

Welding Inspection Handbook



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Welding Inspection Handbook

**Fourth Edition
2015**

**Prepared by the
AWS B1C Standing Task Group on Welding Inspection Handbook**

**Under the Direction of the
AWS Technical Activities Committee**

**Approved by the
AWS Board of Directors**



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THE WELDING INSPECTION HANDBOOK is a collective effort of many volunteer technical specialists to provide information to assist welding inspectors and supervisors in the technology and application of visual and nondestructive examination.

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Foreword

The inspection of welds and welded assemblies requires knowledge of many factors of welding quality control. This includes dimensional inspection, nondestructive examination methods, welding processes, welding metallurgy, destructive testing, and the qualification of welding procedures and personnel. It also includes the examination and test requirements of codes, criteria, and specifications; the acceptance standards to be employed; and an understanding of drawings, and welding and nondestructive examination symbols. Knowledge about discontinuities that may be associated with different welding processes, and the ability to evaluate the difference between discontinuities and rejectable defects, is also an important element of welding inspection.

This fourth edition of the *Welding Inspection Handbook* has been prepared by the AWS B1C Welding Inspection Handbook Task Group. The objective is to provide a reliable source of useful reference information. This is particularly relevant for the technically trained individual who may not be directly involved with inspection but whose position requires knowledge about welding inspection. This book also is intended for the inspector who needs a general refresher in the basic requirements of weld inspection. This fourth edition supersedes the AWS *Welding Inspection Handbook* bearing the same title, and includes changes to numerous clauses to provide clarification, correct inconsistencies, and updates representative of current industry practices.

Underlined text in the clauses and subclauses indicates a change from the 2000 edition. A vertical line in the margin indicates a revision from the 2000 edition.

Additional books on the subjects covered in each chapter may be found in good technical libraries. The many specifications and codes that have been used as examples may also be consulted for more detailed information.

This book is an instructive reference. Codes or specifications applicable to any particular weldment always take precedence over the generalized material contained herein. The text of this book has, of necessity, been written in general terms and cannot include all the conditions applicable to a specific instance. Thus, examples given are general and are used only for the purpose of illustration.

Every effort has been made to present this material in convenient form so that the book can be used as a training text for inspectors, engineers, and welders. Although the information generally relates to the arc welding processes, most of it applies to any weldment—fabricated by any joining process—for which the inspection methods described herein may be required.

For the inspection of brazed assemblies, refer to *The Brazing Handbook* published by the American Welding Society. For the inspection of resistance welded assemblies, refer to AWS/SAE D8.7, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, also published by the American Welding Society.

Information on nondestructive examination methods is available in AWS B1.10M/B1.10, *Guide for Nondestructive Examination of Welds*, and in AWS B1.11M/B1.11, *Guide for the Visual Examination of Welds*.

Comments and inquiries concerning this publication are welcome. They should be sent to the Managing Director, Technical Services Division, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Chapter 1

Scope and Application

1.1 Scope

The scope of this handbook includes testing and examination methods that apply to a majority of metallic and nonmetallic weldments used in construction. The extent of inspections should be clearly defined in contract documents or on drawings that refer to a particular weldment (unless otherwise defined in applicable codes or specifications). Furthermore, acceptance criteria should be clearly understood and agreed upon by both the supplier and the purchaser before any production welding begins. Acceptance criteria for weld discontinuities are specifically excluded from this handbook.

It is the responsibility of those charged with the administration and supervision of inspection to make certain that the principles and methods to be used are properly understood and applied uniformly. This responsibility may include the qualification and certification of inspectors where such certification is required by codes, specifications, job contracts, civil law, or company policies.

The following documents address the qualification of welding inspection and nondestructive examination personnel:¹

- (1) AWS QC1, *Standard for AWS Certification of Welding Inspectors*
- (2) AWS B5.1, *Specification for the Qualification of Welding Inspectors*
- (3) ANSI/ASNT CP-189, *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*
- (4) ASNT Recommended Practice SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*
- (5) ASTM 1316, *Standard Terminology for Nondestructive Testing*
- (6) ISO 9712, *Nondestructive Testing—Qualification and Certification of NDT personnel*

Even when a particular qualification for certification program is not mandatory, every welding inspector should be aware of the ethical criteria for welding inspectors contained in documents such as AWS QC1.

1.2 Application

The information in this handbook pertains to the general duties and responsibilities of welding inspectors and is intended as a reference to help their performance. This book provides specific information about methods of weldment inspection; however, much of the information will also generally apply to the examination of nonwelded components, such as base metal inspection prior

1. See Chapter 17 for addresses of standards writing organizations.

to fabrication. For the inspection process to be effective, the welding inspector should be knowledgeable about each examination method to be employed.

1.3 Units of Measurement

This handbook makes sole use of U.S. Customary Units. Approximate mathematical equivalents in the International System of Units (SI) are provided for comparison in parentheses or in appropriate columns in tables and figures.

1.4 Safety

Safety and health issues and concerns are beyond the scope of this handbook; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

- (1) *ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this handbook may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This handbook does not purport to address all safety and health risks that may be encountered. The user of this handbook should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

Chapter 2

Symbols

2.1 Communication

Communication can determine whether a job will be a success or a failure. In industry, drawings convey the designer's concepts to those performing the work. Intricate details can be much more accurately and efficiently described through graphic presentation than through the written word.

In the case of welded construction, a great deal of information may be required in order for the welder to successfully provide a weld adequate for the designer's intended purpose. Using written notes is one method for conveying the necessary design concepts. However, written descriptions can become quite complex and time consuming for intricate details. A simpler and more efficient method uses welding symbols to define the welding requirements.

The American Welding Society has developed a system of standard welding symbols used and accepted worldwide. Figure 2.1 depicts the various types of weld and welding symbols and explains the purposes and locations of the basic elements. A detailed description of the system can be found in AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Figure 2.2 shows the advantages offered when welding symbols replace graphic illustrations. Figures 2.3 and 2.4 show other welding symbols and how they are used to specify the welding requirements. The adjacent details illustrate the significance of each symbol.

Just as the welding symbol is important to the designer and welder, equally important is the welding inspector's knowledge of its meaning. Without this knowledge, the inspector would be unable to assure that the welder has complied with the requirements set forth by the designer. Typical information conveyed by the welding symbols includes the type of weld, size of weld, weld location, joint configuration, finished condition of face and root of the weld, as well as any special instructions.

Knowledge of the information provided by the welding symbol is essential to the inspector when a weld is to be visually examined (VT). Once the inspector understands what the engineer requires, a thorough and highly effective visual examination can result. Many situations warrant a more extensive check than can be provided by visual examination alone. In such cases, other forms of nondestructive examination (NDE) are often employed.

The inspector can gain a great deal of insight from the welding symbol as to the applicability of a particular test when nondestructive examination is involved. In ultrasonic testing (UT) and radiographic testing (RT), for example, useful information provided by the welding symbol might include: joint configuration weld location, type of weld, and size of weld which can help the NDE technician determine the types of discontinuities which may be present and the best method for their detection. Such details allow the inspector to plan his test so that the best test method, technique, and procedure will be used.

Basic Weld Symbols and Their Location Significance within the Welding Symbol									
Location Significance	Fillet	Plug	Slot	Spot or Projection	Stud	Seam	Back or Backing	Surfacing	Edge
Arrow Side									
Other Side					Not Used			Not Used	
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	
No Arrow Side or Other Side Significance	Not Used	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used
Location Significance	Groove								Scarf for Brazed Joint
	Square	V	Bevel	U	J	Flare-V	Flare-Bevel		
Arrow Side									
Other Side									
Both Sides									
No Arrow Side or Other Side Significance	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	

Supplementary Symbols				Standard Location of the Elements of a Welding Symbol									
Weld-All-Around	Field Weld	Melt-Through	Consumable Insert (Square)										
Backing (Rectangle)	Spacer (Rectangle)	Contour											
		Flush or Flat	Convex										
Basic Joint Types													
Identification of Arrow Side and Other Side Joint													
Butt Joint		Corner Joint											
T-Joint		Lap Joint		Edge Joint		Letter Designations				Where letter designations are to be included in the tail of the welding symbol, refer to Annex A (Normative) Tables of AWS A2.4:2012 © 2012 American Welding Society 550 N.W. LeJeune Road Miami, FL 33126 www.aws.org			

Figure 2.1—AWS Standard Welding Symbols

Typical Welding Symbols					
Double-Fillet Welding Symbol		Chain Intermittent Fillet Welding Symbol		Staggered Intermittent Fillet Welding Symbol	
Plug Welding Symbol		Back Welding Symbol		Backing Welding Symbol	
Spot Welding Symbol		Stud Welding Symbol		Seam Welding Symbol	
Square-Groove Welding Symbol		V-Groove Welding Symbol		Double-Bevel-Groove Welding Symbol	
Symbol with Backgouging		Flare-V-Groove Welding Symbol		Flare-Bevel-Groove Welding Symbol	
Multiple Reference Lines		Complete Joint Penetration		Edge Welding Symbol	
Flash or Upset Welding Symbol		Melt-Through Symbol		Joint with Backing	
Joint with Spacer		Contour Symbols			
With Modified Groove Weld Symbol		Flush	Flat	Convex	Concave

Figure 2.1 (Continued)—AWS Standard Welding Symbols

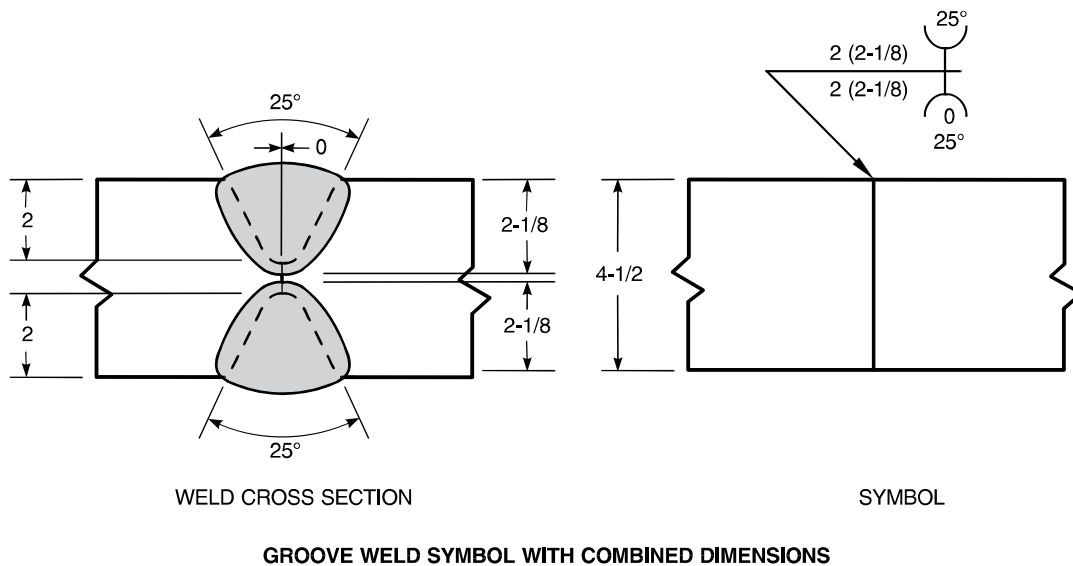


Figure 2.2—Comparison of Welding Symbol and Written Explanation

2.2 Nondestructive Examination Symbols

With the increased use of nondestructive examination by construction industries, it becomes convenient for the engineer to include testing requirements on the fabrication drawings. Noting testing requirements on the drawings helps to avoid many after the fact inconsistencies associated with the extent or type of testing. As with welding symbols, a system has been established to communicate nondestructive examination information using symbols similar to those used for welding. A complete description of this system is included in AWS A2.4.

The construction of nondestructive examination symbols uses the same basic elements found in welding symbols along with similar governing rules. Therefore, arrow side and other side designations retain their same location significance. Figure 2.5 shows the basic elements of the examination symbol and their standard locations with respect to one another.

Figure 2.6 illustrates the shorthand notations used with nondestructive examination symbols.

2.3 Master Chart of Welding, Allied Processes, and Thermal Cutting

Inspection personnel must be familiar with the welding and allied processes within the scope of their work. A welding or allied process is basic to the operation to be performed, and may be subdivided into more specific processes.

In the hierarchy of welding, the welding process stands first. Each welding process definition is complete so that it will stand alone. Processes are defined for prescribed elements of operation. This method of organization is the basis for the Master Chart shown in Figure 2.7.

The chart is a display of a hierarchy of welding and allied processes; the highest generic levels (least specific) are in the center, and the more specific are in boxes on the perimeter. The chart is intended to be comprehensive and includes not only widely used production processes, but also some that are of limited use because they have been replaced by other processes, and those that have only recently been introduced, or have limited applications.

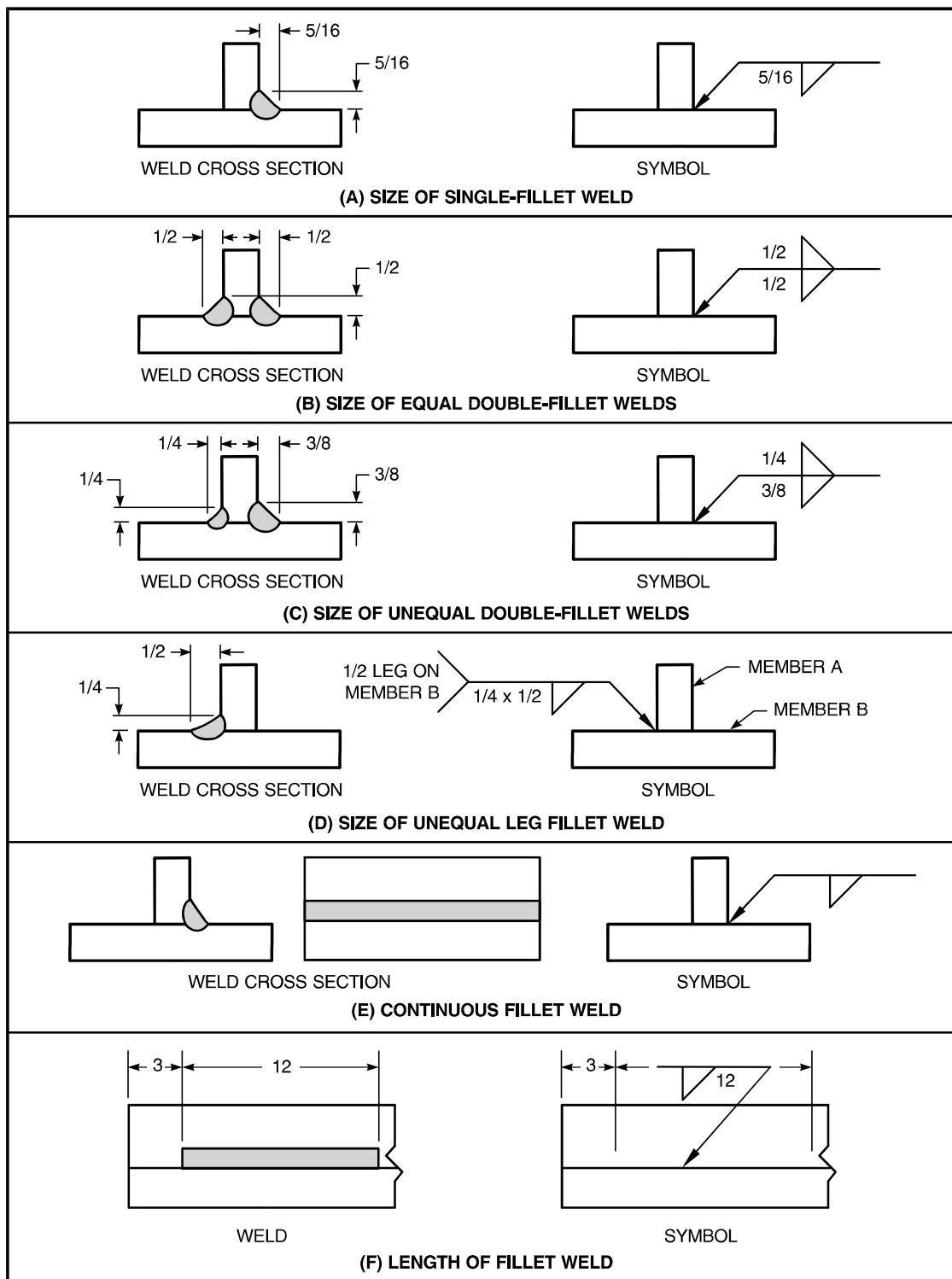


**Figure 2.3—Examples of Typical Fillet Welds
Showing the Corresponding Symbols and Dimensions**

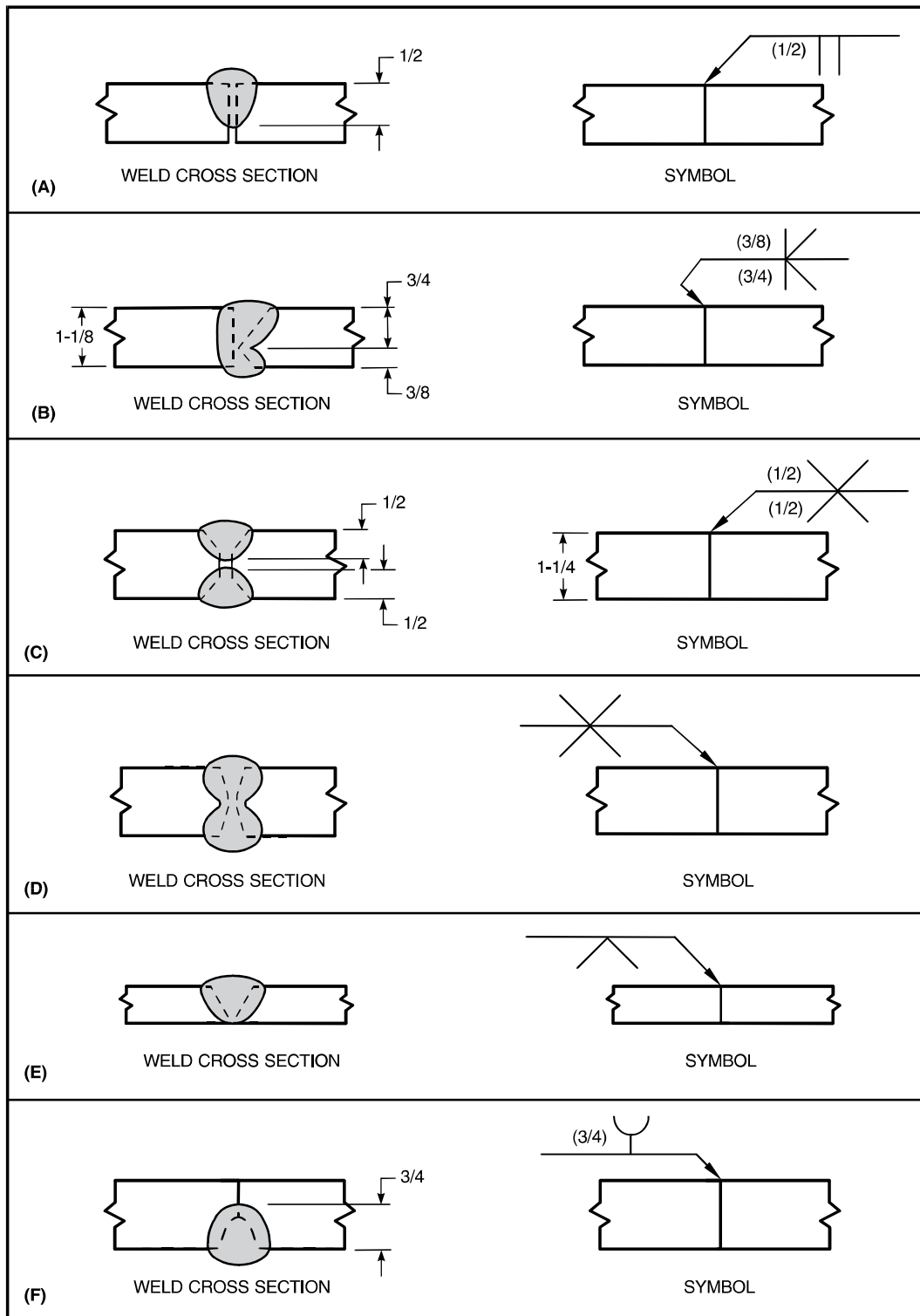


Figure 2.4—Examples of Typical Groove Welds Showing the Corresponding Symbols and Dimensions

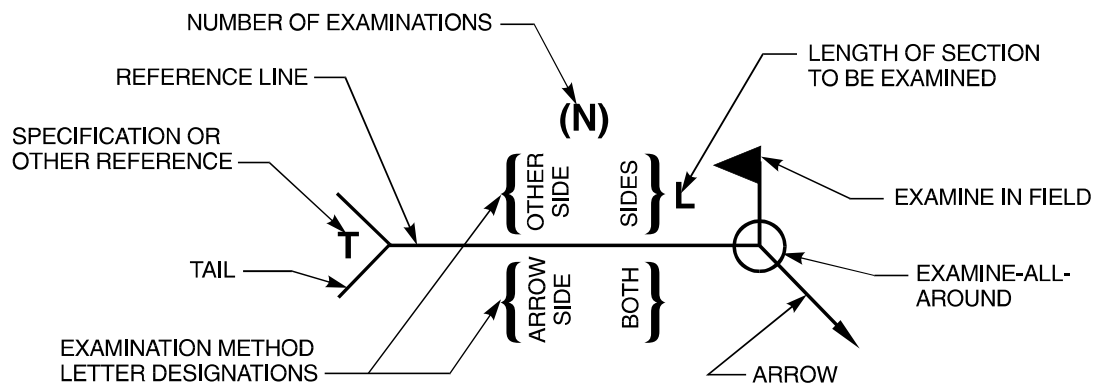


Figure 2.5—Standard Location of Elements for NDE Symbols

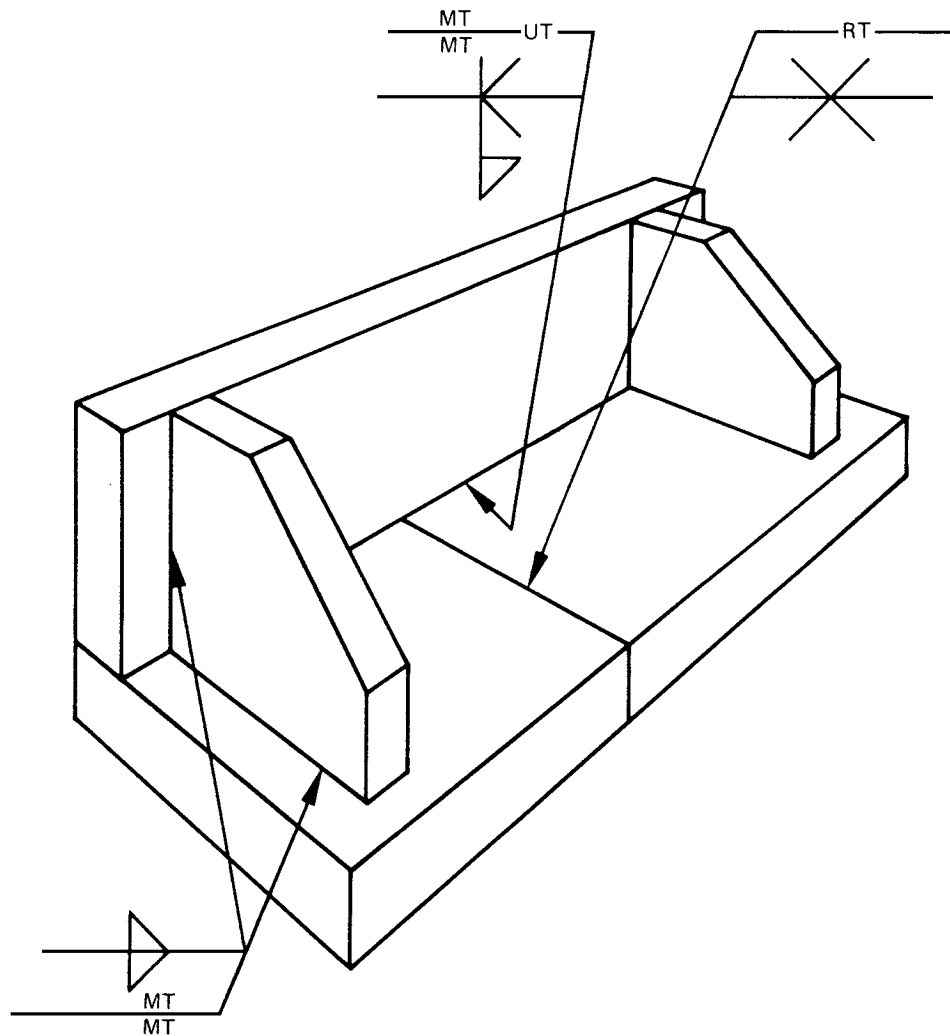


Figure 2.6—Examples of Typical Nondestructive Examination Symbols

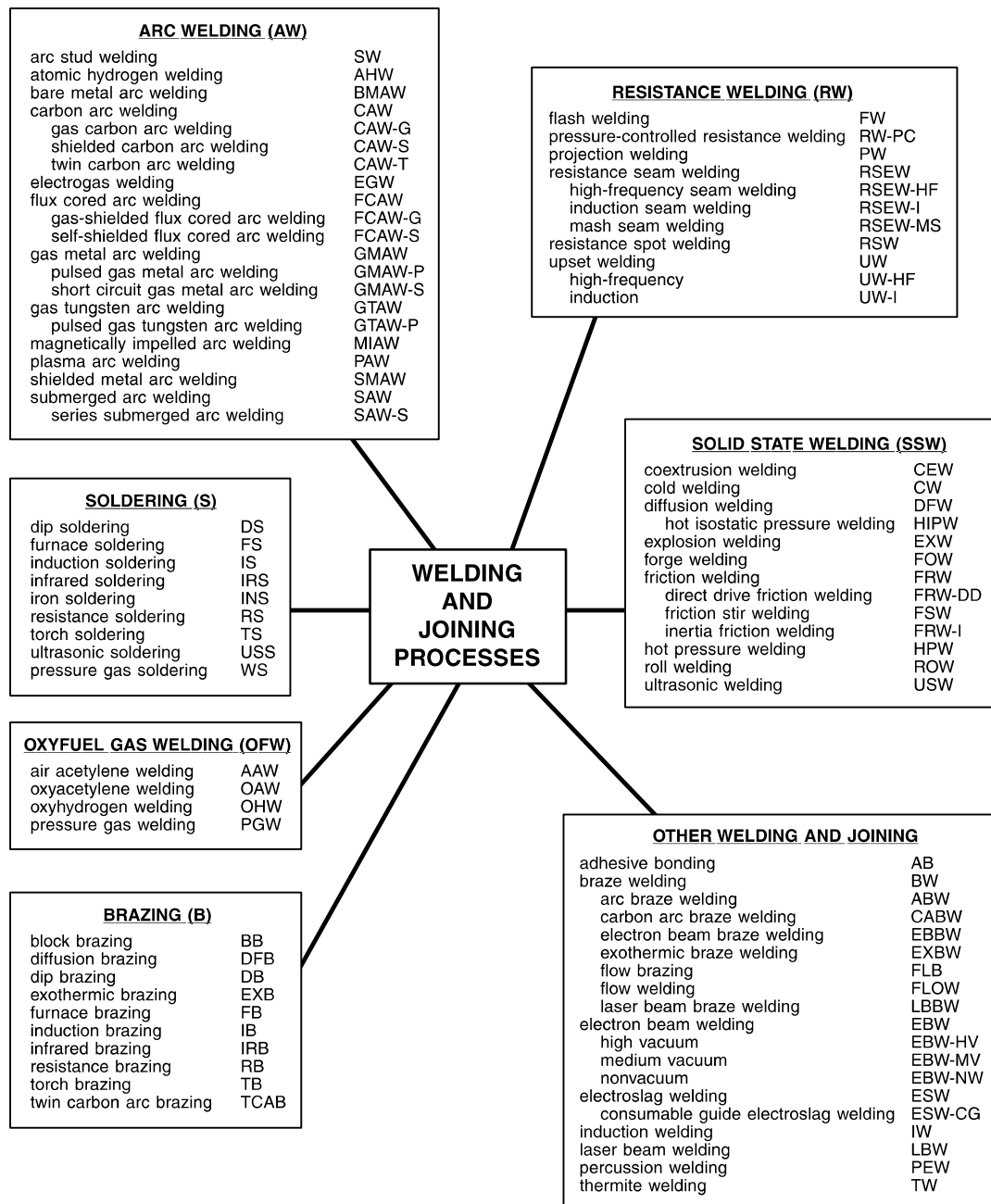


Figure 2.7—Master Chart of Welding, Allied Processes, and Thermal Cutting

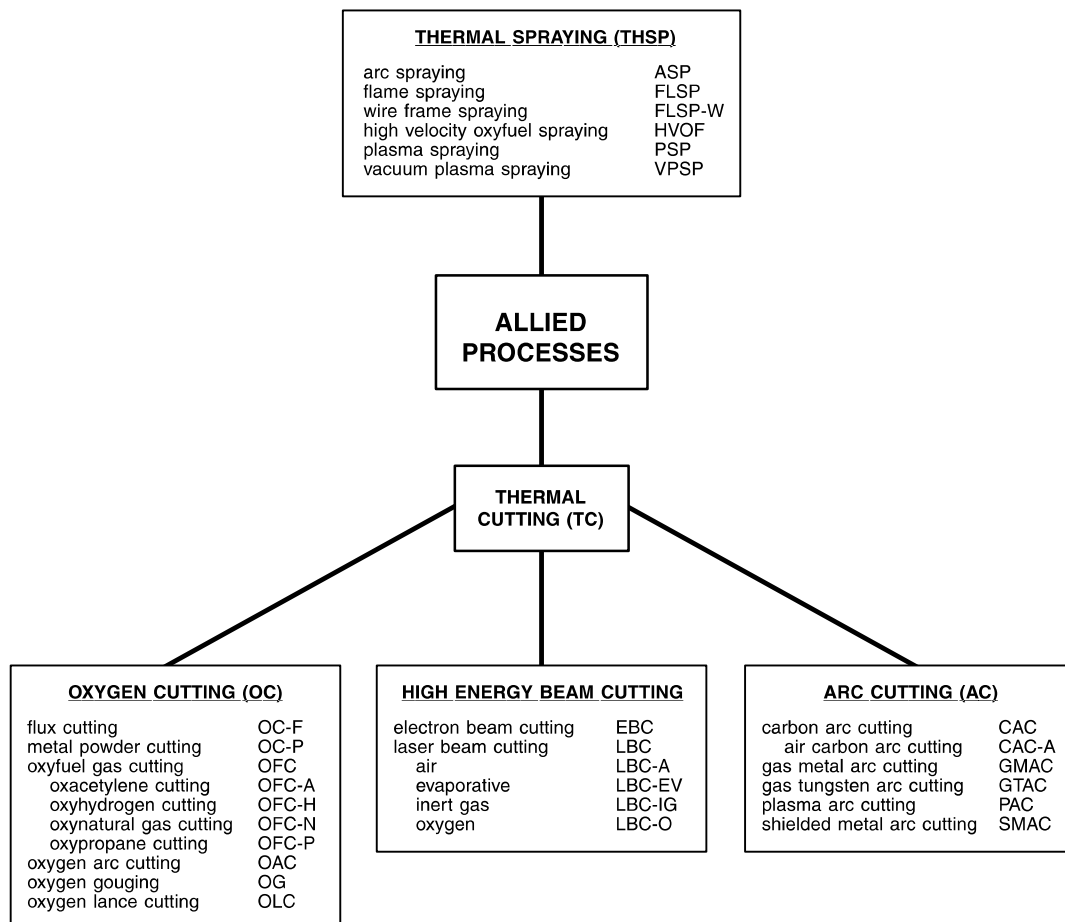


**Figure 2.7 (Continued)—Master Chart of Welding,
Allied Processes, and Thermal Cutting**

2.4 Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terms and definitions used herein.

Chapter 3

Requirements for the Welding Inspector

It is appropriate here to consider attributes desirable for an individual employed as a welding inspector. The nature of the job emphasizes an individual's physical, technical, and ethical qualities. Any weaknesses in these areas can reduce the effectiveness of the individual's performance.

3.1 Inspector Classifications

There are many types of welding inspectors, depending upon technical requirements for the particular fabrication process or processes. These include destructive testing specialists, nondestructive examination specialists, code inspectors, military inspectors, and owner's representative inspectors. All of these may consider themselves welding inspectors simply because they *do* inspect welds.

The fact that welding inspectors work in many different industries performing so many quality related tasks makes it difficult to clearly and concisely describe what a welding inspector is and how that job function is specifically performed.

One fundamental complication is that an individual may perform many functions or only a single function. For example, it is common to perform numerous aspects of welding quality control (e.g., welding procedure qualification, welder performance qualification, in process and final visual examination, destructive testing, and final nondestructive examination). However, it is also common for an individual involved in welding inspection to perform only one of those tasks (e.g., a nondestructive examination specialist).

Another important difference relates to the inspector's employer. The inspector may be directly employed by the manufacturer, the customer, the customer's representative, or an independent agency. While this should not affect the technical application of the individual's inspection skills, it may to some degree influence the logistics of that activity.

In this handbook, however, only a single inclusive category of "inspector" is used, one that includes as many different categories basic to the responsibility of the individual inspector as the particular job may require. Each specific job then would depend upon the relevant requirements, duties, and responsibilities assigned by the inspector's employer.

With this generic approach, descriptions given here are not intended to specifically define the job function of a welding inspector. Information herein should be viewed simply as a general overview of the numerous activities that could be considered part of the welding inspector's job. There will be descriptions of operations and activities which are beyond the scope of certain welding inspectors. In other cases, welding inspectors may be performing other functions that are not specifically addressed in this book. Information provided here should be applied only when in agreement with an inspector's specific job description.

The following are important factors that a company should take into consideration when selecting a person for the job of welding inspector.

3.2 Attributes of the Welding Inspector

The job of welding inspector carries a tremendous amount of responsibility. Selection of the right person for that position should be based on consideration of the following four critical attributes:

- (1) Physical
- (2) Technical
- (3) Ethical
- (4) Personal

3.2.1 Physical

3.2.1.1 Physical Condition. To perform duties in the most effective manner, the welding inspector should be in good physical condition. Since the primary job involves visual inspection, it is obvious that the welding inspector should have good vision, whether natural or corrected. For instance, if color or contrast is important to the inspection process being employed (liquid penetrant, magnetic particle, or color coded parts) then an individual should be tested for the ability to detect those colors.

Another aspect of physical conditioning involves the size of some welded structures. Since welds could be located anywhere on a very large structure, the inspector must be capable of going to the weld at any location in order to make an evaluation. The inspector must comply with safety regulations when performing these duties.

The ability of the welding inspector to get to the work may be reduced if the inspection is not performed immediately after welding. For example, such aids for the welder as ladders and scaffolding may be removed, making access impossible or dangerous. Within safety guidelines, the welding inspector should not be prevented from performing proper inspection because of a physical condition.

3.2.2 Technical

3.2.2.1 Technical Ability. Though in certain situations there may be no specific level of education and training required for welding inspectors, the job may involve interpretation of results. Therefore, an individual must have at least some level of technical knowledge to perform well as an inspector. In order to perform welding inspection, the individual will continually be asked to make judgments based on visual observations of physical characteristics of welds and weldments and their comparison with drawings or standards.

If an individual is unable to understand some written requirement, it will be difficult to make a judgment as to a weld's acceptability in accordance with that standard. There is more to an evaluation than just reading the specifications. Once read, the inspector must interpret its meaning. Even then, some requirement of a code or specification may appear very clear and straightforward when initially read; however, comparison of this written requirement with an existing physical condition may still prove to be extremely difficult.

Technical ability is also necessary in order for the welding inspector to effectively express ideas or inspection findings. Once an inspection has been performed, the inspector must be capable of describing the inspection methods used and the results with sufficient accuracy and

detail to adequately communicate the findings to other parties that may not be familiar with the work being performed.

3.2.2.2 Interpretation of Drawings and Specifications. Another quality which the welding inspector should develop is an ability to understand and apply the various documents describing weld requirements. These include: drawings, codes, specifications, and procedures. These documents provide most of the information regarding what, when, where, and how the inspection is to be performed. In fact, these documents literally constitute the rules under which the welding inspector must perform. They also state the requirements by which the welding inspector will judge the weld quality. Obviously, such documents must be reviewed prior to the start of any work, because the welding inspector should be aware of the job requirements before any production. Many times this review will reveal required “hold points” for inspections, welding procedure and welder qualification requirements, and special processing steps or difficulties such as weld inaccessibility during fabrication.

Although the welding inspector should be thorough in reviewing documents, it is not necessary that requirements be memorized. These are *reference* documents and should be readily available at any time in the fabrication process. Often, the inspector is the individual most familiar with all of these documents. The inspector may be called upon by others for information and interpretation regarding the welding requirements.

3.2.2.3 Inspection Experience. Having actual on the job inspection experience is very important. Text books and classroom studies simply do not provide all of the things needed to inspect effectively. Experience will aid the welding inspector in becoming more efficient. In time, better ways of thinking and working will develop.

On the job experience will also help the inspector develop the proper attitude and point of view regarding job assignment. After working with various codes and specifications, the inspector’s effectiveness will improve because of an improved understanding of welding requirements. To emphasize the need for inspection experience, it is commonplace to see a novice inspector paired with an experienced one so that proper techniques can be passed along. Inspector certification programs may require some minimum level of actual inspection experience.

3.2.2.4 Knowledge of Welding. Another desirable quality for a welding inspector is a basic knowledge of welding and related processes. Because of their background, welders are sometimes chosen as welding inspector trainees. Such a person is certainly better prepared as an inspector to understand many problems that the welder may encounter. This knowledge helps the inspector in gaining respect and cooperation from the welders. Further, this understanding helps the welding inspector predict what weld discontinuities may be encountered in a specific situation.

The welding inspector can then monitor critical welding variables in order to help prevent these welding problems. When the inspector is experienced in welding processes and understands their advantages and limitations, possible problems can be more easily identified and prevented.

3.2.2.5 Knowledge of Examination Methods. Knowledge of various destructive and nondestructive examination methods should be helpful to the welding inspector. Although the inspector may not perform these tests, from time to time it may be necessary to review test results. As with welding processes, the welding inspector is aided by a basic understanding of testing methods. It is important that the inspector be aware of alternate methods which could be applied to enhance visual inspection.

3.2.3 Ethical. In order to safeguard public health and to maintain integrity and high standards of skills, practice, and conduct in the occupation of welding inspection, the inspector must render decisions promptly while remaining impartial and tolerant of the opinions of others. The following recommendations for a welding inspector's behavior are patterned after the ethical requirements specified in AWS QC1, *Standard for AWS Certification of Welding Inspectors*.

3.2.3.1 Integrity. The welding inspector must act with complete integrity (honesty) in professional matters and be forthright and candid with respect to matters pertaining to welding inspector qualification requirements.

3.2.3.2 Responsibility to the Public. The welding inspector is obligated to preserve the health and well being of the public by performing the duties required of weld inspection in a conscientious and impartial manner to the full extent of the inspector's moral and civic responsibilities and qualifications. Accordingly, the welding inspector shall:

- (1) Undertake and perform assignments only when qualified by training, experience and capability;
- (2) Present credentials upon request to persons authorized to examine them;
- (3) Neither falsely represent current status nor seek to misrepresent certification level by modification of certification documents or false verbal or written testimony of current level or status;
- (4) Be completely objective, thorough, and factual in any written report, statement or testimony of the work and include all relevant or pertinent testimony in such communiqués or testimonials;
- (5) Sign only for work that the inspector has inspected, or for work over which the inspector has personal knowledge through direct supervision; and
- (6) Neither be associated with, nor knowingly participate in a fraudulent or dishonest venture or activity.

3.2.3.3 Public Statements. The welding inspector will issue no statements, criticisms, or arguments on weld inspection matters connected with public policy which are inspired or paid for by an interested party, or parties, without first identifying the party, the speaker, and disclosing any possible pecuniary interest.

The welding inspector will not publicly express any opinion on a weld inspection subject unless it is founded upon adequate knowledge of the facts in issue, upon a background of technical competence pertinent to the subject, and upon honest conviction of the accuracy and propriety of the statement.

3.2.3.4 Conflict of Interest. The welding inspector shall avoid conflict of interest with the employer or client and will disclose any business association, or circumstances that might be so considered.

The welding inspector shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties or their authorized agents.

The welding inspector shall not solicit or accept gratuities, directly or indirectly, from any party, or parties, dealing with the client or employer in connection with the welding inspector's work.

The welding inspector shall, while serving in the capacity of an elected, retained, or employed public official, neither inspect, review, nor approve work in the capacity of a welding inspector on projects also subject to the inspector's administrative jurisdiction as a public official; unless this practice is expressly dictated by a job description, specification, or both, and all affected parties to the action are in agreement.

3.2.3.5 Solicitation of Employment. The welding inspector shall neither pay, solicit, nor offer, directly or indirectly, any bribe or commission for professional employment with the exception of the usual commission required from licensed employment agencies.

The welding inspector shall neither falsify, exaggerate, nor indulge in the misinterpretation of personal academic and professional qualifications, past assignments, accomplishments, and responsibilities, or those of the inspector's associates. Misrepresentation of current certification status at the time of, or subsequent to, submission of requested employment information, or in the solicitation of business contracts wherein current certification is either required or inherently beneficial (advertisements for training courses, consulting services, etc.) shall be a violation of this subclause.

The welding inspector is cautioned against functioning as an independent in fields out of his or her capability, without first investigating for possible industry or public requirements and additional education/experience requirements (e.g., industrial labs, in the concrete and soil testing field, etc.).

3.2.4 Personal

3.2.4.1 Professional Attitude. The first, and perhaps the most important personal quality, is a professional attitude. This is a real key to the success of the welding inspector, because it will determine the degree of respect and cooperation the inspector will receive 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 they are fair, impartial and consistent. If an inspector's decisions show partiality or inconsistency, they will undermine the inspector's reliability.

In keeping with this professional attitude, the welding inspector's decision should be consistent with the job requirements so that decisions are neither too critical nor too lenient. For example, it is a mistake to have preconceived ideas as to a component's acceptability. The inspector should review the facts and make decisions based solely on those facts.

This need for professionalism also extends into a person's dress, manner, and language used when dealing with others. If these characteristics become offensive to others, they may well, by themselves, reduce an inspector's effectiveness.

The inspector should develop a positive attitude. The goal is to assure that the welding has been done properly, rather than to try and find something wrong. Every attempt should be made to be cooperative and helpful. When decisions are being formulated, the welding inspector should genuinely consider all opinions and recommendations. Only after carefully listening to input from other involved parties, and combining that information with all the facts and requirements, can the welding inspector make a truly sound judgment.

Membership in professional and technical organizations offers individual inspectors up to date information on revised standards, new industrial practices, and requirements affecting their work.

3.2.4.2 Learning Potential. Individuals are often hired as welding inspectors primarily because of their learning potential. The inspector can perform the job more effectively after being trained extensively in a variety of subjects. In fact, because the job of welding inspector involves so many different aspects, it is virtually impossible to gain all of the necessary information through experience alone. Personal and professional experience must be supplemented by additional training and education.

3.2.4.3 Completing and Maintaining Inspection Records. 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 be capable of accurately communicating all aspects of the inspection, including the results. The records should be legible, neat, and understandable to anyone reading the report. Therefore, the report should contain sufficient detail to be complete. The welding inspector should also consider these records as protection should questions later arise. Reports should contain sufficient information regarding how the inspection was performed so that similar results can be obtained later by someone else.

Once records have been developed, the welding inspector should be capable of maintaining all necessary information in an orderly fashion to facilitate easy retrieval. Accordingly, there are a few "rules of etiquette" relating to inspection records. First, field notes or records should be completed in ink; if incorrect entries are noted, they can be lined out and corrected. This corrective action should then be initialed and dated for explanation. Next, the report should accurately and completely state the job name and inspection location in addition to specific test information. The use of sketches and pictures help to convey information regarding the inspection results. Finally, the completed report should then be signed and dated by the inspector who actually performed the work.

3.3 Certification of Qualification

Education, training, and experience are crucial to the qualification of a welding inspector. A potential welding inspector should be aware that the increasing variety of welding processes, materials, codes, and other standards applied to today's product makes the job more complicated and difficult. This simply means that welding inspectors have an increasingly important job and that this job must be done in a more uniform manner.

Since 1976, the American Welding Society has been actively involved in the examination, qualification, and certification of welding inspection personnel. The guidelines for the Certified Welding Inspector program have been established by the AWS Qualification Committee and Certification Committees and approved by the AWS Board of Directors. The administration of this program is the responsibility of the AWS Certification Department.

In order to qualify as a Senior Certified Welding Inspector (SCWI), Certified Welding Inspector (CWI), or a Certified Associate Welding Inspector (CAWI), an individual must show evidence of specified minimum levels of experience, educational training, and vision requirements which have been established by the AWS Qualification Committee. After these preliminary requirements have been met, the individual is required to successfully pass a three part examination. Upon passing of all three parts of the examination, AWS will certify, register, and document the qualification and issue an identification card. A stamp bearing the individual's name

and certification number may be purchased for use in identifying parts or inspection reports approved by the Certified Welding Inspector. Recertification is required every three years.

For information regarding the CWI program, contact the AWS Certification Department. Other publications from Chapter 17, “Codes and Other Standards,” should be used as references and guides.

Chapter 4

Welding Inspection Operations

The last chapter outlined desirable characteristics and responsibilities of a welding inspector. This chapter concentrates on the most essential operations involved in the welding inspection process.

Welding inspectors can have a diversified range of responsibilities, depending upon the specification or code to which they are working, and the particular manufacturing or fabrication industry in which they are employed. Welding inspection operations will, for the most part, follow the general sequence of the fabrication process. The following outline is a list of activities typically encountered in welding inspection:

- (1) Review of drawings, specifications, and manufacturing instructions
- (2) Review of the manufacturer's approved quality assurance/ quality control program
- (3) Verification of welding procedures and personnel qualifications
- (4) Verification of approved procedure for qualifying welding and inspection personnel
- (5) Selection and examination of production test samples
- (6) Evaluation of test results
- (7) Preparation of test reports and maintenance of records
- (8) Observance and monitoring of recommended safety guidelines.

4.1 Review of Drawings, Specifications, and Manufacturing Instructions

Welding inspectors should have a working knowledge of the product being manufactured, especially those components or subassemblies which they will inspect. Detailed knowledge of drawing requirements, specification requirements, and any manufacturing instructions is essential. It also is helpful to have a knowledge of the material to be used in the weldment because certain metals may require special treatment for satisfactory welding. Welding and related procedures should contain information that incorporates all of the specified variables for performing the operation. Manufacturing instructions detail the use of particular procedures for various phases of fabrication.

The welding inspector should be alert to any changes made in these documents to assure compliance with all other procedures and fabrication requirements. Deviations from drawings, specifications, and manufacturing instructions should be referred to the appropriate technical function for resolution. In some instances, deviations from drawings or specifications should be referred to a regulatory agency for approval.

It is not always possible to write a specification that contains all the detailed information needed to provide an answer for all questions that might arise. Those parts of the specification that are unclear should be referred to the appropriate technical personnel for interpretation.

4.2 Review of the Manufacturer's Approved Quality Assurance/Quality Control Program

The welding inspector should be aware of the manufacturer's quality program (or absence of a quality control program). A quality program provides the administrative steps needed to inspect and control the quality of the completed product. Chapter 6, "Quality Assurance," describes the elements of a good program. Quality assurance includes all planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily to design requirements or intended service. Quality control, which may be included in quality assurance, includes those actions related to the physical characteristics of a material, structure, component, or system. These actions provide a means to control the quality of the material, component, or system to predetermined requirements.

A quality program may include control over a manufacturer's procedures. This may include final approval and control of procedure revisions, or procedures and job order applicability. Other functions might include the administration of the manufacturer's instrument calibration program. A quality assurance program will document compliance to requirements of the applicable code or standard. The inspector should have general familiarity with program requirements to assure that compliance with the program is achieved.

The welding inspector should be familiar with rules, procedures, and methods for handling and reporting discrepancy findings to the manufacturer.

4.3 Verification of Welding Procedure and Personnel Qualifications

Prior to the start of fabrication, the inspector should verify that the fabricator has prepared written welding procedure specifications that meet the applicable specification, standard, or code. The welding procedure should be capable of producing weldments with adequate strength, ductility, and toughness to satisfy the applicable specification or code. Chapter 10, "Qualification of Welding Procedures," describes the elements of a welding procedure specification and explains the reasons for its use.

Prior to the start of production welding, the inspector should review the qualifications of welders and welding operators that will work on the project. It may be desirable, depending upon the contract, to review the fabricator's procedures for qualification of welders and welding operators. Some contracts may require this, and also require that the procedure be approved by the proper personnel. The welding inspector should be sure that (1) only approved welding procedures are used on the applicable contract, and (2) welders and welding operators are qualified. The contract should specify the requirements as to how this may be accomplished.

Additionally, the welding inspector should be alert to changes of variables in any welding procedure. Changes or deviations in the procedural requirements should be brought to the attention of the proper personnel. Revisions should be qualified by tests where required and distributed to welders and welding operators performing the work. New performance qualifications may be required if the revised procedures exceed the welder or welding operator's limitations of variables defined in the applicable specification or code.

The chapters on “Qualification of Welding Procedures” and “Qualification of Welders and Welding Operators” contain sample qualification requirements and examples where welders may not be working within the limits of their qualifications.

The objective of a welding procedure qualification test is to determine the mechanical properties of the welded joint. The objective of performance qualification is to determine the ability of an individual to deposit sound weld metal with a previously qualified welding procedure.

As with welder and welding operator qualifications, inspection personnel should also be qualified prior to the start of the inspection of production welds. The fabricator should ensure conformance to all applicable code and contract requirements for the qualification and certification of inspection personnel. These requirements vary significantly from code to code and also depend on the weld examination/test method. Examples of certification standards are: AWS QC1, *Standard for AWS Certification of Welding Inspectors*; ASNT *Recommended Practice SNT-TC-1A*; and ASNT CP-189, *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*; ASME QAI-1, *Qualifications and Duties for Authorized Nuclear Inspection*; and NB-263, *Rules for Commissioned Inspectors*. The AWS QC1 certification has three levels: Senior Certified Welding Inspector (SCWI), Certified Welding Inspector (CWI), and Certified Associate Welding Inspector (CAWI). See Chapter 16 for more information on the ASNT program.

4.4 Verification of Approved Procedures for Qualifying Welding and Inspection Personnel

Although welding and inspection personnel are qualified in accordance with approved procedures, verification is nonetheless necessary to provide added assurance that procedures are applied properly and competently. To a large extent, the quality of welding and the quality of inspection depend upon the application of the correct inspection procedures. The welding inspector should verify that procedures specifically approved or agreed upon for the job are being used. The welding inspector may find it advantageous to prepare a checklist for each inspection procedure to use as a guide for performing the required duties. Various recognized inspection methods and tests are described in Chapter 13, “Destructive Testing of Welds,” Chapter 14, “Proof Tests,” and Chapter 15, “Nondestructive Examination Methods.”

In general, inspection processes should be performed in sequence with the manufacturing operations, as established by the fabricator. There are good reasons for doing this, some of which are the following:

- (1) Interference between inspection and production is kept to a minimum.
- (2) Inspection operations required at a particular stage of fabrication can be completed (such as when performance of the next manufacturing step would make inspection of the preceding step impossible).
- (3) In process inspection permits early detection and correction of deficiencies, improving economics and efficiency.

The following sequence of welding and inspection operations is offered as a general overall guide. It should be understood that the actual operations and the order in which they are accomplished will depend upon the type of weldment, the method of manufacture, and the requirements of the governing contract. The inspector may want to establish witness or hold points to verify one or more of the items shown in Table 4.1.

Table 4.1
Sequence of Welding and Inspection Operations

Prior to Welding	During Welding	After Welding
• Material Identification — Chemical analysis — Mechanical properties • Base Metal Conditions — Freedom from internal and surface discontinuities — Flatness, straightness, dimensional accuracy • Joint Condition — Edge Shape — Dimensional accuracy — Cleanliness — Root opening — Alignment — Backing — Tack welds • Special Assembly/Fabrication Practice — Adequacy and accuracy of jiggling, bracing, or fixturing — Application and accuracy of pre-stressing or precambering	• Preheat and interpass temperatures — Controls — Measurement methods • Filler Metal — Identification — Control — Handling • Root Pass — Contour — Soundness • Root preparation prior to welding second side • Cleaning between passes • Appearance of passes (sometimes in comparison with workmanship standard) • In-process NDE as required or specified • Conformance to approved welding procedure	• Postheat treatment requirements • Acceptance inspection • Method of cleaning for inspection • Nondestructive examination — Visual examination — Surface contour and finish of welds — Conformity of welds with drawings — Magnetic particle — Liquid penetrant examination — Radiographic examination — Ultrasonic examination — Proof testing — Other suitable methods • Destructive testing — Chemical — Mechanical — Metallographic • Marking for acceptance or rejection • Repairs • Inspection after repair

4.5 Selection and Examination of Production Test Samples

In many types of welded assemblies, certain inspections of the finished product may be performed on samples selected by the welding inspector from the production line. These samples may be selected at random, or in accordance with established criteria. In either case, the selection and the witnessing of the testing of these samples are among the important duties of the welding inspector. In some cases, selection of samples is left to the judgment and discretion of the welding inspector, rather than prescribed by specification or code. In such cases, the number of samples should not be more than is needed to reasonably determine conformance to the required standards. It is common practice for most contracts to mandate a specific sampling plan and, further, to require additional sampling be performed for each unsatisfactory sample until workmanship standards are confirmed.

Certain tests or treatments may be prescribed for the samples selected by the welding inspector. These may include visual, radiography, hydrostatic tests, metallurgical examination, mechanical testing to destruction, or other detailed examinations. The welding inspector should determine that such work, as prescribed, is properly carried out. Various sampling, testing, and inspecting methods are described in this handbook.

4.6 Evaluation of Test Results

It would be impractical for the welding inspector to perform or witness all tests made in connection with some weldments. Where the job requires, however, the welding inspector should witness or observe sufficient test processes to assure that the tests are being performed in the proper manner and that the results are accurate. Evaluation and final disposition of test results will usually require the welding inspector to carefully consider the attributes of the entire process.

From time to time, the welding inspector will review test or inspection results that do not meet the required standards for acceptance in every detail. In this case, the inspector should identify and communicate the nonconformance. The disposition of nonconformances may be to repair, scrap, or perhaps to accept the nonconformance. The inspector should be knowledgeable of the approval authority for disposition of nonconformances and be very clear on the difference between the separate activities of inspection for conformance and disposition of nonconforming attributes. Except where the inspection and production functions are combined, it is rare for the welding inspector to be granted authority to disposition rejectable weld discontinuities.

4.7 Preparation of Test Reports and Maintenance of Records

Any work performed under a specification or code that requires inspection or tests will also require records. However, whether required or not, the welding inspector should keep adequate records. Records provide documentation for the welding inspector should questions arise at some later time.

It is also the welding inspector's duty to check his/her records for completeness and accuracy in accordance with specified requirements and to make certain that they are available when needed.

Any records that require the fabricator's signature should be prepared by the fabricator rather than by the welding inspector.

Records should contain as much detail as necessary. It is desirable that the welding inspector comment on the general character of the work, how well it stayed within prescribed tolerances, difficulties that were encountered, and whether any defects were noted. All repairs should be explained. Copies of these records should go to all persons entitled to receive them, and the welding inspector should keep a copy on file.

4.8 Observance and Monitoring of Recommended Safety Guidelines

Another of the welding inspector's duties is to recognize a safety hazard that could result in injury to welding and inspection personnel. For more information, refer to Chapter 5, "Inspection Safety Considerations" or ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Well versed welding inspectors should be able to recognize problems such as poor ventilation, which could cause dizziness and cause injury to the welder.

When welding is being performed it is a good idea to assure that all aspects of welding safety procedures are being followed. This is true not only for proper welding quality, but to make the shop a safe place to work. These practices do not only show up in good weld quality, but result in money saved in the prevention of down time due to accidents.

Chapter 5

Inspection Safety Consideration

Safety is an important consideration in all shop operations including all aspects of nondestructive examination (NDE). This chapter covers hazards that may be encountered with nondestructive examination equipment and processes. The inspector should read and understand the manufacturers' instructions and the safety data sheets (SDSs) on safety and recommended practices for the inspection process, materials, and equipment, to minimize personal injury and property damage, and assure proper disposal of wastes.

The NDE methods used that are applicable to the inspection of weldments listed below will be discussed in this chapter:

- (1) Visual Testing (VT)
- (2) Liquid Penetrant Testing (PT)
- (3) Magnetic Particle Testing (MT)
- (4) Radiographic Testing (RT)
- (5) Electromagnetic Testing (ET)
- (6) Ultrasonic Testing (UT), and
- (7) Acoustic Emission Testing (AET)

5.1 Visual Testing (VT)

Lighting of the weld joint should be sufficient for good visibility. In addition to ambient light, auxiliary lighting may be needed. The inspector should be aware that improper lighting may cause eye problems. If the area to be inspected is not readily visible, the inspector may use mirrors, borescopes, flashlights, or other aids.

5.2 Liquid Penetrant Testing (PT)

Liquid penetrant inspection material consists of fluorescent and visible penetrants, emulsifiers, solvent base removers, and developer. These materials have the potential to be absorbed through the skin, inhaled, or ingested. They may also be toxic and/or flammable. Safe practices for handling these products are found in the Safety Data Sheet (SDS), see Figure 5.1. The SDSs should be reviewed prior to use for safe handling practices.

5.3 Magnetic Particle Testing (MT)

Operators should be aware of any potential hazards and know how to prevent them. The following precautions are recommended per the Safety Data Sheets by the manufacturer and should be observed.

SAFETY DATA SHEET

1. **IDENTIFICATION**

Company:
Address:
Telephone No.:
Product Use:
Packages:
NFPA Rating:
PIN (Canada):
Revision Date:

2. **HAZARDOUS INGREDIENTS**

<u><i>Ingredient</i></u>	<u><i>Wt/Wt %</i></u>	<u><i>CAS #</i></u>	<u><i>TLV</i></u>	<u><i>PEL</i></u>	<u><i>LD₅₀</i></u>	<u><i>LC₅₀</i></u>
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3. **HAZARDOUS IDENTIFICATION**

EMERGENCY OVERVIEW

Bland oily liquid which may irritate the skin and eyes. Difficult to ignite, but will burn vigorously if engulfed in fire.

POTENTIAL HEALTH EFFECTS

Skin Contact:

Eyes:

Inhalation:

Ingestion:

Medical conditions known to be aggravated by exposure to product:

4. **FIRST AID**

Skin Contact:

Eyes:

Inhalation:

Ingestion:

NOTE: In all severe cases, contact physician immediately. Local telephone operators can furnish number of regional poison control center.

5. **FIRE HAZARD**

Conditions of flammability:

Flash point (Bulk):

Flammable limits in air:

Extinguishing media:

Special fire fighting procedures:

Hazardous combustion products:

Unusual fire hazards:

6. **ACCIDENTAL RELEASE MEASURES**

Mop up or sweep up with absorbent. (For disposal, see Section 13).

7. **HANDLING AND STORAGE**

Avoid breathing spray mist.

Avoid repeated or prolonged skin contact.

Avoid eye contact.

Store away from heat source.

Figure 5.1—SDS Sheet

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Controls: None, unless supplied as spray. Use where ventilation will carry spray mist away from occupied areas.

Personal protection: Wear safety glasses to protect eyes. Wear nitrile rubber gloves if hand exposure is unavoidable.
Respirator with filter if sprayed in enclosed, unventilated space.

9. PHYSICAL PROPERTIES

Initial boiling point (bulk):

Percent volatile:

Density/sp. gravity:

Water solubility:

pH:

10. STABILITY AND REACTIVITY

Stability:

Incompatibility:

Hazardous decomposition products:

Reactivity:

11. TOXICOLOGICAL INFORMATION

Carcinogenicity:

Threshold limit value:

WHMIS information (Canada):

12. ECOLOGICAL INFORMATION**13. DISPOSAL**

As a non-hazardous oily waste, incinerate or send to waste handler who can blend it into secondary fuels.

RCRA:

U.S. EPA Waste Number:

14. TRANSPORTATION

U.S. DOT: 49 CFR 172.101 Hazardous Materials Table

Bulk

Proper shipping name:

Technical Name of Hazardous Component(s):

Hazard class or division:

Identification No.:

Packing Group:

Other Information:

15. REGULATORY INFORMATION

TSCA:

CERCLA:

SARA TITLE III, Section 313:

California Proposition 65:

WHMIS Class (Canada):

Note: This SDS has been prepared to meet WHMIS (Canada) requirements with the exception of using 16 headings.

16. OTHER INFORMATION

Revision Statement

Supersedes:

Prepared by:

Figure 5.1 (Continued)—SDS Sheet

Magnetic powders should be kept dry and protected from moisture at all times. Oil based suspensions may be flammable and should be handled with care where ignition is possible. Be aware that water based suspensions may contribute to a shock hazard when used near electrical equipment.

These materials have the potential to be absorbed through the skin, inhaled, or ingested. They may also be toxic and/or flammable. Safe practices for handling these products are found in the Safety Data Sheet (SDS) (see Figure 5.1). The SDSs should be reviewed prior to use for safe handling practices.

5.4 Radiographic Testing (RT)

Federal, state, and local governments issue licenses for the operation of industrial radiographic equipment. The federal licensing program is concerned mainly with those companies that use radioactive isotopes as sources. To become licensed under federal programs, a facility or operator should show that it meets standard protection of both operating personnel and the general public from excessive levels of radiation.

The amount of radiation that is allowed to escape from the area over which the licensee has direct and exclusive control is limited to an amount that is safe for continuous exposure. In most cases, a maximum exposure of 2 millirems per hour (2 mrem/h), 100 mrem in seven consecutive days, or 500 mrem in a 12-month period is considered to be safe.

5.4.1 Radiation Monitoring. A radiation safety program should ensure that both the facility and all personnel subject to radiation exposure are monitored. Facility monitoring generally is accomplished by performing radiation surveys, i.e., periodically taking readings of radiation leakage during operation of each source under various conditions. Calibrated instruments should be used to measure radiation dose rates at various points within the restricted area and at various points around the perimeter of the restricted area.

To guard against inadvertent leakage of radiation from a shielded work area, interlocks disconnect power to an x-ray tube when an access door is opened, or prevents any door from being opened if the unit is turned on. Alarms are connected to a separate power source which activate audible or visible signals, or both, whenever the radiation level exceeds a preset value.

All personnel within the restricted area should be monitored to assure that no one absorbs excessive amounts of radiation. Devices such as pocket dosimeters and film badges are the usual means of monitoring. Often both devices are worn. Pocket dosimeters may be direct reading or remote reading.

5.4.2 Access Control. Permanent facilities are usually separated from unrestricted areas by shielded walls. Sometimes, particularly with onsite radiographic inspection, access barriers may be only ropes and sawhorses, or both. In such instances, the entire perimeter around the work area should be under continual surveillance by radiographic personnel. Signs that carry a symbol designated by the U.S. Government should be posted around any high radiation area. This helps to inform casual bystanders of the potential hazard, but should never be assumed to prevent unauthorized entry into the danger zone. In fact, no interlock, no radiation alarm, and no other safety devices should be considered a substitute for constant vigilance on the part of radiographic personnel.

5.5 Electromagnetic Testing (ET)

Electromagnetic testing, commonly called eddy current testing, uses alternating current sources, therefore, normal electrical precautions should be observed—see Electrical Hazards Clause 5.7. Eddy current testing does not present unique safety hazards to personnel.

5.6 Ultrasonic Testing (UT) and Acoustic Emission Testing (AET)

With high power ultrasonic and acoustic emission equipment, high voltages are present in the frequency converter and the coaxial cables connecting these components. The equipment should not be operated with the panel doors open or housing covers removed. Door interlocks are usually installed to prevent introduction of power to the equipment when the high voltage circuitry is exposed. The cables are fully shielded and present no hazard when properly connected and maintained. All operators should beware of electrical hazards. See Electrical Hazards Clause 5.7.

5.7 Electrical Hazard

Electrical shock can kill. However, it can be avoided. Do not touch live electrical parts. Read and understand the manufacturing instructions and recommended safe practices. Faulty installations, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

Make sure all electrical connections are tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Do not allow water, grease, or dirt to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, keep the work area, equipment, and clothing dry at all times. Wear dry gloves, rubber soled shoes, or stand on a dry board or insulated platform.

Keep cables and connectors in good condition. Improper or worn electrical connections may set up conditions that could cause electrical shock or short circuits. Do not use worn, damaged, or bare cables. Do not touch live electrical parts.

In case of electrical shock, turn off the power. If the rescuer must resort to pulling the victim from the live contact, use nonconducting material. If the victim is not breathing, qualified personnel should administer cardiopulmonary resuscitation (CPR) as soon as contact with the electrical source is broken. Call a physician and continue CPR until breathing has been restored, or until a physician has arrived. Cover electrical or thermal burns with a clean, dry, and cold (iced) compress to prevent contamination. Call a physician.

5.8 General Safety Information

(1) Wear proper eye and hand protection. Use face shields, safety glasses, and goggles as appropriate. Should a foreign particle enter an eye, promptly flush the eye with water to minimize irritation.

(2) Be aware of electrical hazards—see Clause 5.8.

(3) Be alert for sharp objects, pinch points, and moving objects. Avoid wearing clothing or jewelry that could be snagged by moving machinery. Items of particular concern are rings, necklaces, bracelets, long hair, and loose clothing.

5.9 References

1. *Welding Handbook*, Volume 1. American Welding Society, Miami, FL.
2. Manufacturer's Instructions and Safety Data Sheets (SDSs).
3. *Training for Nondestructive Testing*. ASNT and ASM International, Materials Park, OH

Chapter 6

Quality Assurance

Quality assurance (QA) includes all planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily to design requirements or intended service. This includes periodic audits of the QA system's operation and related controls to assure that they are being implemented and functioning as expected.

Quality control (QC) is the implementation part of quality assurance through examination of physical characteristics and comparison with predetermined requirements from applicable codes, specifications, other standards, and drawings. A quality control program may stand alone or be part of a larger QA plan. In either case, quality control specifications, procedures, and acceptance criteria should be written for all required inspection operations. If a quality program is to be implemented, the following attributes may be considered.

The manufacturer may implement quality programs in conformance to a recognized Standard. Examples of quality system requirements include AWS B5.17, *Specification for the Qualification of Welding Fabricators*, ISO 9001, *Quality Management Systems Requirements*, ASME QA-1 *Qualifications for Authorized Inspection*, and AISC 303, *Code of Standard Practice for Steel Buildings and Bridges, Section 8 Quality Assurance*.

6.1 Quality Assurance Program

It is the responsibility of the manufacturer to provide for the development and implementation of a QA program. The program should describe the company's commitment to provide products and services in accordance with established requirements. The following representative areas should be included in a quality assurance program that describes the elements of a QA system. The QA system is subsequently supported by implementing detailed QC procedures.

6.1.1 Organization Requirements. Administration of the quality assurance program is a vested responsibility of the organization. The QA/QC function's authority and responsibility should be clearly defined, independent of production, and have direct access to upper management. The organization should be staffed with technically qualified personnel to make decisions with regard to:

- (1) Identification of quality problems,
- (2) Determining compliance with specifications and procedures,
- (3) Providing solution(s) through functional channels,
- (4) Determining implementation of solutions, and
- (5) Controlling further actions until an acceptable quality has been attained.

6.1.2 Document Control. Control of documents relating to engineering, procurement, policies, procedures, and instructions should be maintained. Procedures should be implemented to pro-

vide appropriate review of changes prior to revision and issuance of these documents. Document control measures should include the following:

- (1) Identification of individuals responsible for preparation, revision, review, approval, and distribution of documents
- (2) Use of correct documents identified and verified
- (3) Procedures for controlling receipt, reproduction, distribution, storage, and retrieval of contract documents.

6.1.3 Purchasing. The quality assurance department should determine quality assurance and inspection requirements for the project, the magnitude of the inspection work for each class of material and equipment, and the extent of the work to be performed by the department prior to purchasing.

The quality assurance and inspection requirements for procured items should be included in the purchase requisition and include the following, as applicable:

- (1) Descriptive title of item or service desired
- (2) List of drawings and technical specifications, including revision level
- (3) Codes, other standards, and regulatory requirements
- (4) Inspection acceptance criteria
- (5) Special process requirements
- (6) Customer contract requirements
- (7) Documentation and record requirements
- (8) Source inspection and audit requirements

Purchasing should maintain an approved list of acceptable vendors that comply with the specified QA and QC program for the project. This list should be maintained to ensure vendors are selected that have an acceptable QA/QC program. In the event a quality assurance program is not being used, the quality control program should encompass the qualifications of the vendors.

6.1.4 Process Control. Manufacturing processes should be controlled and implemented using established procedures for standard commercial processes and special manufacturing processes. Special processes such as welding, heat treating, nondestructive examination, testing, and inspection should be controlled and accomplished by qualified personnel. Special process procedures should define process methods, personnel training and qualification criteria, required certification and records, as well as requirements from applicable codes, other standards, and specifications.

Welding procedures should be reviewed prior to use to ensure that the procedures meet the specification requirements. Audits or surveillance should be performed during production to ascertain that the correct procedures are being implemented. Welder performance records should be audited periodically to determine that welders are properly qualified to procedures being used for fabrication. If required by specifications, permanent identification or records of welders' performance qualifications should be maintained. It should be noted that a decision to inspect only after completion of welding is not the best way to ensure quality.

6.1.5 Inspection. The quality control personnel who perform inspections during the various stages of fabrication should be qualified in accordance with a formal certification program. It is the responsibility of those charged with the administration and supervision of inspection to assure that inspectors are qualified and certified. Quality control personnel should perform nondestructive examination and destructive testing in accordance with established procedures.

Certification of inspection personnel may be required by contract, codes, specifications, or civil laws. In this regard, it may be beneficial to consider certification of welding inspectors by the American Welding Society under the QC1 *Standard for AWS Certification of Welding Inspectors* program. The American Society for Nondestructive Testing (ASNT) and AWS provide certification guidelines for NDE personnel. Other programs may be used for certification of inspection personnel.

Inspection activities should be performed by quality control personnel in accordance with written procedures and instructions to assure that the product meets applicable requirements.

The welding inspector determines the accuracy, completeness, and acceptability of materials and workmanship. Inspection activities also include verification that:

- (1) Measuring and test equipment used for inspections are calibrated.
- (2) Process hold points are observed.
- (3) Surveillance of manufacturing activities is accomplished.
- (4) Material receiving inspection is performed.

A sampling program may be used to verify acceptability of a group of items. The sample procedure should be based on standard practices and provide sample size and selection process. For example, MIL-STD-105 provides sample sizes and acceptable quality levels.

6.1.6 Identification and Control of Material. The QA/QC procedures should specify the requirements and control of items. Identification and control may be maintained by heat number, part number, serial number, or purchase order number. The identification should be placed on the item. Identification marking should be clear and applied so as not to affect the function or identity of the item during processing.

6.1.7 Nonconforming Materials or Items. The QA/QC program should establish detailed written procedures that describe the controls used for the identification, documentation, segregation, and disposition of nonconforming items, material deficiencies, and procedural requirements. Individuals having the responsibility and authority for the disposition of nonconforming items or deficiencies should be identified in the procedures. Items that do not meet requirements should be so identified to prevent inadvertent use.

6.1.8 Records. Records should document the quality of items and should meet the requirements of the applicable codes, standards, specifications, and/or contracts. Records may include results of inspections, audits, material analyses, and process and test activities. Quality procedures should describe the necessary controls for the identification, preparation, legibility, maintenance, and retrieval of these records, and how they are to be protected against damage, deterioration, or loss. Unless otherwise specified by the engineering design, the retention of records should be based on the requirements of the applicable standard for the project.

6.1.9 Audits. Audits are useful to verify compliance with a quality assurance program and contract requirements and determine the effectiveness of the program. A system should be established by QA/QC procedures for internal and external audits. The audit procedures should include the requirements for training and qualifying auditors, the planning and scheduling of audits, preparation of audit reports, and resolution of audit findings and implementation of corrective actions.

Chapter 7

Ferrous Welding Metallurgy

This is an introduction to metallurgical concepts that influence welding processes and welding quality control. Special emphasis is placed upon the terms often used during inspection activities.

This chapter is intended to provide introductory material. Simplified definitions and explanations will at times be employed.

The vast majority of metals used by industry are classified as ferrous metals; i.e., those which contain the element Iron as their primary constituent. Therefore the emphasis of this chapter is on ferrous metals.

7.1 Carbon Steel

The two general types of steel are plain carbon steels, and alloy steels. Plain carbon steel contains iron with controlled amounts of carbon. Among plain carbon steels are: low carbon types which contain less than 0.30% carbon (C); medium carbon steels contain approximately 0.30% C–0.55% C; and high carbon steels contain up to 1.7% C.

Alloy steel may be defined as steel whose distinctive properties are due to the presence of one or more alloying elements other than carbon.

Carbon steels are alloyed with the following elements:

- (1) *Chromium*. Increases resistance to corrosion; improves hardness and toughness, improves the response to heat treatment.
- (2) *Manganese*. Increases strength and responsiveness to heat treatment.
- (3) *Molybdenum*. Increases toughness and improves strength at higher temperatures.
- (4) *Nickel*. Increases strength, ductility and toughness.
- (5) *Vanadium*. Promotes fine grain structure.

Plain carbon steels contain iron plus small quantities of other elements. The five most common elements mixed with iron and their quantitative limits in a representative grade, AISI/SAE 1020 steel, are the following:

- | | |
|--------------------|-------------|
| (1) Carbon (C) | 0.18%–0.23% |
| (2) Manganese (Mn) | 0.30%–0.60% |
| (3) Silicon (Si) | 0.30% max. |
| (4) Phosphorus (P) | 0.040% max. |
| (5) Sulfur (S) | 0.050% max. |