

CERTIFICATION CERTIFICATION CERTIFICATION CERTIFICATION MANUAL

**For
Welding Inspectors**

Fourth Edition



American Welding Society



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Preface

In 1976, the American Welding Society (AWS) introduced a much-needed certification program, specifically for those individuals who perform visual welding inspection. Shortly thereafter, the AWS Qualification and Certification Committee initiated the development of a publication that could serve as a valid reference for those individuals interested in becoming a Certified Welding Inspector. Prior to the initial publication of the *Certification Manual for Welding Inspectors* in 1977, relevant information on the subject could be found scattered among various documents.

Numerous changes have occurred both in the AWS Certified Welding Inspector program and examination and in the technology related to welding inspection. Consequently, AWS sought to update the information contained in the Certification Manual. Much of the information contained herein is drawn from other AWS publications, including *Welding Inspection*, Second Edition, *Welding Inspection Technology*, AWS B1.11, *Guide for the Visual Examination of Welds*, and AWS B1.10, *Guide for the Nondestructive Examination of Welds*. The reader is encouraged to review these and other documents for even more detailed descriptions of much of the information contained in this new edition.

Welding inspectors are employed in a variety of industries. As a result, their duties will differ somewhat from one situation to the next. This book has been developed under the assumption that a welding inspector will be performing quality control duties of a general nature. Some inspectors, for example, may be working at a field construction site where they are in charge of overall welding quality. At the other extreme, in a large organization, a quality assurance department may make many of the decisions that the manual assigns solely to the inspector. The welding inspector will always perform a key role. The individual inspector's specific role in the quality control activity must, therefore, mesh with many other activities and personnel, as outlined in the pages which follow.

In this fourth edition, there has been an attempt to update the technical information, where appropriate. One of the areas where readers of previous editions will note changes is in the terminology used for describing various weld characteristics. There is an ongoing effort to use standard terminology when talking about welding operations and related weld characteristics. Questions appear at the end of each chapter. The questions have been included to provide those individuals who are preparing for the CWI examination with numerous examples of the types of questions that appear on the test. The questions appear in the same format (multiple choice with five options) as the questions on the CWI examination. While this is intended to specifically aid those studying for the test, it should also be beneficial to others from the standpoint of improving their comprehension of the information presented in the text. An Answer Key for all chapters appears in Annex C.

I hope this presentation will prove helpful to those interested in becoming welding inspectors and eventually becoming an AWS Certified Welding Inspector. The job of welding inspector is a tremendously challenging and important one, and those seeking the CWI qualification should be commended and encouraged. My desire is that this book will assist in reaching that goal.

Eugene G. Hornberger
Welding Consultant

CHAPTER 1

The Welding Inspector

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Chapter 1—The Welding Inspector

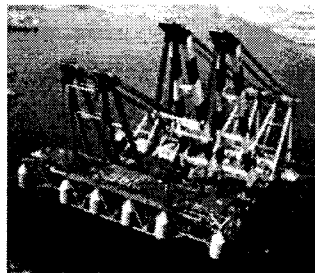
Introduction

Welding inspectors function as quality representatives of organizations that may be a manufacturer, purchaser, insurance company, or government agency. The inspector is responsible for judging the acceptability of a product according to a written specification. The inspector must understand both the limitations and intent of the specification. The goal of the welding inspector is to strive for the required quality, but not to delay completion and delivery schedules without proper cause.

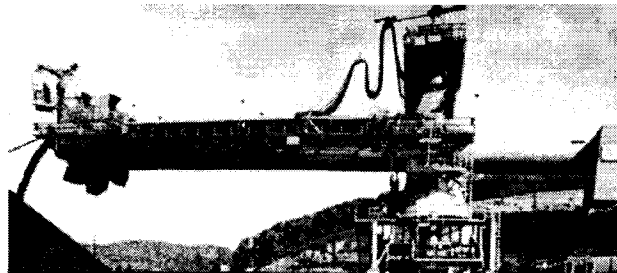
Welding inspectors find themselves working in dozens of different industries, with each situation having slightly different job responsibilities. Among those industries employing welding inspectors are energy production, chemical processing, petroleum product refining and distribution, transportation, and bridge and building construction (see Figure 1.1).

The welding inspector is a composite person—a highly qualified specialist in the field of welding. Welding inspectors can be classified as:

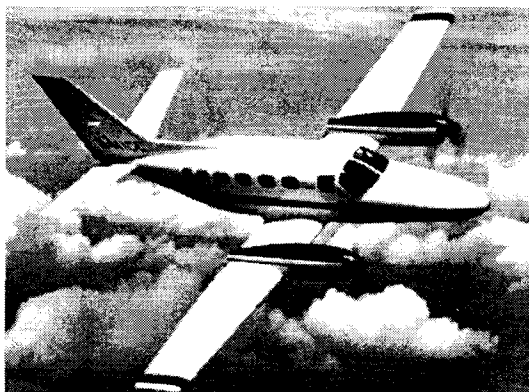
- Code or governing agency inspector



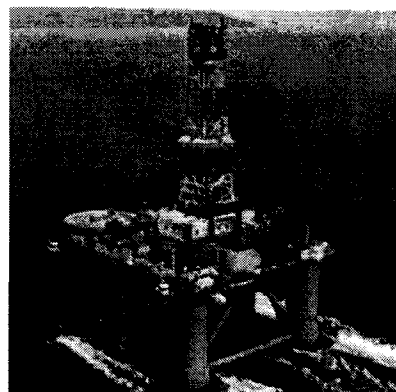
Nippon Steel



Lukens Steel Company



Cessna Aircraft Corporation



Western Oceanic Inc.

Figure 1.1—Industries Utilizing Welding Inspectors

- Purchaser's, customer's, or owner's inspector
- Fabricator's, manufacturer's, or contractor's inspector
- Architect's or engineer's inspector

Inspectors working in small welding fabrication, construction, or erection shops are often required to be more versatile than those working in larger industries. An inspector working in a small shop may be the receiving inspector, in process inspector, and final inspector. In fact, the inspector may be a one-man Quality Control Department. An inspector working in these situations must be knowledgeable in all facets of welding inspection.

Even though the in-house inspector may have different duties from the outside inspector, only a single inclusive category of inspector is considered within this manual. The content of this manual may sometimes apply to all the categories above or be limited to one or more of them. In all cases, however, the inspector has the necessary qualifications and is competent to make the examinations appropriate for the type of weldment being inspected.

Important Qualifications for the Welding Inspector

For a person to become a welding inspector, there are a number of important qualifications. Any person who wishes to do their inspection job conscientiously and professionally must take these qualifications seriously.

Physical Condition

A welding inspector must be active and in good physical condition. Inspection requires examination before, during, and after fabrication; therefore, climbing around large fixtures and assemblies may be a job requirement. Inspection conditions are frequently difficult, since work may be positioned for the convenience of welders and welding operators, but not necessarily for the inspector.

Short of unnecessary endangerment, the inspector must be able to see the weld to perform the visual inspection. Inspecting completed welds in the shortest possible time requires the same means of access to the weld that the welder had.

Vision

Good vision is vital. The ability to examine weld surface conditions and judge their acceptability according to written quality requirements are the primary functions of a welding inspector. An American Welding Society (AWS)

Certified Welding Inspector (CWI) is required to have 20/40 vision, as determined by corrective eye charts, and Jaeger J-2, at 12 in. near-vision acuity, with or without corrective lenses. The required eye examination may also include a color perception test for red/green and blue/yellow differentiation; however, color perception for most visual welding inspection jobs is not a requirement. According to AWS QC1, *Standard for AWS Certification of Welding Inspectors*, "It is the employer's responsibility to determine and enforce any color perception requirement."

Professional Attitude

It is extremely important that the welding inspector maintain a professional attitude. Attitude determines the degree of success or failure. Success will be dependent upon the cooperation of associates in all departments, and the welding inspector must have their respect to obtain their help. It is important that the welding inspector strive to remain impartial and be consistent in all decisions. The inspector should develop a definite system for inspection procedures, and maintain an attitude of being neither stubborn nor readily swayed by arguments. Under no circumstances may the welding inspector seek favor or incur obligation through personal or pending decisions.

Knowledge of Welding and Inspection Terminology

The improper use of welding terminology by a welding inspector could create an embarrassing situation if such use became apparent to others in job-related conversations. Consequently, the welding inspector must know and correctly communicate the language of welding. The job of welding inspector requires communication of findings to the shop personnel who create the welds and make repairs, and the engineers who plan the work and accept the final structure. The vocabulary used in speaking and writing must be in terms understandable to all levels of personnel involved.

Inspectors should review the latest edition of AWS A3.0, *Standard Welding Terms and Definitions*, which provides AWS-approved terminology used to describe the various aspects of welding. It is advisable that welding inspectors study and consult this standard until the terms become part of their natural vocabulary.

This manual describes the types of joints and welds, parts of welds, and weld application terminology (Chapter 5); terminology related to destructive testing (Chapter 8) and nondestructive examination (Chapter 12); names and descriptions of weld and base metal discontinuities (Chapter 11); terms related to welding metallurgy (Chap-

ter 7); and terminology related to various welding processes (Chapter 10).

Knowledge of Drawings and Specifications

An inspector must be familiar with engineering drawings and able to understand specifications. Welding inspectors must be able to read and understand blueprints and drawings and must know welding and nondestructive examination symbols. It is not necessary to memorize the various standards and specifications that may be in effect; however, the welding inspector should be familiar with the contents of these documents so that information can be quickly referenced.

Knowledge of Testing Methods

Numerous destructive and nondestructive examination methods are available for use in determining whether a base metal, weld metal, and/or a weldment meets certain specification requirements. Although others may perform the testing, the welding inspector must be aware of test basics, including: application technique, obtainable information, and the advantages and limitations of the method.

The welding inspector must also be certain that the technicians performing nondestructive examination (NDE) have the proper credentials, and the inspector must be familiar enough with the method to determine if the test results obtained meet prescribed requirements.

Ability to Produce and Maintain Records

A welding inspector should be able to develop and maintain inspection records and write concise, accurate reports. The reports should be simple and understandable to anyone familiar with the project. At the same time, reports should be thorough enough so that the reasoning behind decisions will remain clear months or years after completion of the project. It is important to remember that well-known facts at the time of the writing often are not remembered as clearly, completely, or accurately at a later date. Records should include not only all results of inspections and tests, but also supporting records relating to welding procedures, welder qualifications, drawing or specification revisions, etc. Good records also protect the welding inspector's reputation.

Knowledge of Welding Processes

Since the welding inspector spends the major portion of his time evaluating welds, knowledge of the various welding processes is essential. Further, actual experience as a welder or welding operator is valuable to a welding inspector, but is not mandatory. Welding experience

broadens the inspector's welding knowledge, commands respect, and gives his opinions more credibility when weld quality is being evaluated. Some employers require actual welding experience as a prerequisite to becoming a welding inspector; however, welding experience is not a prerequisite to certification as an AWS Senior Certified Welding Inspector (SCWI), Certified Welding Inspector (CWI), or Certified Associate Welding Inspector (CAWI). The inspector who is familiar with the advantages and limitations of the various welding processes is able to identify problems when, or even before, they occur.

Ability to be Trained

To be considered effective, welding inspectors are expected to possess expertise in a number of different areas, and the ability to be trained in areas of unfamiliarity. Many employers select potential welding inspectors based on their ability to study and gain the necessary knowledge. Training in fundamental engineering can be applied as partial satisfaction of the experience requirements for becoming a CWI. AWS QC1 outlines these limits for the CWI program.

Inspection Experience

The attitude and point of view of a good inspector is acquired only through inspection experience. Even experience in inspecting non-welded materials is extremely helpful in the inspection of weldments, since a good inspector has developed a distinct way of thinking and working. Those "learning the ropes" should observe the behavior and techniques of experienced inspectors.

To comply with the experience requirement for AWS certification, the welding inspector must show evidence of having performed the functions of a welding inspector. Other job functions that have a close relationship to welding inspection also provide this evidence. Periods of qualifying experience are counted by the actual number of calendar months employed at jobs (not the number of employers). The jobs must have a close relationship to fabrication of weldments according to a code, standard, or specification, and directly involve one or more of the following:

- **Design.** Preparation of plans and drawings for weldment construction/fabrication.
- **Production.** Planning and control of welding materials, welding procedures, and welding operations for weldment fabrication.
- **Construction.** Fabrication and/or erection of weldments.

- **Inspection.** Detection and measurement of weld discontinuities; verification of fabrication requirements.
- **Repair.** Repair of defective welds.

Section 5 of AWS QC1 contains the requirements for the three levels of certification: SCWI, CWI, and CAWI.

Ethical Requirements for the Welding Inspector

Introduction

This manual describes the technical methods, procedures, processes, and functions of the welding inspector. However, effective weld inspection requires not only the performance of duties consistent with the specification requirements, but also the practice of professional conduct and ethical principles. What follows is the “Code of Ethics” for welding inspectors, which is included in AWS QC1. Consult the latest edition for the most recent requirements.

Preamble

To safeguard the public’s health and well-being and to maintain integrity and high standards of skills, practice, and conduct in the occupation of welding inspection, the AWS SCWIs, CWIs, and CAWIs shall be cognizant of the following principles and the scope to which they apply, with the understanding that any unauthorized practice is subject to the AWS Qualification and Certification Committee’s review and may result in suspension, reprimand, or revocation of certification.

Integrity

The SCWI, CWI, and CAWI shall act with complete integrity (honesty) in professional matters and be forthright and candid with the Committee or its representatives on matters pertaining to AWS QC1.

Responsibility to the Public

The SCWI, CWI, and CAWI shall act to preserve the health and well-being of the public by performing the required weld inspection duties in a conscientious and impartial manner, to the full extent of the inspector’s moral and civic responsibility and qualification. Accordingly, the SCWI, CWI, and CAWI shall:

- Undertake and perform assignments only when qualified by training, experience and capability.
- Present credentials upon request.

- Neither falsely represent current status nor seek to misrepresent certification level (SCWI/CWI/CAWI) by modifying certification documents or giving false verbal or written testimony of current level or status.
- 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.
- Sign only for work the inspector has inspected or has personal knowledge of through direct supervision.
- Neither associate with nor knowingly participate in a fraudulent or dishonest venture.

Public Statements

The SCWI, CWI, or CAWI shall issue no statements, criticisms, or arguments on weld inspection matters connected with public policy that are inspired or paid for by an interested party, or parties, without first identifying the party and speaker, and disclosing any possible financial interest.

The SCWI, CWI, or CAWI shall publicly express no opinion on welding inspection subjects, unless such opinion is founded upon adequate knowledge of the facts in issue, possession of a background of technical competence pertinent to the subject, and having an honest conviction as to the accuracy and propriety of the statement.

Conflict of Interest

The SCWI, CWI, or CAWI shall avoid conflict of interest with the employer or client and will disclose any business association or circumstance that might be so considered.

The SCWI, CWI, or CAWI 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 SCWI, CWI, or CAWI shall not solicit or accept gratuities, directly or indirectly, from any party or parties dealing with the client or employer in connection with the SCWI’s, CWI’s, and CAWI’s work.

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

The Solicitation of Employment

The SCWI, CWI, or CAWI shall neither pay, solicit, or offer, directly or indirectly, any bribe or commission for professional employment, with the exception of the usual commission required from licensed employment agencies.

The SCWI, CWI, or CAWI 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 SCWI/CWI/CAWI 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 section.

The SCWI, CWI, or CAWI credentials may only be used for the field of welding inspection. AWS has not qualified those individuals for non-welding inspection.

CAUTION

Although the CWI may have established excellent credentials, certification alone may not legally qualify the inspector to provide inspection services to the public. Contract documents, building or jurisdiction laws may require that inspection be performed under the direction and responsibility of others, such as a registered Professional Engineer (P.E.).

Unauthorized Practice

Any violation of any part of the standard of conduct prescribed by AWS QC1 if related to a SCWI's, CWI's, or CAWI's occupation, including any violation of the Code of Ethics contained in AWS QC1, shall constitute an unauthorized practice that is subject to the imposition of sanctions.

Establishing Lines of Communication

The welding inspector must possess the physical, technical, and ethical qualifications mentioned above, as well as the skill of a communicator (see Figures 1.2 and 1.3). The welding inspector's success will be affected by the ability to convey information to others, as well as the ability to understand what others are trying to explain.

Communication can occur in numerous forms, including spoken or written words, pictures, numbers, or gestures. Each provides an effective means of conveying information; however, the inspector should always be cautious regarding verbal communication. It is often impor-

tant to have verbal communication supported by written information, especially when it relates to changes in the inspection requirements or results.

Any form of communication should be a continuous loop. That is, the receiver should have the opportunity to respond to the sender. Effective communication must be considered as a two-way proposition.

The welding inspector is often the central figure in many fabrication situations; consequently, the inspector must be capable of communicating effectively with many individuals involved in the project. The welding inspector must be able to establish lines of communication with a varied number of associates to accomplish the necessary tasks and responsibilities efficiently and professionally. For example, the associates of a fabricator's inspector will often include the personnel listed below.

Reporting Supervisor

Virtually all welding inspectors report to someone; in some cases, it is the chief inspector. In other situations, it could be the project engineer, a plant manager, an architect, or government official. Regardless of who this individual is, the welding inspector should be able to refer

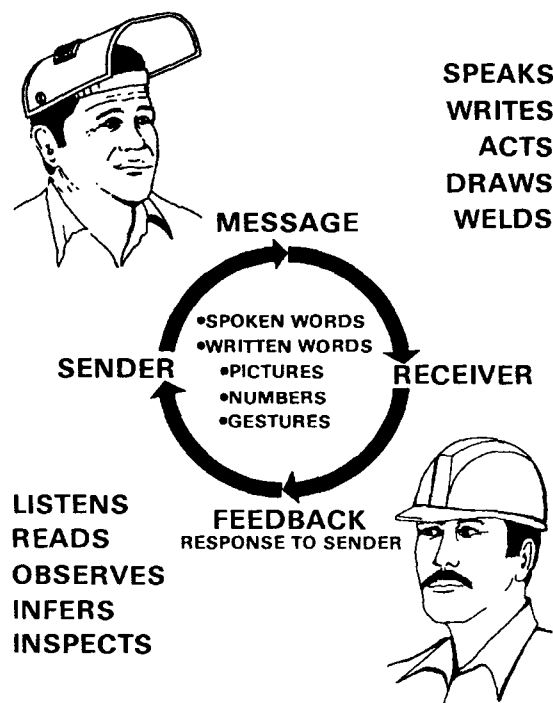


Figure 1.2—The Welding Inspector—
A Communicator

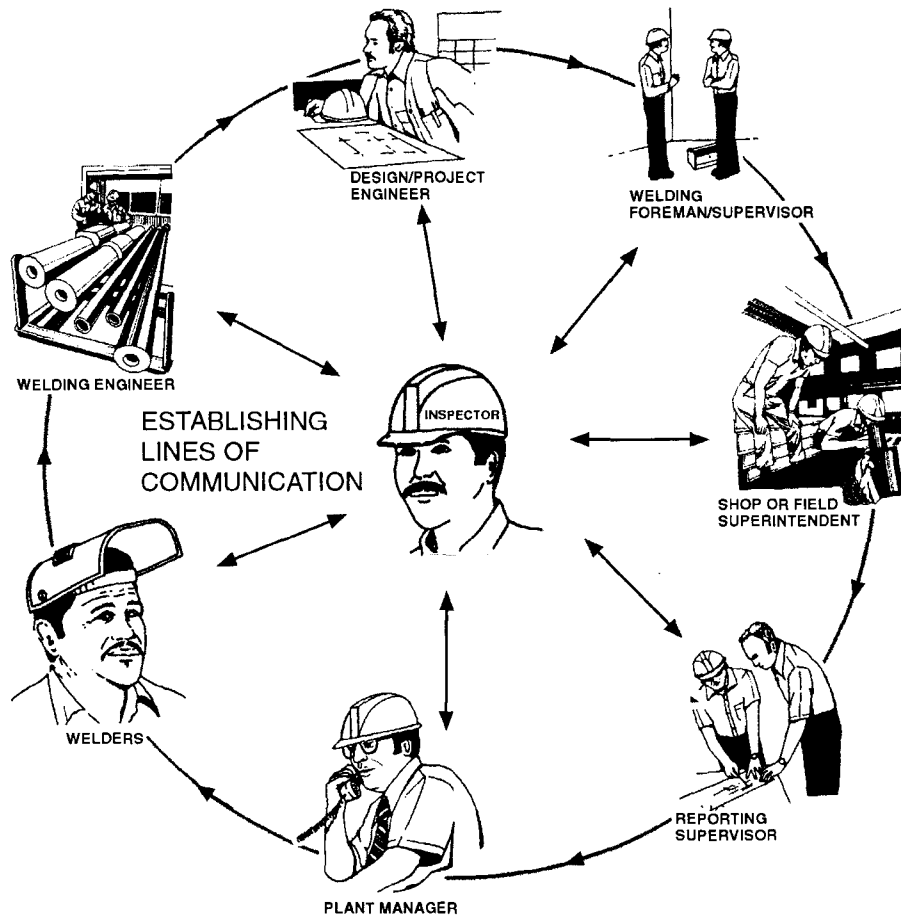


Figure 1.3—Establishing Lines of Communication

questions or job difficulties to their supervisor for answers or guidance. Through direct communication, the supervisor should be able to help the inspector become more knowledgeable about the job and, therefore, more effective.

Welders

The relationship between the inspector and the welder is of utmost importance. The welder often knows which welds are of borderline quality, or where the joint fitup was improper or not as specified. A welder who regards the inspector as an enemy will not be concentrating on making each weld a good one. At any rate, the welder will not be trying to make the inspector's job any easier. In most cases, good rapport between the welder and inspector results in improved quality and higher efficiency, because problems are identified and corrected as they occur, instead of later when repair is costly.

Welding Foremen or Supervisors

The welding foreman or supervisor is highly important to the inspector. When assigned a group of welders who are equally qualified to meet specifications, the foreman will decide which welder is best-suited for the more difficult welding jobs. Both the welding inspector and the foreman should be in agreement as to which welders are considered qualified to produce satisfactory welds.

At times, the fabricator's representative may suggest that the welding inspector tell the welder what the fabricator wants; however, this would make the welding inspector a party to the operation, and perhaps eliminate the fabricator's responsibility to meet the specification requirements. It is important to remember that the inspector's authority extends only to the determination as to whether the weld is acceptable or rejectable. Volunteering unsolicited information may overstep an inspector's responsibility and should, therefore, be limited.

Since supervisors are also concerned with production, some communication must occur to indicate when parts or assemblies will be ready for inspection. After that inspection, the supervisor will need to know if the welding has been found to be acceptable. If rejects are noted, then more communication will be necessary to describe and locate the defect, so that repairs can be accomplished.

Shop or Field Superintendent

It may also be necessary to discuss weld quality matters with the shop or field superintendent, as a result of some aspect of the welding quality having an effect on the overall production schedule of a project. In other cases, the welding inspector may simply have encountered some problem that is beyond the responsibility of the welding foreman or supervisor.

Plant Manager

Communication with the plant manager is much the same as that with the shop or field superintendent. Since plant managers are responsible for production, as well as product quality, they are very concerned about learning what the status of some part may be when it is subjected to inspection. A single rejected weld could result in delays for the entire project. The welding inspector needs to keep the plant manager informed and aware of the acceptability or rejectability of certain items, so that appropriate scheduling can be accomplished.

A weldment is an assembly whose component parts are joined by welding. A weldment may consist of many pieces and welds or it can be fairly simple with few parts and welds.

Design/Project Engineers

The design engineer is responsible for the details of any welded fabrication. Their intentions are communicated through drawings and specifications. The project engineer is then responsible for the interpretation of these requirements when the work is being performed. The welding inspector may need to communicate with either or both of these individuals regarding these welding requirements. An overview of the job in consultation with the project engineer will reveal any fabrication or inspection tasks that may require additional planning.

For example, in a massive, complex weldment, weld sequencing may be necessary to ensure weld soundness and minimized distortion; or modification of some design detail may be needed to facilitate successful fabrication and inspection.

Welding Engineer

The welding inspector should have access to the welding engineer, welding technician, or welding specialist so that possible welding-related construction problems can be brought to the engineer's attention before they become inspection problems. The welding inspector can be thought of as the welding engineer's "eyes" while the welding is being performed. When such an arrangement exists, the welding inspector can communicate with the welding engineer to describe fabrication problems, so that corrective action can be instituted.

Proper communication is important to the inspection process. The welding inspector's primary function is to inspect the fabricator's work to see that it meets the requirements of the contract. The quality of work being accomplished is the substance of the welding inspector's reports. Whether the fabricator takes advantage of this information may depend upon how clearly it has been presented in the report. The fabricator still has full responsibility for the quality of the final product.

Proper communication will allow the welding inspector to keep in touch with the activities of the production organization. Early correction of a fault results in producing a satisfactory product instead of one that would otherwise have to be rejected and subsequently repaired.

Summary

The job of welding inspector requires a wide variety of talents and physical capabilities. The individual must be both mentally and physically prepared for the many tasks at hand. The inspector's day-to-day existence dictates that with proper knowledge and training, the inspector can submit accurate reports, maintain that information for future reference, and act in an ethical manner.

Good welding inspectors are invaluable to a company. When permitted to act as specified by an effective quality control system, the welding inspector often can save a company money by identifying problems when or before they occur, to minimize correction costs.

Review—Chapter 1—The Welding Inspector

- Q1-1** Of the following, which is considered an important duty of the welding inspector?
- a. it is a welding inspector's responsibility to judge the quality of the product in relation to some form of written specification
 - b. it is a welding inspector's responsibility to monitor welding operations
 - c. a welding inspector must be able to interpret the specification requirements
 - d. all of the above
 - e. none of the above
- Q1-2** Of the following, which is not considered an important attribute of a welding inspector?
- a. welding experience
 - b. inspection experience
 - c. professional attitude
 - d. engineering experience
 - e. ability to be trained
- Q1-3** What document describes the important requirements of the AWS Certified Welding Inspector program?
- a. AWS D1.1
 - b. AWS A5.1
 - c. AWS QC1
 - d. AWS D14.1
 - e. none of the above
- Q1-4** As a welding inspector, must you know how to weld?
- a. yes, according to AWS D1.1
 - b. yes, according to AWS QC1
 - c. yes, if inspecting highway bridges
 - d. no, according to AWS D1.1
 - e. not mandatory, according to AWS QC1
- Q1-5** Which of the following are important ethical requirements for the welding inspector?
- a. integrity
 - b. professional ability
 - c. good physical condition
 - d. volunteering public statements regarding an inspection for personal exposure
 - e. all of the above
- Q1-6** Of those attributes considered to be important in the welding inspector, which is probably most influential in their gaining the cooperation and respect of others with whom they work?
- a. ability to be trained
 - b. professional attitude
 - c. ability to complete and maintain inspection records
 - d. good physical condition
 - e. ability to interpret drawings and specifications
- Q1-7** The welding inspector is likely to work in which of the following industries?
- a. shipbuilding
 - b. automotive
 - c. bridge construction
 - d. pressure vessel construction
 - e. all of the above

- Q1-8** According to the requirements of the AWS CWI program, what is the necessary visual acuity of a welding inspector?
- 20/20 natural vision
 - 20/20 corrected vision
 - 20/40 natural vision
 - 20/40 corrected vision
 - 20/40 natural or corrected vision
- Q1-9** Which of the following could be considered essential knowledge for a welding inspector?
- nondestructive testing
 - welding symbols
 - welding processes
 - destructive testing
 - all of the above
- Q1-10** When a weld requires repair due to some deficiency, to whom should your inspection report be directed?
- to the welder whose mark is on the weld
 - to another welder, better trained
 - to the project engineer
 - to the welding engineer
 - to the welding foreman or supervisor
- Q1-11** What professional attributes are most helpful in performing inspection duties?
- being informed, impartial, and consistent in your decisions
 - being close friends with welders and superiors
 - being a former welder
 - being a non-union employee
 - being a nondestructive examination technician (NDE) as well as a CWI
- Q1-12** With whom may the welding inspector communicate during the performance of his or her inspection responsibilities?
- welding engineer
 - welding foreman
 - welders
 - inspection supervisor
 - all of the above
- Q1-13** What document defines the proper terminology for use by the CWI?
- AWS QC1
 - AWS A3.0
 - AWS D1.1
 - AWS A5.1
 - none of the above
- Q1-14** With regard to drawings and specifications, the CWI must:
- be familiar with engineering drawings and able to understand specifications
 - memorize the content
 - memorize those portions of these documents applicable to a particular job
 - all of the above
 - none of the above

CHAPTER 2

Welding Inspector Responsibilities

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Chapter 2—Welding Inspector Responsibilities

Introduction

The welding inspector holds a position of responsibility that requires a professional attitude, good character, ability, and common sense. Since a welding inspector works at various fabrication plants and job sites, strict observance of all rules and regulations—especially those pertaining to personal conduct, safety, and security—is mandatory. The welding inspector should never consider himself entitled to special privileges. In dealing with the fabricating organization, the welding inspector should be impartial, render decisions promptly, and be tolerant of the opinion of others during communications. It is important to remember to rely on the facts when making decisions, and to carefully evaluate differing opinions.

To effectively perform visual inspection, it is necessary to observe as many individual stages of fabrication as possible. Consequently, the various responsibilities of the welding inspector are categorized by *when* they occur; specifically, before, during, and after welding. An example of typical inspection requirements is listed below.

Inspection Responsibilities Before Welding

- Review all applicable drawings and standards.
- Check purchase orders to ensure that base and filler materials are properly specified.
- Check and identify materials as they are received against the purchase specifications.
- Check the chemical compositions and mechanical properties shown on mill test reports against specified requirements.
- Check the condition and storage of filler metals.
- Check the condition and adequacy of equipment to be used.
- Check weld joint edge geometries.
- Check joint fit.
- Check joint cleanliness.
- Check the welding procedures and welder qualifications.
- Check preheat temperature.

Inspection Responsibilities During Welding

- Check welding parameters and techniques for compliance with welding procedure.
- Check quality of individual weld passes.
- Check interpass cleaning.
- Check interpass temperature.
- Verify that in-process nondestructive examination (NDE) is performed, if required.

Inspection Responsibilities After Welding

- Check finished weld appearance.
- Check finished weld sizes and lengths.
- Check dimensional accuracy of completed weldment.
- Select production test samples.
- Evaluate test results.
- Verify that additional NDE has been performed, if required.
- Verify that postweld heat treatment has been done satisfactorily, if required.
- Prepare and maintain inspection reports.

Inspection Responsibilities Before Welding

Knowledge of Drawings and Standards

Drawings, designs, standards, contracts, etc., should be studied in advance so that the welding inspector is aware of the construction details, the proposed use of subassemblies, and the specifics of the welding operation (see Figure 2.1). Note which materials are to be used in the welded structure and whether any of them require special treatment for satisfactory welding. This information should be clearly stated in the standards or welding procedures. If not, the project engineer should be contacted for clarification.

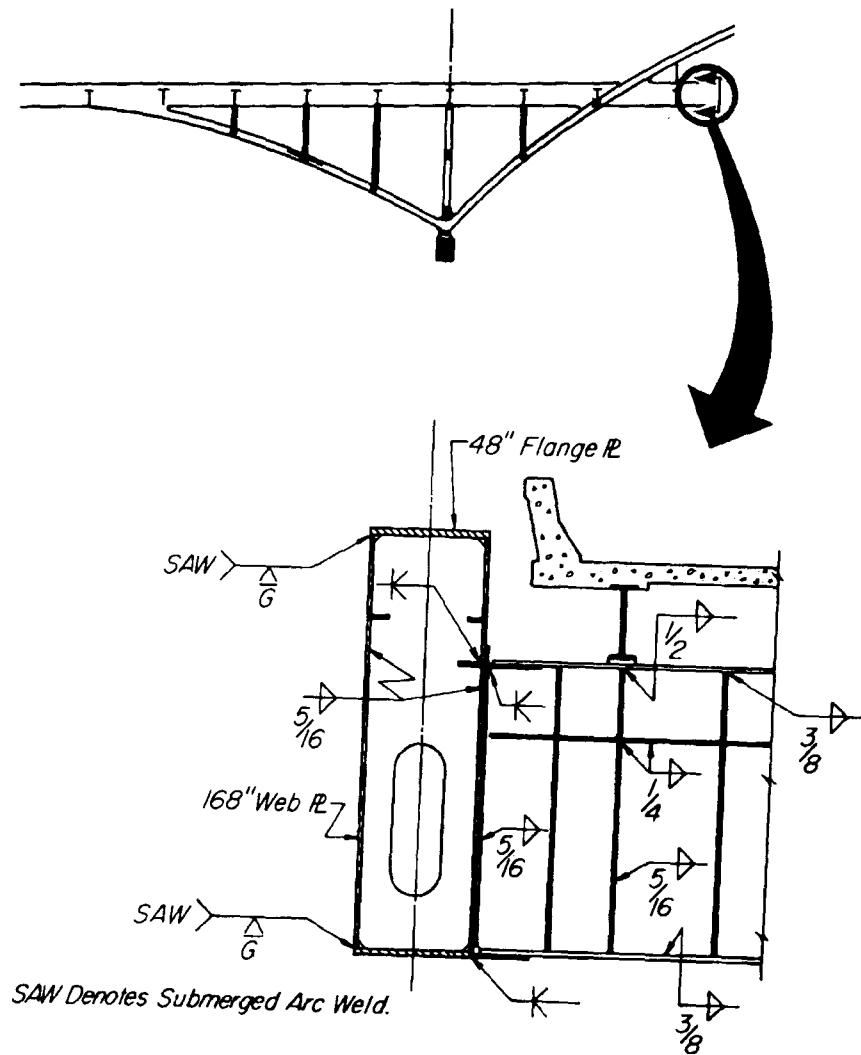
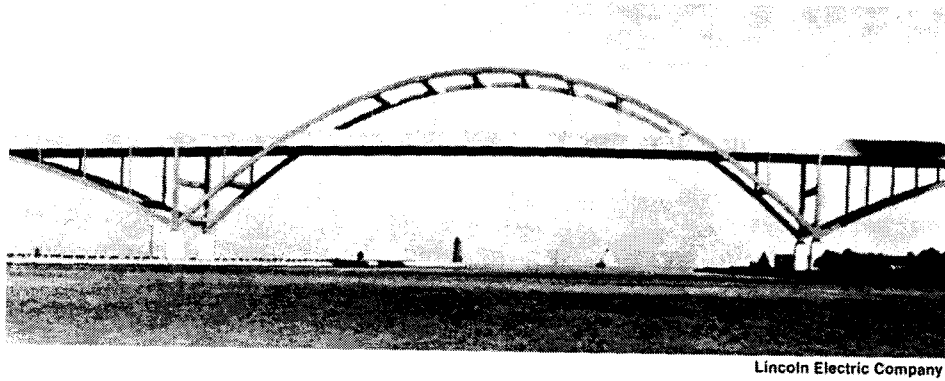


Figure 2.1—Knowledge of Drawings and Standards is Important

The term "Standard" applies collectively to codes, specifications, recommended practices, classifications, methods, and guides that have been prepared by a sponsoring organization and approved in accordance with established procedures. Standards for welding are published in cooperation with the American National Standards Institute (ANSI).

During fabrication of a welded structure or component, the welding inspector may be called upon to interpret drawings or standards on the spot. Prior study of the drawings and design requirements will enhance the inspector's ability to make clear and concise decisions, which in turn, will speed completion of the work under contract, increase the inspector's professional image, and greatly aid in exercising authority.

When situations that require a deviation from the drawing or detailed procedure arise during the fabrication of any structure, it is the welding inspector's responsibility to alert the project engineer or quality assurance (QA) personnel, who will decide whether the deviation in question should be permitted or rejected.

Sometimes, acceptance or rejection of a large welded structure will be involved. It may be the inspector's duty, after careful study, to recommend whether the error can be corrected and whether the method of correction to be used will still ensure a satisfactorily completed product in accordance with the drawings and standards. In all cases, extreme caution should be exercised in accepting deviations. Deviations from drawings should be referred to the design agency for approval. Their approval should be received "in writing."

It is not always possible to write an all-inclusive standard containing all the detailed information needed to provide an answer for any question that might arise. If parts of the standard have requirements that are not fully defined, the inspector is often responsible for determining the meaning and intent of that document. Communication with engineering and design personnel may be necessary before responding to a fabricator.

Purchase Specifications Check

The specifications for the job should identify all the materials that will be used, including all consumable material, such as welding electrodes, welding or brazing fluxes, shielding gases, consumable inserts, and backing bars or rings. The inspector should review the purchase order or contract to see that the materials ordered meet the specification requirements. For example, commercial specifications for steel, such as ASTM A 572, frequently include more than one grade of the product, which must

be individually identified on the purchase order to obtain the correct grade.

As another example, specifications for welding electrodes, such as AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, cover a dozen or more electrode classifications in one document. In A5.1, the six E70XX electrodes are all equivalent in strength, but they are not interchangeable when low-hydrogen grades are required. If low-hydrogen types are required, either E7015, E7016, E7018, or E7028 must be called out on the purchase order.

Job Material Verification

Since many metals look alike, the potential exists for inadvertent mixups. To prevent mistakes such as these, the inspector must verify upon receipt that the materials supplied match the applicable purchase order, and the material test reports (MTRs) must be checked against the applicable specification (see Figure 2.2). In some cases, additional requirements specify that the proper identification be visibly marked on each piece, preferably at multiple locations. For example, identification will be lost for the rest of the plate, if the first slice cut off by the shop removes the labeled end displaying the grade stamp. Good practice calls for re-marking remnants produced in cutting operations prior to the actual cutting, while the identity is still verifiable.

Identification of low-hydrogen welding electrodes becomes impossible when stockroom clerks prematurely remove electrodes from their containers for storage in holding ovens. The individual electrodes will still bear classification numbers on their coverings (at the stub end); however, the manufacturer's control number appears only on the now-discarded container. In critical work, the manufacturer's control number may be needed for each weld. If this is a requirement, the preferred container for a welding electrode is its original unopened package. An alternative is storage in an electrode oven with an oven map posted on the front of the oven or in another suitable location.

Chemical Analysis and Mechanical Properties Tests

Confirming tests of incoming materials are desirable for many reasons. The number of tests required will depend on the inspector's judgment and past experience, unless everything is specified under quality assurance procedure requirements. The inspector should request tests on representative samples of questionable incoming

CERTIFICATION OF TESTS

CUSTOMER TECNIWELD, INC. RECEIVED MAY 19 1999

PURCHASE ORDER 4563 AML
Q. M.
DATE SHIPPED 5-14-99

DESCRIPTION

1 3/4" THK., 10 PCS. 39-1/2 O. D. X 9-5/8 I. D. TEMP

2 _____

3 _____

4 _____

SPECIFICATION: ASTM-A-516 GR. 70 PVQ - FINE GRAIN

PROPERTIES	1	2	3	4
HEAT NO.	91E060			
C	.22			
MN	1.05			
P	.009			
S	.022			
SI	.23			
NI	.02			
CR	.02			
MO	.005			
CU	.02			
V	.004			
YIELD PSI	48.2 KSI			
TENSILE PSI	76.3 KSI			
%ELONGATION	8" = 25.0			
% RED OF AREA				
BEND TEST				

WE HEREBY CERTIFY THAT THE ABOVE MATERIALS HAVE BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE APPLICABLE SPECIFICATION AND THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THIS COMPANY.

SWORN TO AND SUBSCRIBED
BEFORE ME THIS _____
DAY OF _____ 19 _____

NOTARY PUBLIC

JANE DOE
Notary Public, State of Ohio
Recorded in Cuyahoga County
My Commission Expires 2/22/2001

GENERAL STEEL SHEET & PLATE, INC.
ANYTOWN, U.S.A.
By I. B. Manager

Figure 2.2—Typical Example of a Mill Test Report

materials to verify chemical composition and mechanical properties. Where material test reports from reliable suppliers (that is, suppliers accredited through an approved quality assurance program) give assurance of conformance, the welding inspector should ask for check tests when errors are strongly suspected.

Base Metal Defects Investigation

The quality of mill products supplied for a job must equal or exceed the quality specified for the final weldment or structure. Base metals almost always contain many small discontinuities, the impact of which depends on the thickness of the metal, the type of loading, and the criticality of the design. In some instances, these discontinuities may be cause for rejection; while in other similar situations, they may not.

A discontinuity is an interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

The welding inspector has the responsibility to see that discontinuities in the base metal are detected, identified, evaluated, and properly repaired, where necessary, so that they will not be incorporated into the welded product. This requires that the inspector be aware of the acceptable limits for these discontinuities. At times, there may be a need to communicate with the responsible engineer in deciding what to do about a major discontinuity.

Some specifications may require that a defective piece be rejected and replaced, unless it can be repaired. In fact, some defects may require rejecting the piece altogether. On the other hand, the specification may permit minor restoration, such as flame straightening of members accidentally bent in shipping or handling. As another example, the presence of laminations will rule out placing a particular plate where it must withstand tensile stresses in the through thickness direction; however, the same plate may be used in a different location with complete safety. Engineering should make that decision. The welding inspector must then inspect any replacement materials.

Condition and Storage of Filler Materials Check

The welding inspector should check the condition of filler metals to be used, especially in the case of shielded metal arc welding (SMAW) electrodes having a flux coating that can be easily damaged. Other types of filler metals that are stored out in the open can also deteriorate

with time. For example, solid wire and flux cored electrodes can develop rust, which could then result in the production of porosity in the weld.

After removal from their shipping containers, low-hydrogen-type SMAW electrodes must be stored in electrically heated, vented, and thermostatically controlled storage ovens to maintain their low moisture content (see Figure 2.3).

In addition to these filler metals, some fluxes and flux cored electrodes also require special protection from moisture, such as rain or high humidity. Some submerged arc fluxes even require heated storage containers.

Welding Equipment Check

All welding equipment, including that to be used for testing, should be checked periodically for operational capability, calibration, and safety. For example, always check the ammeters and voltmeters on welding machines, because due to mishandling, shop contamination, and overloads, these meters may not always be accurate. Periodic calibration is recommended.

The equipment should also be checked to make certain it has the necessary output capacity to satisfy the welding procedure requirements. Welding leads, gas hoses, and wire feed apparatus must also be examined to ensure good condition and operability.

Weld Joint Edge Geometry Check

Specific tolerances for weld joint edge geometries are listed in various codes and specifications. The prequalified joints found in AWS D1.1, *Structural Welding Code—Steel*, are typical examples. Inspection responsibilities include examination of the unwelded joint for edge geometry, including root face dimensions and

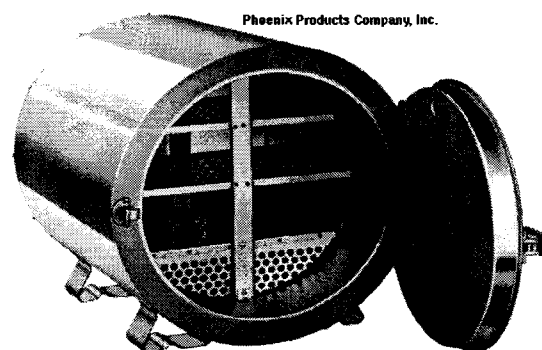


Figure 2.3—Electrode Oven

groove angles. The suitability of the joint for the welding process to be used will be discussed in greater detail in Chapter 6.

Weld Joint Fit Check

When examining the unwelded joint, the welding inspector should also observe the fit of the parts. For butt joints, alignment and root opening are important. It is important to remember that prestressing or cambering may be needed for welds that will be subject to distortion as a result of weld shrinkage stresses. The fabricator should not attempt such welds without the necessary knowledge. Procedure modifications may produce an acceptable weld; however, the welding inspector should offer suggestions to the project engineer, not to the foreman. If the foreman later says, "You told me to do it this way," the inspector may find it difficult to reject an unacceptable weld.

The fit of backing preparations needs particular attention, i.e., backing bars and rings should fit tightly against the pieces to be joined.

Transverse joints between segments of a backing material are undesirable, because they induce cracking in the root pass. For this reason, when welding is performed in accordance with AWS D1.1, steel backing on groove welds is required to be made continuous for the entire length of that backing member.

Weld Joint Cleanliness Check

In welding, the cleanliness of the base metal surfaces in and adjacent to the joint is a critical factor. Welding over contamination such as oil, grease, paint, moisture, rust, etc., will likely result in porosity in the completed weld. In many cases, this contamination could also lead to the occurrence of incomplete fusion, or even cracking. Consequently, it is imperative that the welding inspector check the cleanliness of the weld zone prior to welding.

Welding Procedure Qualification Check

The fabricator must prescribe the details of the welding procedure that will be followed in producing weldments. Welded joints should be produced with acceptable mechanical properties, as required by the particular specification or code. Chapter 9 of this manual describes the basic elements of a welding procedure specification, the reasons for its use, its qualification, and the responsibilities

of the welding inspector in verifying proper application of the welding procedure on the job.

Welder Qualification Check

Codes and specifications that apply to the fabrication of weldments usually require qualification of all welders and welding operators. It is the welding inspector's duty to verify that every welder and welding operator who works under the code or specification has been properly qualified in accordance with those requirements. Verification can be made either by witnessing each test, or by reviewing verified test results. It is important for the welding inspector to monitor the welders and welding operators, to ensure that they are working within the scope of their qualifications with respect to such variables as base metal type and thickness, position of welding, welding process, electrode type and size, etc.

Welding codes and specifications generally do not require requalification of procedures, welders, or welding operators for each new contract or design. The welding inspector should review the requirements of the contract specification or code to make this determination. It is important to remember that the main objective of qualification checking is to ensure that procedures and welders or welding operators are adequate for the intended purpose. To be fair to the fabricator and purchaser, the inspector should make every effort to avoid unnecessary qualification tests.

Preheat Temperature Check

Most codes and specifications require that certain materials be preheated prior to welding. In Chapter 6, there is a discussion of reasons why preheat is necessary. For carbon steels, preheat will be required as the base metal alloy content or thickness increases. Most often, preheat temperature is verified using temperature-indicating crayons that are formulated to melt at the temperature noted on their coatings (see Figure 2.4). However, digital contact pyrometers are an effective alternative.

Since preheat is necessary to prevent degradation of the base metal properties during the welding operation, the preheat temperature should be measured 3 in. from the edge of the weld preparation.

Normally, the temperature should be maintained during all welding of the joint. For most carbon steels, the preheat is specified as a minimum. However, for some types of steels, such as quenched and tempered, the preheat temperature is expressed as a range of temperatures having a minimum and maximum value.

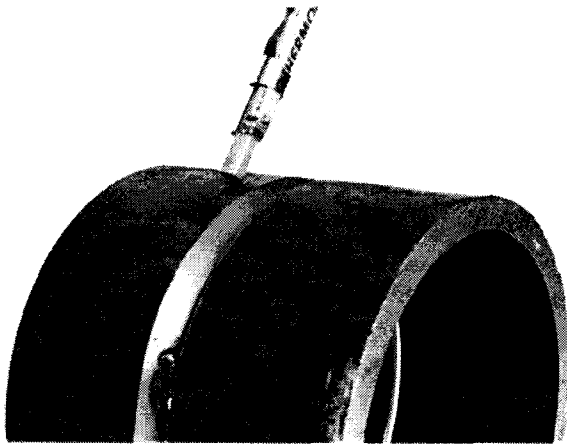


Figure 2.4—Temperature-Sensitive Crayon for Measuring Metal Temperature

Welding Inspector Responsibilities During Welding

To continue ongoing welding quality control, the welding inspector has numerous items to check as the welding process is actually being performed. As was the case for inspections performed prior to welding, checks performed during welding can help to detect problems as they occur, making them easier to correct. During this phase of the fabrication process, the inspector's knowledge of welding is extremely beneficial, since part of the inspection involves evaluation of the actual welding technique, as well as the resulting weld quality. It is unrealistic to expect the welding inspector to observe the deposition of each and every weld pass; therefore, the experienced welding inspector should be able to select those aspects of the welding sequence that are considered to be critical enough to warrant his presence.

Following are some aspects of the visual welding inspection phase.

Check Production Welding for Compliance with Welding Procedure

When conducting inspection during production welding, the inspector must rely on the welding procedure to guide that inspection. This document will specify all important aspects of the welding operation, including welding process, materials, specific technique, preheat and interpass temperature, plus any additional information

that describes how the production welding should be performed.

The welding inspector's job is to monitor the production welding to ensure that it is being performed in accordance with the appropriate procedure (see Figure 2.5).

Check the Quality of Individual Passes

One aspect of inspection during production welding is visual examination of the individual weld passes as they are deposited. If necessary, any surface discontinuities can be detected and corrected at this time. It is also important to note any weld profile irregularities that may hinder subsequent welding, e.g., during the welding of a multipass groove weld. If one of the intermediate passes exhibits a very convex profile when deposited—creating a deep notch at its toe—this configuration may prevent a subsequent pass from properly fusing at that location. If noted, the welding inspector could request that grinding be performed at this point, to ensure that thorough fusion is attained on the next pass.

Checking in-process quality is especially critical in the case of root bead. In most situations, this portion of the weld cross section represents the most difficult welding condition, especially in the case of an open root joint.

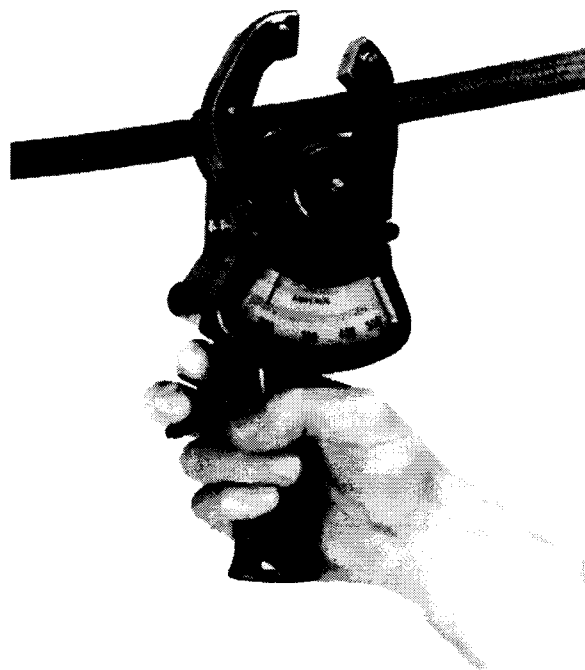


Figure 2.5—Tong Test Ammeter

In conditions of high restraint, the shrinkage stresses from welding may result in fracture if the root pass is not thick enough to resist those stresses. The welding inspector should be aware of these problems and thoroughly check the root pass prior to any additional welding, so that any irregularities can be found and corrected as they occur.

Check Interpass Cleaning

Another aspect that should be evaluated during the welding operation is the cleanliness of intermediate weld passes. If the welder fails to thoroughly clean the weld deposit between individual passes, there is a possibility that slag inclusions and/or incomplete fusion could result (see Figures 2.6 and 2.7). This is especially critical when using a welding process that uses a flux for protective shielding. Careful interpass cleaning is also recommended for those processes using gas shielding. Proper cleaning may be hindered when the deposited weld exhibits a convex profile that prevents sufficient access to the slag coating. As discussed above, additional grinding to remove the objectionable profile and facilitate proper cleaning may then be necessary.

Check Interpass Temperature

The welding inspector may also need to monitor welding procedures requiring interpass temperature control. As with preheat, the interpass temperature can be specified as a minimum, maximum or both. The inter-

pass temperature is also measured on the base metal surface near the weld zone. Devices such as temperature-indicating crayons and surface contact pyrometers are used for these measurements.

Confusion sometimes exists as to where preheat and interpass temperatures should be measured. Preheat is measured 3 in. away from the weld joint along the entire length of the joint—regardless of the length of the joint. On pipe joints, preheat is measured along the entire circumference. The preheat should also be measured both on the topside of the joint and the back side to ensure preheat has soaked through the material being welded. Interpass temperatures are measured 1 in. from the joint, before beginning the next pass or layer—not at starts and stops of beads in a single pass or layer. On a fixed pipe joint, interpass is measured when the welder changes direction.

In-Process Nondestructive Examination (NDE)

At various stages during production, some welds may require a type of nondestructive examination other than visual examination. For example, it is common for the root pass to be evaluated using magnetic particle or penetrant testing to ensure that it is free of surface discontinuities or cracking (see Figure 2.8). Problems discovered at this time will result in a relatively easy and inexpensive repair, compared to that required if the problem is not detected until the weld is completed.

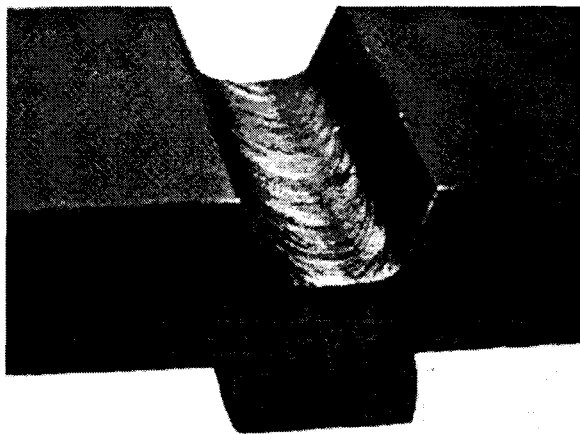


**Figure 2.6—Proper Cleaning
Between Weld Passes**

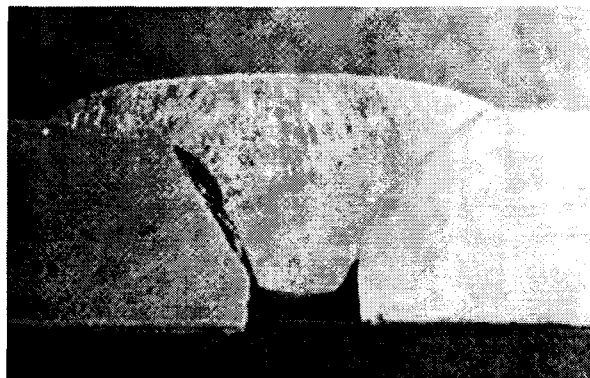


**Figure 2.7—Cross Section
of a Partial Penetration
Groove Weld with Heavy
Slag Inclusion**



Figure 2.8—Magnetic Particle Testing of a Partially Filled Groove Weld

Nondestructive examination operations shall be performed by an individual qualified in accordance with the recommendations of ASNT's SNT-TC-1A, or equivalent. If qualified, the welding inspector can perform this inspection, as well as the visual examination; however, a separate NDE technician will usually perform the examination. The welding inspector is required to verify that the proper test has been administered and the results have been properly recorded.

Welding Inspector Responsibilities After Welding

Upon completion of a weld, the welding inspector must examine the finished product to ensure that all preceding steps have been performed to produce a quality weld. If all of the preliminary steps have been performed as required, the postweld inspection should simply confirm that the weld is of sufficient quality and size. Since the codes specify the required attributes of the finished weld, however, the welding inspector must visually examine the weld to determine if those requirements have been met. Some of the important aspects of postweld inspection are discussed below.

Check Final Weld Appearance

In general, visual inspection after welding consists of looking at the appearance of the finished weld. This visual examination will detect surface discontinuities in the

weld and adjacent base metal. Of special importance during this aspect of the welding inspection is the evaluation of the weld's profile. Sharp surface irregularities could result in premature failure of a component during service or difficulty in film interpretation if the weld is to be radiographed. These visible features are evaluated in accordance with the applicable code that describes the permissible amount of certain types of discontinuity.

Check Final Weld Sizes and Lengths

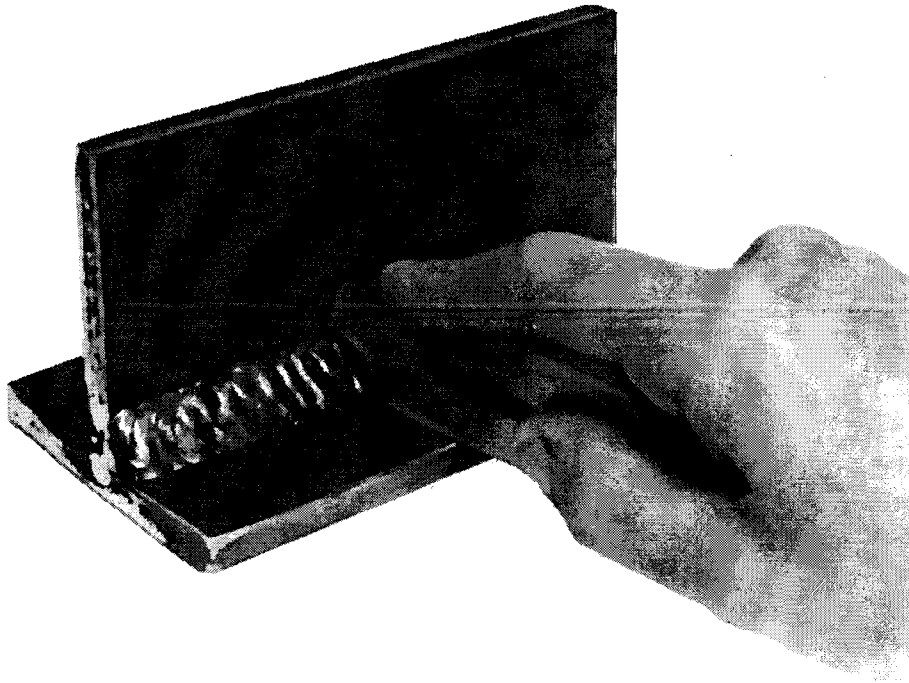
During visual examination, the weld should be measured to determine that it is of sufficient size, as specified on the drawing. For example, a primary concern for a groove weld is whether or not the groove is filled flush with the base metal surfaces, or has the required reinforcement. Any underfill that is present must be corrected by the deposit of additional weld metal. Excessive weld reinforcement must be removed to maintain the specified height and blend smoothly with adjacent base metal.

For fillet welds, size determination is normally accomplished with the aid of a fillet weld gauge (see Figure 2.9). Although this measurement could be determined using standard measuring devices, fillet weld gauges facilitate accurate gauging of the fillet weld size. Numerous types of fillet weld gauges are available, including gauges or templates that are specially made for a particular fillet weld configuration.

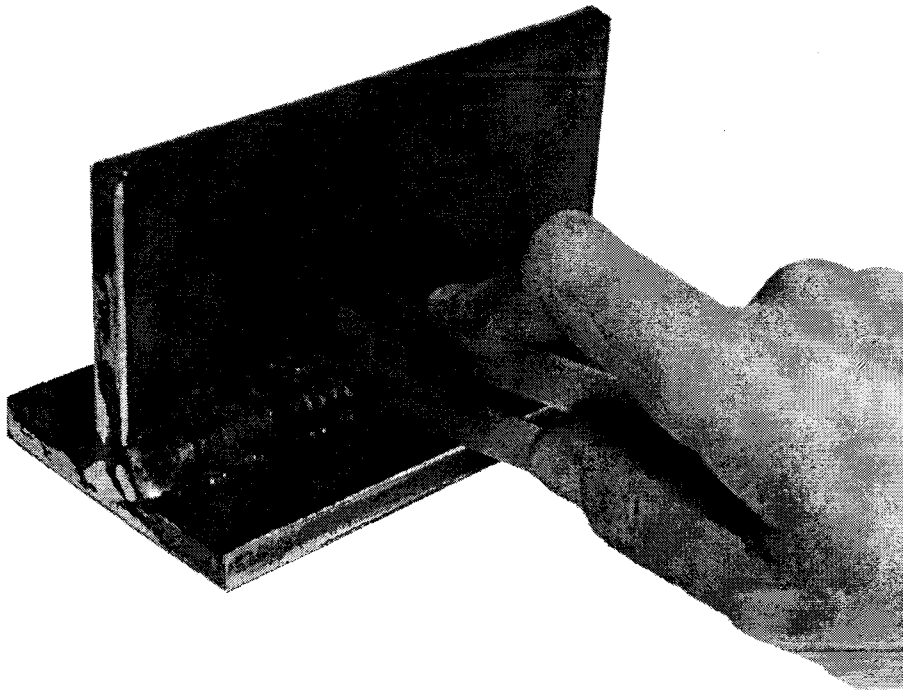
Since fillet weld sizes are designated as nominal dimensions, some tolerance should be applied to their measurement. Commercially available gauges are typically graduated in 1/16 in. increments; therefore, it is reasonable to gauge fillet weld sizes to the closest 1/32 in. Conditions warranting such an approach include the difficulty in properly positioning the eyes to view the gauge, the fact that weld sizes cannot be thought of in terms of machining precision, gauge inaccuracies, base and weld metal surface irregularities, and the difficulty in determining the exact location of the toe of a convex fillet weld.

Once a weld has been determined to be of sufficient size, the welding inspector must then evaluate the length to ensure that enough weld metal was deposited to satisfy the requirements (see Figure 2.10). This is particularly important in cases where intermittent fillet welds have been specified. Each segment should be measured, as well as their center-to-center, or pitch, distances.

Continuous groove or fillet welds are considered to be of sufficient length only if they are filled to their full cross section, for the entire length of the shorter of the two members being joined. Normally, minimum lengths are specified; therefore, the presence of extra fillet weld length is not considered rejectable. However, in some cases, excessive weld lengths may be unacceptable.

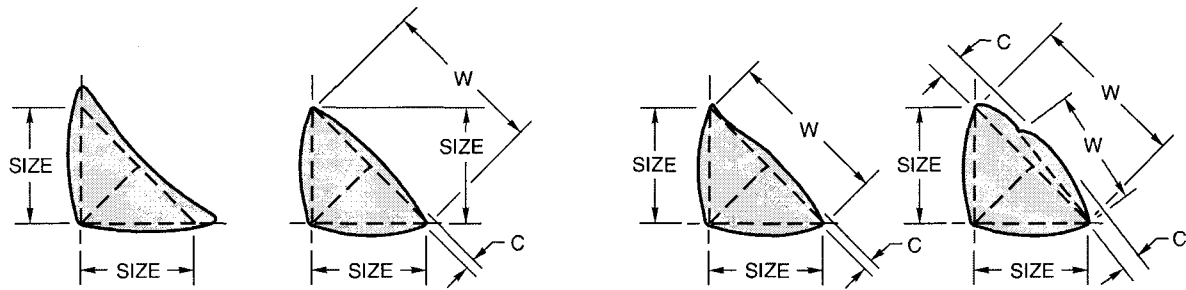


(A) CONVEX FILLET WELD



(B) CONCAVE FILLET WELD

Figure 2.9—Evaluating Size with a Fillet Weld Gauge

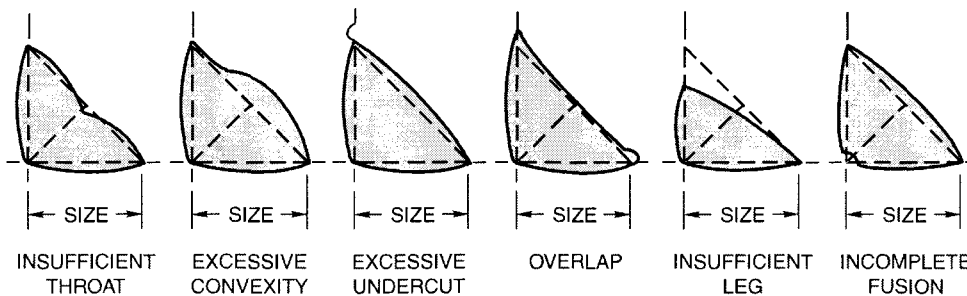


(A) DESIRABLE FILLET WELD PROFILES

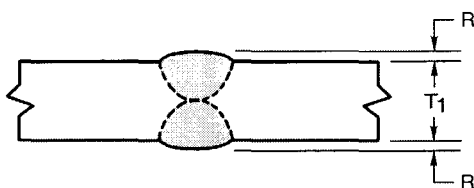
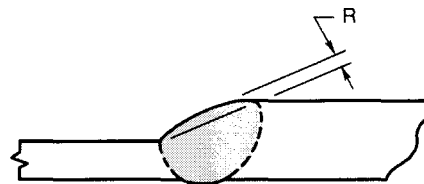
(B) ACCEPTABLE FILLET WELD PROFILES

NOTE: CONVEXITY, C, OF A WELD OR INDIVIDUAL SURFACE BEAD WITH DIMENSION W SHALL NOT EXCEED THE VALUE OF THE FOLLOWING TABLE:

WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W	MAX CONVEXITY, C
$W \leq 5/16$ in. (8 mm)	1/16 in. (2 mm)
$W > 5/16$ in. (8 mm) TO $W < 1$ in. (25 mm)	1/8 in. (3 mm)
$W \geq 1$ in. (25 mm)	3/16 in. (5 mm)

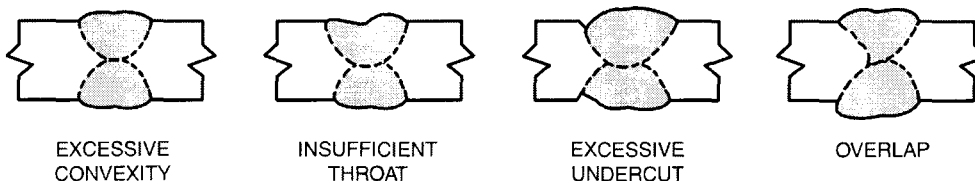


(C) UNACCEPTABLE FILLET WELD PROFILES

BUTT JOINT—
EQUAL THICKNESS PLATEBUTT JOINT (TRANSITION)—
UNEQUAL THICKNESS PLATE

NOTE: REINFORCEMENT R SHALL NOT EXCEED 1/8 in. (3 mm). SEE 5.24.4.

(D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT



(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS

Figure 2.10—Acceptable and Unacceptable Weld Profiles

Check Dimensional Accuracy of Completed Weldment

Other measurements are required to evaluate the overall dimensional accuracy of the completed weldment, since the shrinkage stresses from welding may have caused the size of the part to change. For example, a weld deposited around the outside of a machined bore may cause the diameter of that bore to be reduced, necessitating further machining to provide the appropriate bore size. Dimensional evaluation will also determine whether any distortion resulted from welding. The localized heat of welding could cause members to be distorted or misaligned, with respect to other parts of the weldment. These measurements will determine if the amount of distortion that is present is enough to cause the part to be rejected or unusable.

Selection of Production Test Samples

In welded assemblies, inspection of the product may be performed on samples taken from the production line. These samples may be selected at random, or according to an established order. In either case, witnessing sample selection and testing is one of the welding inspector's important duties. Selection of samples is sometimes left to the inspector's judgment and discretion; however, it is not necessary to take more samples than required to determine conformance. Typical tests include radiography and other nondestructive examinations, hydrostatic tests, chemical analysis, metallurgical examinations, and destructive mechanical testing. It is important to ensure that such work is properly carried out. Various sampling plans, test processes, and inspection methods are described in Chapters 7 and 10.

Evaluation of Test Results

It is impractical to expect that a welding inspector will witness all tests; however, enough tests should be witnessed to satisfy the inspector that tests are being performed in the proper manner and results are being accurately reported. It is important to ascertain that the testing equipment calibration is documented. When the tests have been performed, the inspector must evaluate

the results and decide whether the product meets the specifications.

Final Nondestructive Examination

Some welds must also be examined upon completion using other nondestructive examination in addition to visual inspection. This testing may be performed by the welding inspector or other NDE technician. In either case, the individual performing the test shall be properly qualified.

A CWI certification does not qualify an individual to perform nondestructive examinations. If an individual other than the welding inspector performs the examination, the inspector is required to verify that the NDE was performed by qualified personnel in the specified manner. In this case, the welding inspector's primary responsibility is to review the information to ensure that the results are complete. The welding inspector is then responsible for the maintenance of those records.

Maintaining Records and Reports

Code work always requires record keeping. Whether specified or not, complete records (i.e., detailed notes or formal inspection reports) should be kept by every inspector.

The welding inspector should check official records for completeness and accuracy and make certain that the records are available. Records that require the fabricator's signature should be prepared by the fabricator, not by the inspector. Records should be as detailed as necessary and entries should be in ink. Errors are to be crossed out with a single line and not erased; otherwise, record tampering may be suspected. The final report should comment on the general character of the work, how well it stayed within prescribed tolerances, difficulties that occurred, and any defects that were noted. Repairs should be explained. Reports describing the presence of weld defects should be accompanied by reports describing acceptance of subsequent repairs. Copies of reports should be distributed to all involved parties, and the welding inspector should maintain a copy for his records should some question later arise. Chapter 13 provides a detailed description of this aspect of the welding inspector's responsibilities.

Review—Chapter 2—Welding Inspector Responsibility

- Q2-1** Which of the following is an acceptable way to correct an error on an inspection report?
- draw a line through the incorrect portion of the report
 - erase the incorrect word or words
 - throw away the report
 - line out the error, make the correction, and initial and date the correction
 - none of the above
- Q2-2** What records should you keep as a CWI?
- copies of reports of all inspections you perform
 - copies of reports relevant to your areas of responsibility (material test reports, welder qualification paperwork, procedure qualification paperwork, etc.) even though you didn't prepare them
 - copies of sales literature describing welding equipment
 - a and b above
 - all of the above
- Q2-3** When a particular type of weld is consistently marginal, with rejects occurring, what action would be appropriate for you as the inspector?
- tell the welder what you want
 - bring the problem to the attention of production personnel in order for corrective action to be taken, if possible
 - simply continue to accept or reject the welds according to specified criteria (no more action is appropriate for inspectors)
 - all of the above
 - none of the above
- Q2-4** A specification for a weld joint that must be immediately accepted or rejected lacks detailed information about that particular joint. Who should rule on the meaning and intent of the specification?
- the designer
 - the welding engineer
 - the project engineer or quality assurance personnel (if their approval is required by contract)
 - you, as the CWI
 - none of the above
- Q2-5** How can you identify an individual low-hydrogen electrode that a welder is already consuming to make a weld?
- read the classification numbers painted on the covering near the stub end of the electrode
 - ask the welder what it is
 - ask the welding foreman
 - look at the completed weld and identify the type of electrode by the visual appearance of the weld deposit
 - look on the drawing or specification to determine what type of electrode is required for that weld
- Q2-6** How should low-hydrogen electrodes be stored before use?
- in their original unopened containers
 - in ovens held at a temperature that ensures the maintenance of their low moisture content
 - in tool room cribs, properly labeled, ready for quick distribution
 - a or b above
 - all of the above
- Q2-7** What joint fit should you insist on?
- within tolerances specified on drawings or specifications
 - groove welds should have minimal root openings to reduce distortion
 - root openings greater than 1/8 in. to ensure complete penetration
 - fillet welds should have root openings so that the resulting weld's effective throat will be greater
 - none of the above

- Q2-8** Which welders are allowed to work on a “code” job?
- a. only those with certification papers from former jobs
 - b. only those tested by the fabricator for this particular job
 - c. only those qualified in accordance with job specifications
 - d. only those you have requalified for this job
 - e. all of the above
- Q2-9** How should low-hydrogen electrodes out of their original containers be stored?
- a. in their original resealed containers
 - b. in vented electric storage ovens
 - c. in open tool crib shelves
 - d. in individual welders’ electrode pouches
 - e. none of the above
- Q2-10** How can a CWI verify that the specified material is used on the job?
- a. for code jobs, each piece of material must be correctly marked with its identity
 - b. perform a quick carbon analysis with a field test kit
 - c. material must be scrapped if no identification is evident
 - d. once the material leaves the storage area, the CWI no longer has to verify it
 - e. none of the above
- Q2-11** If a mill product has imperfections such as splits, tears, or surface irregularities, what action should you as the inspector take?
- a. reject any imperfect materials
 - b. judge whether or not the imperfections meet acceptance criteria according to applicable job specifications
 - c. ignore the irregularities, if not in the immediate vicinity of the weld joint
 - d. wait until the welder finishes the weld to see if any cracking occurs, before making any judgment
 - e. none of the above
- Q2-12** Which of the following is a welding inspector’s responsibility prior to welding?
- a. check joint fit
 - b. check preheat temperature
 - c. check interpass temperature
 - d. a and b above
 - e. b and c above
- Q2-13** A 1/4 in. fillet weld is specified on the drawing. When the CWI inspects the weld, it is measured to be 3/8 in. What should be done?
- a. reject the weld for being oversize
 - b. accept the weld if no weld size tolerances are specified
 - c. ask for an engineering review of the design
 - d. b and c above
 - e. none of the above
- Q2-14** Fillet welds may be measured using a tolerance of:
- a. +1/16 in.
 - b. +1/32 in.
 - c. -1/16 in.
 - d. -1/32 in.
 - e. no tolerance

CHAPTER 3

Safety

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Chapter 3—Safety

Introduction

Since welding inspectors frequently work in the same environment as the welder, they can be exposed to many potential safety hazards, i.e., electric shock, falling, radiation, eye hazards such as ultraviolet (UV) 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 be exposed to these conditions only momentarily. The welding inspector should strive to observe all safety precautions, such as the use of safety glasses, hard hats, protective clothing, or any other appropriate apparatus. For a detailed look at recommended safety precautions, refer to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

Management's Responsibility

Safety is an important consideration in all welding, cutting, and related work. The most important components of an effective safety and health program are 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 cutting and welding operations (see Figure 3.1). When these operations are done in other than designated areas, management must ensure that a proper procedure is established and followed to protect personnel and property. Management must also be certain that only approved welding, cutting, and allied equipment such as torches, regulators, welding machines, electrode holders, and personal protective devices are used.

Adequate training is mandated under provisions of the *U.S. Occupational Safety and Health Act (OSHA)*. Thorough and effective training is a key aspect of any safety and health program, since welders and other equipment operators work most safely when they are properly trained in the performance of their job. Proper training includes instruction in both the safe use of equipment and processes, and the safety rules that must be followed.

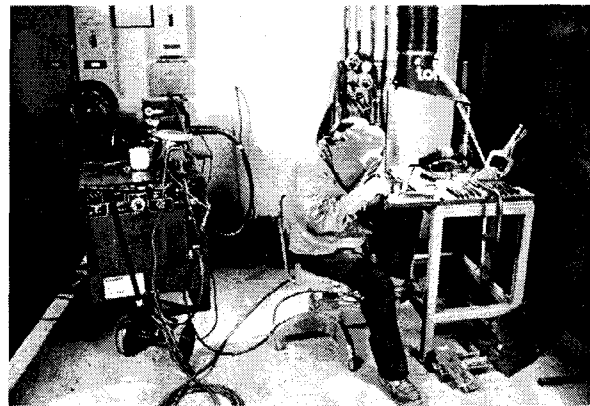


Figure 3.1—Designated Welding Area

Personnel need to know and understand the rules and the consequences of failing to comply with them.

The Working Environment

Good housekeeping is essential to avoid injuries. For example, a welder's vision is often restricted by necessary eye protection, and workers passing by a welding station frequently must shield their eyes from the flame or arc radiation. In both cases, limited vision increases the probability of tripping over objects left on the floor; therefore, shop personnel must ensure that the area is clear of potential hazards. The production area should be designed so that gas hoses, cables, mechanical assemblies, and other equipment does not obstruct walkways or interfere with routine tasks.

When work is performed aboveground or at floor level, safety rails or lines must be provided to prevent falls. Safety lines and harnesses can help restrict workers to safe areas and catch them in case of a fall. Since unexpected events, such as fume releases, fire, and explosions can and 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 should be avoided.

To avoid a safety hazard, equipment, machines, cables, hoses, and other apparatus should never be placed in passageways, on ladders, or on stairways. Warning signs specifying that eye protection must be worn should be prominently posted in all welding areas. Occasionally, a “firewatch” employee must be assigned to maintain safety during cutting or welding.

Personnel in areas adjacent to welding and cutting operations must be protected from radiant energy and hot spatter by the use of flame-resistant screens or shields, suitable eye and face protection, and by wearing protective clothing. If feasible, work stations should be separated by noncombustible screens or shields, which allow air circulation both at floor level and above the screen.

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

The risk of fire is also increased by the presence of combustibles in the work area, or by welding or cutting too close to unshielded combustibles. Flammable gases, vapors, and dust—when mixed with certain proportions of air and oxygen—may also present explosion and fire dangers. Welding, brazing, soldering, cutting, or operating equipment capable of producing heat or sparks, must not be performed in atmospheres containing flammable gases, vapors, or dust.

Eye and Face Protection

Welding helmets or handshields containing appropriate filter and cover plates must be used by welders, welding operators, and nearby personnel when viewing an arc. Safety spectacles, goggles, or other types of suitable eye protection must also be worn during other types of welding and cutting operations (see Figure 3.2). Such devices must have full-conforming side shields, when worn in areas where 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 emitted from adjacent welding or cutting operations when the welding helmet is raised or removed (see Table 3.1). Number 2 filter plates are recommended for general purpose protection.



Figure 3.2—Eye, Ear, and Face Protective Equipment

When wearing welding shields, welders frequently neglect to wear safety glasses under the hood, which is not a good practice. The welding shield does not protect the eyes from stray sparks and grinding particles. Any worker who has performed welding, particularly out-of-position welding, can attest to the number of sparks that enter and bounce around the helmet. These sparks can easily enter the eye; therefore, it is good practice to wear safety glasses with side shields under the welding shield.

Oxyfuel Gas Welding, Cutting, Brazing, Soldering, and Submerged Arc Welding

Safety goggles with filter plates and full-conforming side shields must be worn while performing oxyfuel gas welding and cutting. During submerged arc welding, the arc is covered by flux and not readily visible; therefore, an arc welding helmet is not needed. Because the arc occasionally flashes through the flux, however, the operator should wear tinted safety glasses. During torch brazing and soldering, a bright yellow flame may be visible. An appropriate tinted safety glass is recommended.

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 clothing, because it is not so readily ignited. Cotton clothing, if used, should be chemically treated to reduce its combustibility. Clothing treated with nondurable

Table 3.1
Lens Shade Selector

Operation	Shade Number
Soldering	2
Torch Brazing	3 or 4
Oxygen Cutting	
Up to 25.4 mm (1 in.)	3 or 4
25.4 mm to 152.4 mm (1 to 6 in.)	4 or 5
152.4 mm (6 in.) and over	5 or 6
Gas Welding	
Up to 3.2 mm (1/8 in.)	4 or 5
3.2 mm to 12.7 mm (1/8 in. to 1/2 in.)	5 or 6
12.7 mm (1/2 in.) and over	6 or 8
Shielded Metal Arc Welding	10
1.6 mm (1/16 in.), 2.4 mm (3/32 in.), 3.2 mm (1/8 in.), 4.0 mm (5/32 in.) electrodes	
Gas Tungsten Arc Welding (Nonferrous)	11
Gas Metal Arc Welding (Nonferrous)	
1.6 mm (1/16 in.), 2.4 mm (3/32 in.), 3.2 mm (1/8 in.), 4.0 mm (5/32 in.) electrodes	
Gas Tungsten Arc Welding (Ferrous)	12
Gas Metal Arc Welding (Ferrous)	
1.6 mm (1/16 in.), 2.4 mm (3/32 in.), 3.2 mm (1/8 in.), 4.0 mm (5/32 in.) electrodes	
Shielded Metal Arc Welding	
4.7 mm (3/16 in.), 5/6 mm (7/32 in.), 6.4 mm (1/4 in.) electrodes	12
7.9 mm (5/16 in.), 9.5 mm (3/8 in.) electrodes	14
Atomic Hydrogen Welding	10 to 14
Carbon Arc Welding	14

flame retardants must be treated again after each washing or cleaning. Polyester clothes, which can melt and cause severe burns, should not be used. Frayed denim will burn as if dipped in gasoline. Outer clothing should be kept free of oil and grease.

Cuffless pants and covered pockets should be worn to avoid spatter or spark entrapment. Pockets should be emptied of flammable material that can be ignited by sparks or weld spatter and cause severe burns. Pants should be worn on the outside of shoes. Protection of the head is also recommended. Flammable hair preparations should not be used.

Durable gloves of leather or other suitable material should be worn, because gloves not only protect the hands from burns or abrasion, they also provide insulation from electrical shock.

Ear Protection

Sparks or hot spatter in the ears can be serious and particularly painful. Properly fitted, flame-resistant ear

plugs or ear muffs should be worn whenever operations pose such risks. Excessive noise, particularly continuous noise at high levels, can severely damage hearing. In welding, cutting, and allied operations, noise may be generated by the process, the equipment, or both. Hearing protection devices are required for some operations. Additional information is presented in the AWS publication, *Arc Welding and Cutting Noise*. Air carbon arc and plasma arc cutting are processes with high noise levels. Engine-driven generators sometimes emit a high noise level, as do some high-frequency and induction power sources.

Fumes and Gases

Welders, welding operators, and other personnel in the area must be protected from overexposure to fumes and gases produced during welding brazing, soldering, and cutting operations. 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. Protection from excess exposure is usually accomplished by ventilation. Proper ventilation can significantly reduce 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, or general, where the shop air is changed or filtered (see Figure 3.3).

The single most important factor influencing exposure to fume is the position of the welder's head, with respect to the plume. When the head is in such a position that the fume envelops the face or helmet, exposures can be very high. Therefore, welders must be trained to keep their heads to one side of the fume plume. The size of the welding or cutting enclosure is important, because it affects the background fume level. Fume exposure in a tank, pressure vessel, or other confined space will be higher than in a high-bay fabrication area.

Confined Spaces

Special consideration must be given to the safety and health of welders and other workers in confined spaces. See the latest edition of ANSI Publication Z117.1, *Safety Requirements for Working in Tanks and Other Confined Spaces*, 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, i.e., 12 V. If 110 V is required, the circuit must be protected by an approved ground fault circuit interrupter.

In case of emergency, a means of removing workers quickly has to be provided. Safety belts and lifelines, when used, should be attached to the worker's body in such a way to avoid the possibility of becoming jammed

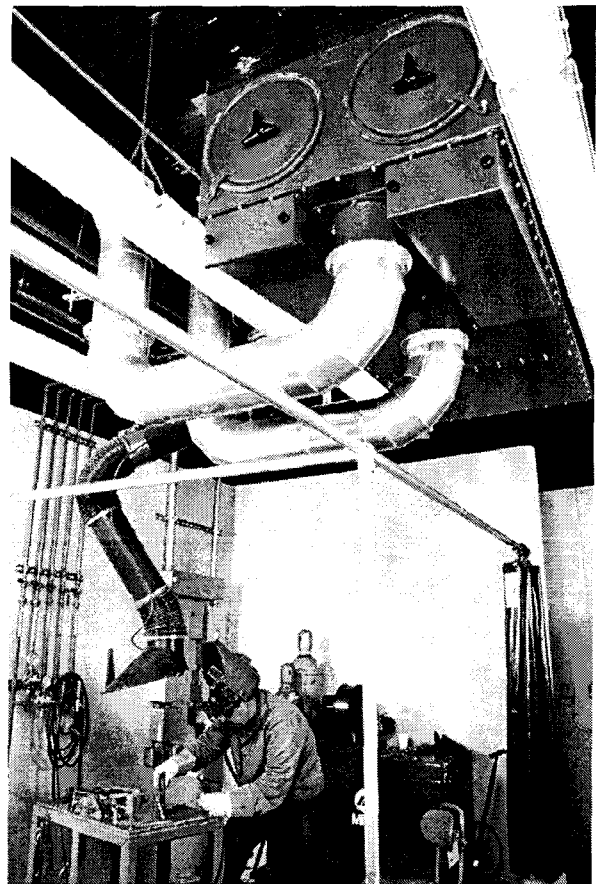


Figure 3.3—Movable Fume Extractor Positioned Near the Welding Arc

in the exit. A trained helper should be stationed outside the confined space with a preplanned emergency rescue procedure.

In addition to keeping airborne contaminants in breathing atmospheres at or below recommended limits, ventilation in confined spaces must (1) ensure adequate oxygen for life support, (2) prevent accumulation of an oxygen-enriched atmosphere, and (3) prevent accumulation of flammable mixtures. Before a worker enters a confined space, the space should be tested for toxic or flammable gases and vapors and adequate or excess oxygen.

Heavier-than-air gases, such as argon (Ar), methylacetylene propadiene (MAPP) (also referred to as methylacetylene propadiene stabilized or MPS gas), propane, and carbon dioxide (CO₂) may accumulate in pits, tank bottoms, low areas, and near floors. Lighter-than-air gases, such as helium and hydrogen, may accumulate in tank tops, high areas, and near ceilings. The same precautions apply as for confined spaces. If practical, a continuous monitoring system with audible alarms should be used for work in confined spaces.

Handling of Compressed Gases

Gases used in welding and cutting operations are packaged in containers called cylinders. Only those cylinders designed and maintained in accordance with specifications of the U.S. Department of Transportation (DOT) may be used in the United States.

When handling cylinders, the following general safety precautions should be taken:

- Gas cylinders must not be welded.
- Cylinders must not be allowed to become part of an electric circuit, because arcing may result.
- Cylinders must not be used as work rests or rollers.
- Cylinders should be protected from bumps, falling objects, and weather; they should not be dropped.
- Cylinders should be kept in areas where temperatures do not fall below -0°F, or exceed 130°F.
- Proper cradles or cradle slings should be used to secure cylinders for hoisting.
- Electromagnets should not be used when handling cylinders.
- Cylinders must always be secured by the user against falling during either use or storage.
- Acetylene and liquefied gas cylinders should be stored and used in the upright position.

Before using gas from a cylinder, the contents should be identified only by the label on the cylinder. Any other

means of identification, such as cylinder color, banding, or shape (which may vary among manufacturer, geographical area, or product line) may be completely misleading and should not be used. If a cylinder has no label, the contents should not be used and the cylinder should be returned to the supplier.

A valve protection cap is provided on the cylinder, to protect the cylinder valve. This cap should always remain in place, unless the cylinder is in use. The cylinder should never be lifted manually or hoisted by the valve protection cap. 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 (NFPA). Safe handling and storage procedures are discussed in the *Handbook of Compressed Gases*, published by the Compressed Gas Association (CGA).

Appropriate pressure-reducing regulators should be used to withdraw gases from cylinders; however, such regulations must be used only for the gas and pressure given on the label. Cylinders containing high-pressure gases must be opened slowly, to prevent rapid pressurization of the regulator. Once high-pressure cylinders are opened, the tank valve should be opened all the way to “back seat” the valve. Tank valves on cylinders containing fuel gases should not be opened more than one turn. When not in use, the tank valves should be closed, the lines purged, and the pressure-regulating screw backed out.

Gases

Oxygen

Oxygen is nonflammable, but it supports the combustion of flammable materials. It can initiate combustion and vigorously accelerate it. Oxygen cylinders should not be stored near combustibles, or with cylinders of fuel gas. Oxygen should never be used as a substitute for compressed air. 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. Oxygen valves, regulators, and apparatus should never be lubricated with oil. Oxygen must never be used to power compressed air tools. Similarly, oxygen must not be used to blow dirt from work and clothing, which are often contaminated with oil, grease, or combustible dust.

Fuel Gases

Fuel gases commonly used in oxyfuel gas welding (OFW) and oxyfuel gas cutting (OFC) are acetylene, methylacetylene propadiene, natural gas, propane, and propylene. Acetylene in cylinders is dissolved in a solvent,

so that it can be safely stored under pressure. In its free state, acetylene should never be used at pressures over 15 psi, because it can dissociate with explosive violence at higher pressures. Acetylene and MAPP should never be used in contact with silver, mercury, or alloys containing 70% or more copper, because the gases react with these metals to form unstable compounds that may detonate under shock or heat.

Fuel Gas Fires

The best procedure for avoiding fuel gas fires from a fuel gas or a liquid is to prevent leaks, which will keep the fire contained within the system. All fuel gas 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 is the 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 more than one turn, because in this way, it can be shut off quickly in an emergency.

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.

Shielding Gases

In some welding processes, argon, helium, carbon dioxide, and nitrogen are used for shielding. All except carbon dioxide are used as brazing atmospheres. These gases are odorless and colorless, and can displace air needed for breathing.

Before being entered by personnel, confined spaces containing these gases must be well ventilated. If there is any question regarding safety, the space should first be checked for adequate oxygen concentration with an oxygen analyzer. If an oxygen analyzer is not available, an air-supplied respirator should be worn by personnel entering the space.

Electric Shock

Most welding and cutting operations employ some type of electrical equipment. To protect workers from fatalities and injuries caused by electric shock in welding and cutting operations, proper safety precautions should be followed.

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 on the amount of current, the duration and path of the flow, and the state of health of the victim at the time of receiving

the shock. 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.

Currents greater than about 6 milliamperes (mA) are considered *primary shock currents*, because they can cause direct physiological harm. Steady-state currents between 0.5 and 6 mA are considered *secondary shock currents*. Secondary shock currents can cause involuntary muscular reactions, normally without 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.

In welding and cutting work, electrical equipment is generally powered from ac sources of between 115 and 575 V, or by engine-driven generators. Most welding is done with less than 100 arc volts. Electric shock in the welding industry usually occurs as a result of accidental contact with bare or poorly insulated conductors operating at such voltages. Therefore, welders must take precautions against contacting bare elements, in welding and primary circuits.

Electrical resistance is usually reduced in the presence of water or moisture. To prevent electric shock when performing arc welding or cutting under damp or wet conditions, including when perspiring heavily, the inspector must wear dry gloves and clothing in good condition. The welding inspector should be protected from electrically conductive surfaces, including the ground. Minimal protection can be afforded by rubber-soled shoes; however, an insulating layer, such as a rubber mat or a dry wooden board, is preferable. Similar precautions against accidental contact with electrically conductive surfaces must be taken by the welding inspector, especially when working in cramped kneeling, sitting, or prone positions. Rings and jewelry should be removed before welding, to decrease the possibility of electric shock.

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

Equipment should be installed in a clean, dry area. When this is not possible, equipment should be adequately protected from dirt and moisture. Installation—including disconnects, fusing, and certain types of incoming power lines—must be performed in accordance with the requirements of ANSI/NFPA 70, *National Electric Code*, and local codes. Electrical connections must be tightly installed, and should be periodically checked thereafter.

Review Chapter 3—Safety

- Q3-1** The welding inspector is exposed to which of the following safety hazards?
- radiation
 - falling objects
 - electrical shock
 - eye hazards
 - all of the above
- Q3-2** A document that covers safety in welding and cutting is:
- AWS D1.1
 - API 1104
 - ANSI Z49.1
 - ASME Section IX
 - ASME B31.1
- Q3-3** Eye hazards found in welding operations include:
- grinding dust
 - weld spatter
 - radiation
 - smoke and fumes
 - all the above
- Q3-4** In avoiding fumes during welding, the most important factor is:
- the type of base metal
 - the position of the welder's head
 - the type of welding process
 - the position of the welding machine
 - the type of filler metal
- Q3-5** Acetylene becomes unstable above what pressure?
- 5 psi
 - 10 psi
 - 15 psi
 - 25 psi
 - none of the above
- Q3-6** Electric currents above approximately 6 milliamperes (mA) are considered:
- secondary currents
 - primary currents
 - harmful
 - b and c above
 - not harmful
- Q3-7** When operating gas cylinders, the cylinder valve should be opened:
- all the way on the acetylene cylinder
 - one turn on an oxygen cylinder
 - one turn or less on an acetylene cylinder, all the way on the oxygen cylinder
 - whatever is convenient
 - none of the above
- Q3-8** Proper handling of compressed gas cylinders includes:
- not welding on cylinders
 - not including the cylinders in the ground or electrical circuit
 - securing them properly
 - identifying the gas prior to use
 - all of the above

Q3-9 The most important component of an effective safety and health program is:

- a. safety rules
- b. safety procedures
- c. management support
- d. welding helmet
- e. protective equipment

Q3-10 Safety training is mandated under provisions of:

- a. *AWS Safe Practices*
- b. OSHA
- c. ASME code
- d. *AWS Welding Handbook*, Volume 2
- e. none of the above

Q3-11 Protective equipment suitable for eye protection from welding radiation includes:

- a. welding helmets with filter lens
- b. clear safety glasses
- c. safety goggles with filter plates
- d. protective screens
- e. all of the above

Q3-12 Suitable clothing materials for welding and cutting are:

- a. 65% cotton, 35% polyester
- b. wool
- c. chemically treated cotton
- d. b and c above
- e. none of the above

CHAPTER 4

Standards, Including Codes and Specifications

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Chapter 4—Standards, Including Codes and Specifications

Introduction

The responsibility associated with inspection is quite large. People who inspect for a living must have a critical eye, knowledge of their field, and the ability to exercise judgment.

Some welding applications are more critical than others; however, all welding inspections are important, no matter how critical the weld or the application. The importance of welding inspection activities is underscored by the array of standards that inspectors must use.

There are many approaches to inspection. Today's growing technical demands by purchasers and the cost of product liability rule out casual inspection. However, there are still areas of interpretation; i.e., when selecting the level of and severity of inspection. Where life and safety are involved, the quantity and quality of welding inspection usually must conform to a code, standard, or specification. The welding inspector frequently inspects work in accordance to a particular code. Several organizations, including AWS and ASME, have developed codes for various areas of concern.

Requirements of Standards, Codes, and Specifications

The term "standard" applies to numerous types of documents, including codes and specifications. Other types of documents considered to be standards are procedures, recommended practices, groups of graphic symbols, classifications, and definitions of terms. So, once a "standard" has been specified, you as an inspector must then judge the adequacy of product based upon how it compares with that established standard. Standards can be considered mandatory, such as a code, or nonmandatory, as is the case for a recommended practice. Nonmandatory standards use the words "should" and "could" in place of "shall" and "will." Nonmandatory standards become mandatory when referenced by a code. For example, the American Society for Nondestructive Testing's (ASNT)

Recommended Practice No. SNT-TC-1A establishes guidelines for the qualification and certification of NDT personnel. Because Section 6 of AWS D1.1 requires that NDT personnel be qualified in accordance with SNT-TC-1A, the practice becomes mandatory.

The term standard applies collectively to codes, specifications, recommended practices, classifications, methods and guides that have been prepared by a sponsoring organization, and approved in accordance with established procedures. Standards for welding are published in cooperation with the American National Standards Institute (ANSI).

The code may come from a government agency or a private agency such as an engineering society. A code is defined as "a body of laws, as of a nation, city, etc., arranged systematically for easy reference." For example, cities have "building codes" that describe the construction requirements for structures in that municipality. Since a code consists of rules having legal status, the code is also considered mandatory, and text in the code will contain words such as "shall" and "will." A specific code includes conditions and specifications for the item in question. The code frequently will include descriptions of methods to determine if those conditions and requirements have been achieved.

During the execution of any inspection, the welding inspector must constantly refer to the codes, standards, specifications, or a combination of the three, to learn many important requirements for the fabrication or construction taking place. A number of these documents, which relate to some aspect of weld quality, are primarily produced by national professional organizations or government agencies. The type of weldment being constructed will determine the requirements to be enforced.

The following discussion includes descriptions of these various welding codes, standards and specifications and their areas of coverage.

A code is a standard consisting of a set of conditions and requirements relating to a particular subject, and indicating appropriate procedures by which it can be determined that the requirements have been met. It is a standard that is suitable for adoption by a governmental authority as a part of a law or regulation, or as specified by other mandatory documents. A code is intended to be mandatory, and it should be used when so required by a governmental authority or specified by other mandatory documents. Other mandatory documents could be documents issued by agencies such as purchasing departments, trade associations, or insurance companies.

Codes Important to Welding

Structural Welding Code—Steel (AWS D1.1)

AWS D1.1, *Structural Welding Code—Steel*, is published by the American Welding Society, with new editions scheduled for publication every other year. AWS D1.1 describes the welding requirements for steel structures, including statically loaded, dynamically loaded, and tubular structures.

The following is a listing of the various sections of AWS D1.1 and their areas of coverage:

- (1) General Requirements
- (2) Design of Welded Connections
 - Part A—Common Requirements of Nontubular and Tubular Connections
 - Part B—Specific Requirements for Nontubular Connections (Statically or Cyclically Loaded)
 - Part C—Specific Requirements for Cyclically Loaded Nontubular Connections
 - Part D—Specific Requirements for Tubular Connections
- (3) Prequalification of WPSs
- (4) Qualifications
 - Part A—General Requirements
 - Part B—Welding Procedure Specifications (WPS)
 - Part C—Performance Qualification
- (5) Fabrication
- (6) Inspection
 - Part A—General Requirements
 - Part B—Contractor Responsibilities
 - Part C—Acceptance Criteria
 - Part D—Nondestructive Testing Procedures
 - Part E—Radiographic Testing
 - Part F—Ultrasonic Testing of Groove Welds
 - Part G—Other Examination Methods
- (7) Stud Welding

- (8) Strengthening and Repairing Existing Structures
- Annexes—Mandatory Information
- Annexes—Nonmandatory Information
- Commentary

Section 6 of AWS D1.1 describes two categories of welding inspectors: fabrication/erection and verification. *Fabrication/erection* inspection and testing is the responsibility of the contractor, unless otherwise stated in the contract; while *verification* inspection and testing is the responsibility of the owner or engineer. AWS D1.1 does make this distinction, however, the requirements of the code are intended to apply equally to the work of both parties.

Subsections 6.1 through 6.5 describe the welding inspector's duties and responsibilities, and 6.6 details the contractor's responsibilities in satisfying the requirements of inspection personnel. Beginning at 6.9, the methods for nondestructive examination in accordance with AWS D1.1 are listed. For information pertaining to the various NDE methods, refer to Table 4.1.

Other AWS Structural Welding Codes (D1.2, D1.3, D1.4, D1.5, and D1.6)

In addition to D1.1, AWS has developed five other codes dealing with structural welding requirements:

- (1) D1.2, *Structural Welding Code—Aluminum*
- (2) D1.3, *Structural Welding Code—Sheet Steel*
- (3) D1.4, *Structural Welding Code—Reinforcing Steel*
- (4) D1.5, *Bridge Welding Code*
- (5) D1.6, *Structural Welding Code—Stainless Steel*

Table 4.1
Nondestructive Testing
Methods—D1.1 Code Reference

Test Method	Applicable Code References
Radiographic	Section 6, Part E
Ultrasonic	Section 6, Part F
Magnetic Particle	Section 6, ASTM E 709
Liquid Penetrant	Section 6
NDT Personnel Qualification	6.14.6.1 (SNT-TC-1A)
The acceptance criteria for both the visual inspection and non-destructive examination are found in the following code locations, depending upon the type of structure being constructed.	
Type of Structure	Weld Acceptance Criteria Reference
Statically Loaded, Dynamically Loaded, and Tubular Structures	Section 6