point necessary to provide adequate flow. Opened in this way, it can be shut off quickly in an emergency. Usually, this is less than one turn of the handle. If the immediate valve controlling the burning gas is inaccessible, another upstream valve may cut off the flow of gas.

Most fuel gases in cylinders are in liquid form or dissolved in liquids. Therefore, the cylinders should always be used in the upright position to prevent liquid surges into the system.

A fuel gas cylinder can develop a leak and sometimes result in a fire. In case of fire, the fire alarm should be sounded, and trained fire personnel should be summoned immediately. A small fire near a cylinder valve or a safety device should be extinguished. When possible, extinguish the fire by closing the valve, using water, wet cloths, or fire extinguishers. If the leak cannot be stopped, after the fire is extinguished, the cylinder should be removed by trained fire personnel to a safe outdoor location, and the supplier notified. A warning sign should be posted, and no smoking or other ignition sources should be allowed in the area.

With a large fire at a fuel gas cylinder, the fire alarm should be actuated, and all personnel should be evacuated from the area. The cylinder should be kept wet by fire personnel with a heavy stream of water to keep it cool. It is usually better to allow the fire to continue to burn and consume the issuing gas rather than attempt to extinguish the flame. If the fire is extinguished, there is danger that the escaping gas may ignite with explosive violence.

Shielding Gases

Argon, helium, carbon dioxide (CO_2), and nitrogen are used for shielding with some welding processes. All, except carbon dioxide, are used as brazing atmospheres. They are odorless and colorless and can displace air needed for breathing.

Confined spaces containing these gases must be well ventilated before personnel enter them. If there is any question about the space, it should be checked first for adequate oxygen concentration with an oxygen analyzer. If an analyzer is not available, an air-supplied respirator should be worn by anyone entering the space. Containers of these gases should not be placed in confined spaces, as discussed previously.

Electric Shock

Electric shock can cause sudden death. Injuries and fatalities from electric shock in welding and cutting operations can occur if proper precautionary measures are not followed. Most welding and cutting operations employ some type of electrical equipment. For example, automatic oxyfuel gas cutting machines use electric motor drives, controls and systems. Lightning-caused electrical accidents may not be avoidable. However, all others are avoidable, including those caused by lack of proper training.

Electric shock occurs when an electric current of sufficient amount to create an adverse effect passes through the body. The severity of the shock depends mainly on the amount of current, the duration of flow, the path of flow, and the state of health of the person. The current is caused to flow by the applied voltage. The amount of current depends upon the applied voltage and the resistance of the body path. The frequency of the current may also be a factor when alternating current is involved.

Shock currents greater than about 6 milliamperes (mA) are considered primary because they can cause direct physiological harm. Steady state currents between 0.5 mA and 6 mA are considered secondary shock currents. Secondary shock currents can cause involuntary muscular reactions without normally causing direct physiological harm. The 0.5 mA level is called the perception threshold because it is the point at which most people just begin to feel the tingle from the current. The level of current sensation varies with the weight of the individual and to some extent between men and women.

Most electrical equipment, if improperly installed, used, or maintained, can be a shock hazard. Shock can occur from lightning-induced voltage surges in power distribution systems. Even earth grounds can attain high potential relative to true ground during severe transient phenomenon. Such circumstances, however, are rare.

In welding and cutting work, most electrical equipment is powered from AC sources of between 115 V and 575 V, or by engine-driven generators. Most welding is done with less than 100 arc volts. (Fatalities have resulted with equipment operating at less than 80 V.) Some arc cutting methods operate at over 400 V and electron beam welding machines at up to about 150 kV. Most electric shocks in the welding industry occur as the result of accidental contact with bare or poorly insulated conductors operating at such voltages. Therefore, welders must take precautions against contacting bare elements in the welding circuit, and also those in the primary circuits.

Electrical resistance is usually reduced in the presence of water or moisture. Electrical hazards are often more severe under such circumstances. When arc welding or cutting is to be done under damp or wet conditions including heavy perspiration, the inspector must wear dry gloves and clothing in good condition to prevent electric shock. The welding inspector should be protected from electrically conductive surfaces, including the earth. Protection can be afforded by rubber-soled shoes as a minimum, and preferably by an insulating layer such as a rubber mat or a dry wooden board. Similar precautions against accidental contact with bare conducting surfaces must be taken when the welding inspector is required to work in a cramped kneeling, sitting, or lying position. Rings and jewelry should be removed before welding to decrease the possibility of electric shock.

The technology of heart pacemakers and the extent to which they are influenced by other electrical devices is constantly changing. It is impossible to make general statements concerning the possible effects of welding operations on such devices. Wearers of pacemakers or other electronic equipment vital to life should check with the device manufacturer or their doctor to find out whether any hazard exists.

Electric shock hazards are reduced by proper equipment installation and maintenance, good operator practice, proper clothing and body protection, and equipment designed for the job and situation. Equipment should meet applicable NEMA or ANSI standards, such as ANSI/UL 551, *Safety Standard for Transformer Type Arc Welding Machines*.

If significant amounts of welding and cutting are to be done under electrically hazardous conditions, automatic machine controls that safely reduce open circuit voltage are recommended. When special welding and cutting processes require open circuit voltages higher than those specified in NEMA publication EW-1, *Arc Welding Power Sources*, insulation and operating procedures that are adequate to protect the welder from these higher voltages must be provided.

A good safety training program is essential. Employees must be fully instructed in electrical safety by a competent person before being allowed to commence operations. As a minimum, this training should include the points covered in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society). Persons should not be allowed to operate electrical equipment until they have been properly trained.

Equipment should be installed in a clean, dry area. When this is not possible, it should be adequately guarded from dirt and moisture. Installation must be done to the requirements of NFPA 70, *National Electrical Code*, and local codes. This includes disconnects, fusing, and types of incoming power lines.

Terminals for welding leads and power cables must be shielded from accidental contact by personnel or by metal objects, such as vehicles and cranes. Connections between welding leads and power supplies may be guarded using (1) dead front construction and receptacles for plug connections, (2) terminals located in a recessed opening or under a nonremovable hinged cover, (3) insulating sleeves, or (4) other equivalent mechanical means.

The workpiece being welded and the frame or chassis of all electrically powered machines must be connected to a good electrical ground. Grounding can be done by locating the workpiece or machine on a grounded metal floor or platen. The ground can also be connected to a properly grounded building frame or other satisfactory ground. Chains, wire ropes, cranes, hoists, and elevators must not be used as grounding connectors or to carry welding current.

The work lead is not the grounding lead. The work lead connects the work terminal on the power source to the workpiece. A separate lead is required to ground the workpiece or power source to earth ground.

Care should be taken when connecting the grounding circuit. Otherwise, the welding current may flow through a connection intended only for grounding, and may be of a higher amount than the grounding conductor can safely carry. Special radio-frequency grounding may be necessary for arc welding machines equipped with high-frequency arc initiating devices.

Connections for portable control devices, such as push buttons carried by the operator, must not be connected to circuits with operating voltages above 120 V. Exposed metal parts of portable control devices operating on circuits above 50 V must be grounded by a grounding conductor in the control cable. Controls using intrinsically safe voltages below 30 V are recommended.

Electrical connections must be tight and be checked periodically for tightness. Magnetic work clamps must be free of adherent metal particles and spatter on contact surfaces. Coiled welding leads should be spread out before use to avoid overheating and damage to the insulation. Jobs alternately requiring long and short leads should be equipped with insulated cable connectors so that idle lengths can be disconnected when not needed.

Equipment, cables, fuses, plugs, and receptacles must be used within their current-carrying and duty cycle capacities. Operation of apparatus above the current rating or the duty-cycle results in overheating and rapid deterioration of insulation and other parts. Actual welding current may be higher than that shown by indicators on the welding machine if welding is done with short leads or low voltage, or both. High currents are likely with general purpose welding machines when they are used with processes that use low arc voltage, such as gas tungsten arc welding.

Welding leads should be the flexible type of cable designed especially for the rigors of welding service. Insulation on cables used with high voltages or high-frequency oscillators must provide adequate protection. The recommendations and precautions of the cable manufacturer should always be followed. Cable insulation must be kept in good condition, and cables repaired or replaced promptly when necessary.

Welders should not allow the metal parts of electrodes, electrode holders, or torches to touch their bare skin or any wet covering of the body. Dry gloves in good condition must always be worn. The insulation on electrode holders must be kept in good repair. Electrode holders should not be cooled by immersion in water. If water-cooled welding guns or holders are used, they should be free of water leaks and condensation that would adversely affect the welder's safety. Welders should not drape or coil the welding leads around their bodies.

A welding circuit must be de-energized to avoid electric shock while the electrode, torch, or gun is being changed or adjusted. One exception concerns covered electrodes with shielded metal arc welding. When the circuit is energized, covered electrodes must be changed with dry welding gloves, not with bare hands. De-energization of the circuit is desirable for optimum safety even with covered electrodes.

When a welder has completed the work or has occasion to leave the work station for an appreciable time, the welding machine should be turned off. Similarly, when the machine is to be moved, the input power supply should be electrically disconnected at the source. When equipment is not in use, exposed electrodes should be removed from the holder to eliminate the danger of accidental electrical contact with persons or conducting objects. Also, welding guns of semiautomatic welding equipment should be placed so that the gun switch cannot be operated accidentally.

Fires resulting from electric welding equipment are generally caused by overheating of electrical components. Flying sparks or spatter from the welding or cutting operation, and mishandling fuel in engine driven equipment are among other causes. Most precautions against electrical shock are also applicable to the prevention of fires caused by overheating of equipment. Avoidance of fire from sparks and spatter was covered previously.

The fuel systems of engine driven equipment must be in good condition. Leaks must be repaired promptly. Engine driven machines must be turned off before refueling, and any fuel spills should be wiped up and fumes allowed to dissipate before the engine is restarted. Otherwise, the ignition system, electrical controls, spark producing components, or engine heat may start a fire.

Key Terms and Definitions

ACGIH—American Conference of Governmental and Industrial Hygienists. This group is concerned with the proper, safe levels of exposure to hazardous materials.

adiabiatic recompression—the term given to the temperature rise that can occur when some gases at high pressures are released suddenly. (Normal pressure gas releases usually result in a cooling of the gas by the decompression.)

ANSI—American National Standards Institute. An organization promoting technical and safety standards.

ANSI Z49.1—*Safety in Welding, Cutting, and Allied Processes*, a document outlining safe practices for welding and cutting operations.

ANSI Z87.1—*Practice for Occupational and Educational Eye and Face Protection.*

asphyxiation—loss of consciousness as a result of too little oxygen or too much carbon dioxide in the blood.

AWS—American Welding Society. AWS is the technical leader in welding and related issues.

combustibles—any material that can easily catch fire.

cryogenic—very cold service, usually well below 0°F.

DOT—Department of Transportation. A federal or state agency covering the transport of materials.

filter lens—in welding, a shaded lens, usually glass, that protects the eyes from radiation from the welding arc and other heat sources. Welding lenses are numbered, with the higher numbers offering the greatest protection. See Table 2.1, Lens Shade Selector, for appropriate lens selection.

fire watch—a person whose primary responsibility is to observe the work operation for the possibility of fires, and to alert the workers if a fire occurs.

flammable—anything that will burn easily or quickly. (Inflammable has the same meaning.)

fume plume—in welding, a smoke-like cloud containing minute solid particles arising directly from molten metal.

fuse plug—a plug filled with a material, usually a metal that has a very low melting point. Often used as a heat and/or pressure relief device.

fume release—a general term given to the unexpected and undesired release of materials.

galvanized material—any material having a zinc coating on its surface. Common galvanized items are sheet metal and fasteners.

hot work permit—a form designed to ensure that all safety precautions have been considered prior to any operation having open flames or high heat.

lock, tag, and try—the phrase noting the physical locking-out of equipment, tagging it for identification, and trying the equipment to make sure it is not operable prior to beginning any repair work.

MSDS—Material Safety Data Sheet. A document that identifies materials present in products that have hazardous or toxic properties.

NEMA—National Electrical Manufacturers Association.

OSHA—Occupational Safety and Health Act. This federal law outlines the requirements for safety in the workplace.

pascal (Pa)—in the metric system, the unit for pressure, or tensile strength. The U.S. customary equivalent is psi, pounds per square inch. One psi equals 6895 Pa.

pinch points—any equipment geometry that can lead to pinching parts of the body, especially the hands or feet, while working on the equipment.

safety glasses—spectacles with hardened and minimum thickness lenses that protect the eyes from flying objects. Improved eye protection occurs when side shields are attached to the safety glasses.

standby—in welding, a person trained and designated to stand by and watch for safety hazards, and to call for help if needed. Most often used for vessel entry safety.

TLV—Threshold Limit Value. The permissible level of exposure limits for hazardous materials.

toxic—poisonous.

vapors—the gaseous form of a substance.