



American Welding Society

The Practical Reference Guide for



Visual Inspection of Pressure Vessels and Pressure Piping

THE PRACTICAL REFERENCE GUIDE for WELDING INSPECTION MANAGEMENT— Visual Inspection of Pressure Vessels and Pressure Piping

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AUTHOR NOTES

Visual inspection (VT) is one of the more important inspection methods used to ensure the quality of both new fabrication, as well as equipment and piping after some period of service. It is used in all industries, and should be considered as the basic inspection method prior to the selection of any other inspection method. A phrase that puts VT in the proper perspective follows:

"It has been shown repeatedly that an effective program of visual inspection, conducted by properly trained personnel, will result in the discovery of the vast majority of those defects which would otherwise be discovered later by some more expensive nondestructive test method."

Note the emphasis on proper training; without such training, the inspector often only *looks* at things without actually inspecting them, and critical discontinuities are often overlooked. It is to that end, the training of visual inspectors, that this Guide was prepared. Proper visual inspection requires inspector training in many disciplines and the training should be a continuous, ongoing process. New technologies useful to visual inspection are continuing to be developed, and these must be incorporated into the overall inspection efforts to optimize results.

It was once stated that, *"Inspectors must have been half crazy to have selected inspection as a lifetime career!"* While many of us may agree with that statement in part, most would agree that inspection is a very challenging and satisfying career path, and we remain quite proud to be called inspectors.

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Introduction

In one version of a perfect world of manufacturing, there are no inspectors. None are needed because each and every person in the workforce has been so thoroughly trained, possesses and applies all the necessary personal attributes, and is paid a reasonable salary such that all manufacturing mistakes are completely eliminated. Think of that perfect scenario: a manufacturing world without mistakes. Some of today's quality approaches reach for that ideal goal and have developed precepts that considerably reduce online inspection requirements. The concept of "continuous improvement" is an important part of that quest for perfection, and is found in many quality-concept documents.

One approach to quality is found in the documents, modified by American organizations, commonly referred to as ISO Standards. These often become the basis for "ISO Certification," which many manufacturing sites obtain and market as part of their quality program. In the U.S., these ISO quality program standards and guides are published under the combined authority of ANSI (American National Standards Institute), ISO (International Organization for Standards), and the ASQ (American Society for Quality), as "Q" documents. Two of these are Q9004-1, *Quality Management and Quality System Elements—Guidelines*, and Q9001, *Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing* (see Figure 1). A thorough understanding of these two quality documents is very helpful in organizing a Quality Assurance program for fabrication companies. Additional ASQ documents covering fabrication quality are Q9002, *Quality Systems—Model for Quality Assurance in Production, Installation, and Servicing*, and Q9003, *Quality Systems—Model for Quality Assurance in Final Inspection and Test*. Their cost is minimal and can be obtained from the American Society for Quality, 611 East Wisconsin Avenue, Milwaukee, WI 53202.

However, as much as these new quality programs have improved quality in many areas, in our less-than-ideal, real world, there still remains a need for skilled inspectors. Most have seen various versions of the old saying, "People do what you inspect, not what you expect." While that statement appears to be quite cynical, many critical manufacturing efforts still follow that credo with great success. Inspection will continue to be a necessary skill for

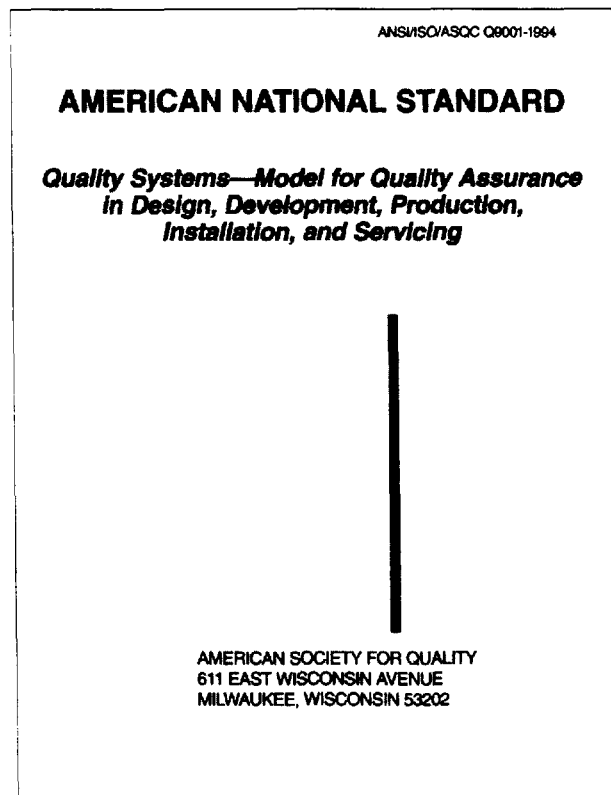


Figure 1. ANSI/ISO/ASQC Q9001-1994.

decades to come, especially in the fabricating industries, and visual inspection will certainly continue on the front line of that inspection effort.

In the broad field of Quality Assurance, the control of welding operations and fabrication of process equipment encompasses many technical disciplines including engineering design, materials selection, welding processes, welding procedures, non-destructive inspection, and corrosion mechanisms. Visual inspection plays an important role in all of these and it requires proper training of personnel to provide the necessary function of quality control at each stage of fabrication as well as continued inspections during the life of the component.

Inspector certification programs, such as the AWS CWI and SCWI certifications, have been developed to ensure a basic minimum qualification of the visual inspection personnel (see Figure 2). Other organizations such as the American Petroleum Institute (API), the National Association of Corrosion Engineers (NACE), and the American Society for Nondestructive Testing (ASNT), have developed

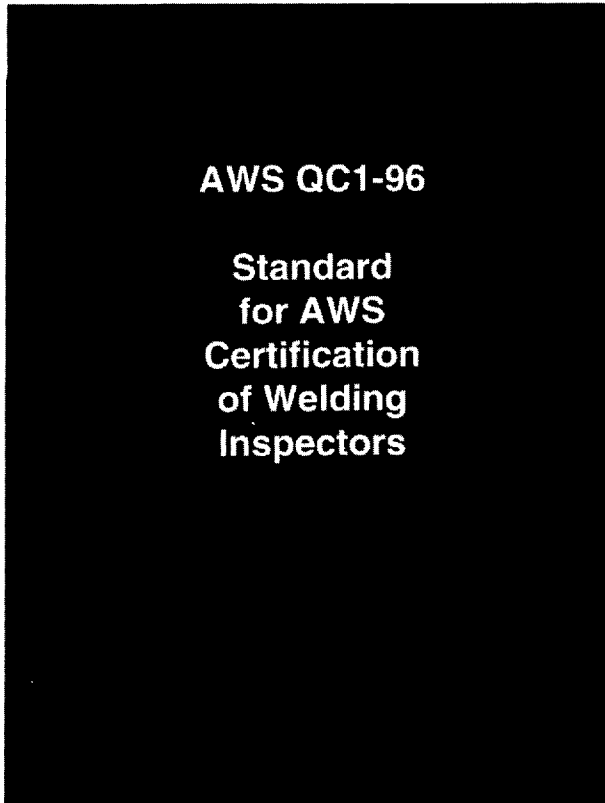


Figure 2. AWS QC1-96—Standard for AWS Certification of Welding Inspectors.

certification programs for general and/or specific industries. Additionally, several industries and private companies have produced industry-specific or in-house training programs to train the inspectors on their particular needs. Nuclear power industries have such programs, as do the petroleum, petrochemical, and aerospace industries.

Visual inspection is learned through experience; almost everyone has the inherent capability to see things, but visual inspection requires a more thorough observance of details that requires considerable training, and the learning curve is usually very experience-intensive. One of the first requirements of a visual inspector in the fabricating realm is to be able to read and interpret engineering drawings. Unless the inspector has this first capability, the requirements of the fabrication cannot be properly determined. Many inspectors learn blueprint reading in school, either in a drafting or engineering

drawing course; others learn on the job. The method of learning to interpret fabrication drawings is not the important issue. Rather, it is the interpretation itself that must be included as part of an inspector's skills.

Slang terms and incorrect terminology often lead to confusion and errors. So, a second requirement is to know and understand the proper terminology pertinent to a given industry. Proper terminology includes the mechanical aspects of stress, strain, strength, ductility and many others that aid in describing the mechanical properties of the materials used in manufacture. It also includes the necessary terminology of welding and fabrication processes, including joint and weld geometry and welding processes as well as typical discontinuities. Various base and weld metal discontinuity types have been defined by AWS and are described in AWS B1.10, AWS B1.11, AWS A3.0, and in the convenient AWS publication *The Everyday Pocket Handbook for Visual Inspection and Weld Discontinuities—Causes and Remedies* (see Figure 3 and Annex D—Selected References). Excerpts from some of these are found in Annex C—Discontinuities. Knowledge of corrosion terms is also required when completing in-service inspections of pressure equipment. Corrosion terms can also be found in several of the references noted in Annex D—Selected References.

An important third requirement for the visual inspector is a thorough knowledge of the fabrication codes pertaining to the various industries. The petroleum industry relies on API specifications, the railroad industry relies on the AAR standards, and building construction relies on the AWS structural codes. Almost every industry has specific codes that pertain to their particular needs and the inspector must have access to, and be familiar with, the applicable codes.

A fourth requirement is precise documentation of inspection results. Verbal statements regarding inspections usually have little value; the inspection results must be documented such that they can be referred to months or years later with absolute understanding and clarity. With today's computer technology, there is little or no excuse not to have complete, clear, legible, and retrievable documentation of inspection results readily available as needed. Today's technology also includes the excellent digital cameras that permit photographs of the equipment or condition to be easily inserted into the records. Video cameras are another method of

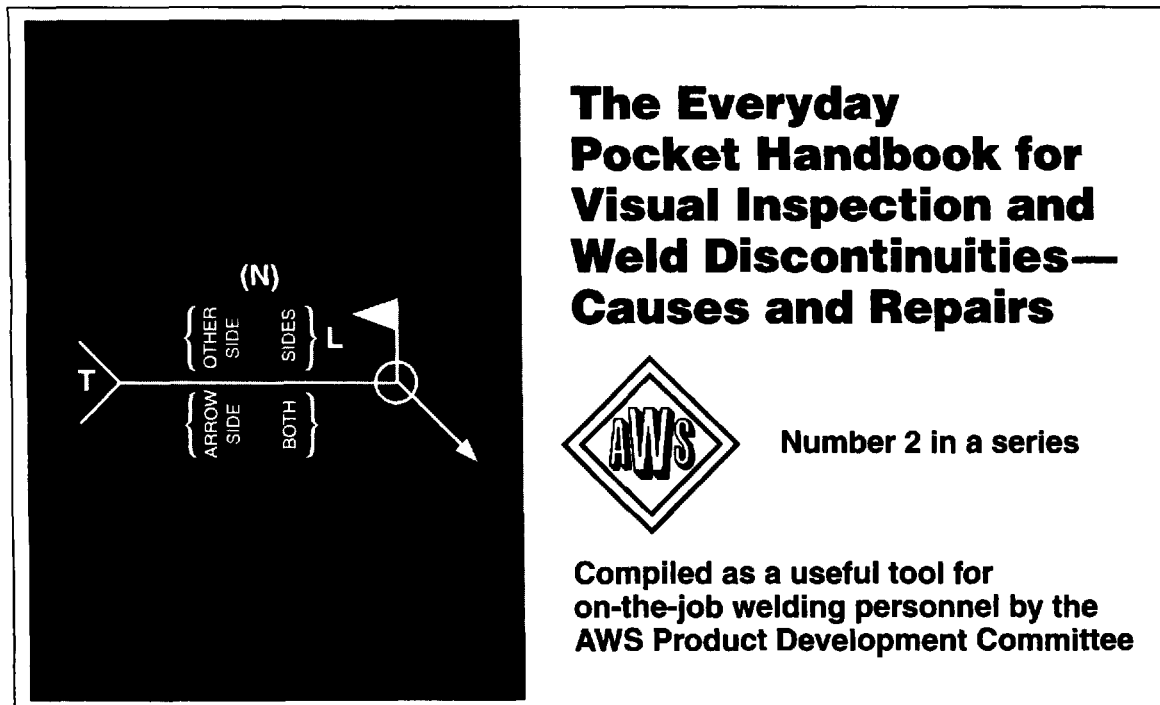


Figure 3. The Everyday Pocket Handbook for Visual Inspection and Weld Discontinuities—Causes and Repairs.

recording inspection results. As one inspector noted, "In today's world, if it's not written down, it hasn't happened!"

It is certainly recognized that the actual requirements for thorough visual inspection may vary from one industry to another, but all visual inspection contains the four basic requirements noted above that must be met to inspect an item to the desired and required level. Inspection not only applies to the original fabrication of the components, but extends to the in-service inspections as well. Fitness for purpose inspections must often continue for the life of the component, and this usually requires some form of periodic inspection, performed to written guidelines, to ensure the continued safe operation of the item. Most are somewhat familiar with the stringent rules for continued inspection for aircraft; they receive periodic inspections after a set number of hours of operation. Many pressure vessel codes have similar requirements but usually have longer time periods between inspections.

It is not the purpose of this Guide to repeat in great detail all the visual inspection procedures found in these other documents. Rather, practical approaches to the broad topic of visual inspection will

be covered, both for new fabrication and in-service inspections. The emphasis will be on piping and vessels for pressure containment.

New Fabrication

A good starting point for any new fabrication project is close communication between the manufacturing personnel and the design groups. To use a petrochemical process as an example, the manufacturing group knows the task it wants to perform whether it is to manufacture polyester sheeting material, polyethylene pellets for molding machines, or acids to use as ingredients for other manufacturing processes. The group conveys its desired result to the design group and after several discussions and iterations, the final design of the component is completed. During this design stage, it is very helpful to have input from the welding and metallurgical engineers as well as the inspectors to assist in a design that first of all can be fabricated, and secondly, inspected adequately. All too often, designs are too quickly put together only to find out the materials selected pose tremendous difficulty in

welding, or the design makes it impossible to thoroughly inspect.

The design of each separate component for a complex process is sometimes done in a rather random fashion. For example, a vessel is needed to mix the raw ingredients and is designed by the pressure vessel group. Then a distillation column is needed and is designed by the distillation column designers. A heat exchanger is needed and is designed by the heat exchanger designer. When insufficient communication exists between these various groups, it can lead to costly redesign, or material changes, to incorporate exactly what is needed.

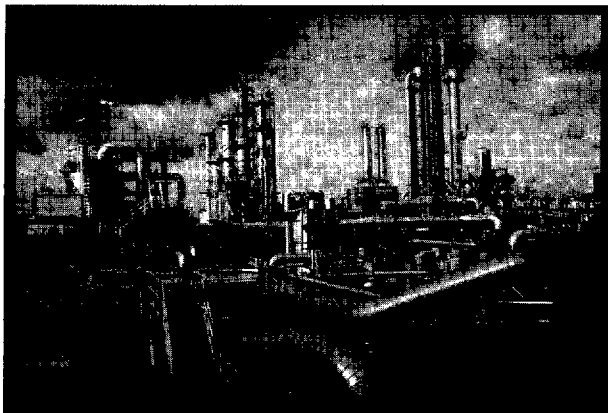


Figure 4. A typical petrochemical complex showing the complexity and variety of pressure vessels and piping arrangements.

A far better approach is to have good liaison between the various design sections through a project manager to ensure compatibility of each component, especially regarding the materials of construction and corrosion issues. The selection of materials incorporates many different aspects including cost, availability, strength, weldability, and corrosion resistance. Selection of the correct material may require fabrication and corrosion testing to ensure suitability. Visual inspection of these corrosion tests may be an initial inspection requirement for the project, and requires an understanding and knowledge of the various corrosion tests by the inspector. Often these are done to ASTM specifications and the inspector must have ready access to them.

Pressure containment usually requires the use of welding operations in the manufacturing of the piping and vessels needed. In the fabrication of

new equipment, the welding operations usually get considerable attention up front. There are several reasons for this, but they often include the general lack of knowledge of welding techniques by many of the engineering staff as well as previous experiences with weld failures. A list of the initial requirements for fabrication inspection will usually include the following:

Base Metals and Filler Metals

These should be purchased to specifications listing all the necessary requirements, with a supporting Material Test Report requirement on the purchase order. These necessary requirements usually include the mechanical properties, chemistry, size, shape, manufacturing method, surface finish, heat treatment, and quantity. Base metals are often ordered to ASTM, ASME, or API specifications; filler metals are usually ordered to AWS specifications. Specific items may require additional data, such as the protective coatings for corrosion resistance of steel products or shipping container requirements for low-hydrogen electrodes, and all the materials should always be inspected upon receipt to ensure compliance. Often, for critical applications, check analyses on the chemistry or mechanical properties may be made to reflect a higher degree of certainty. For filler metals, this may require the preparation of a weld sample to a specification for chemical or mechanical testing, with its preparation witnessed by an inspector.

Once the proper materials have been received and confirmed, it is imperative that storage of these materials maintains their proper identification (ID). There are many different systems used for maintaining the ID of materials. Coding by different paint colors can be an acceptable method for materials control, but consideration should be given to the effects of sun and weather on the color. Color changes do occur with exposure to sun, and this must be recognized. Color changes over time have led to mistakes in alloy identification. Weather can also cause deterioration of the materials, and protection may be needed during storage.

Piping is often ink marked every three or four feet along its length with its specification, grade, heat number, etc., which helps maintain its identification. Plate is often stamped or paint marked with its ID on one corner. Consider what happens if a portion of the plate is used. Often, the corner with the

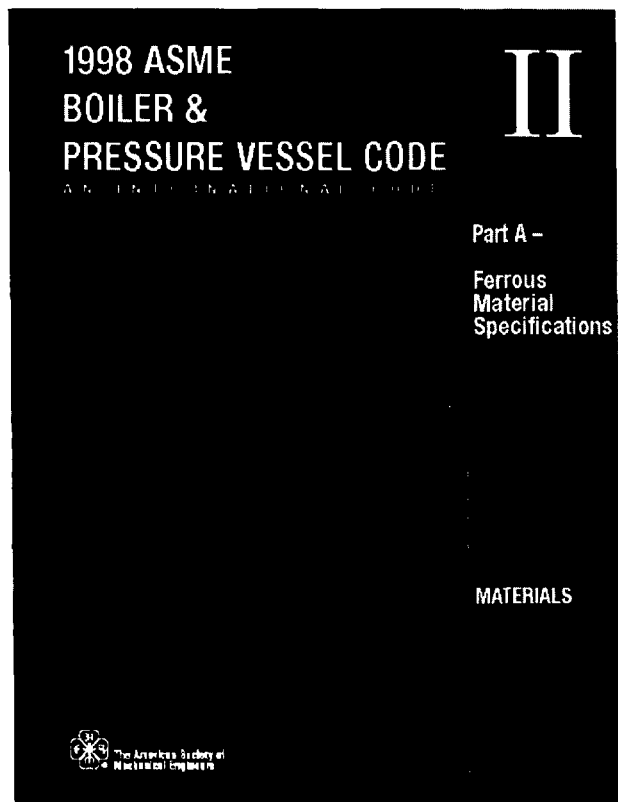


Figure 5. ASME Section II, Part A, covering ferrous material specifications. Section II, Part B of the same code covers nonferrous materials.

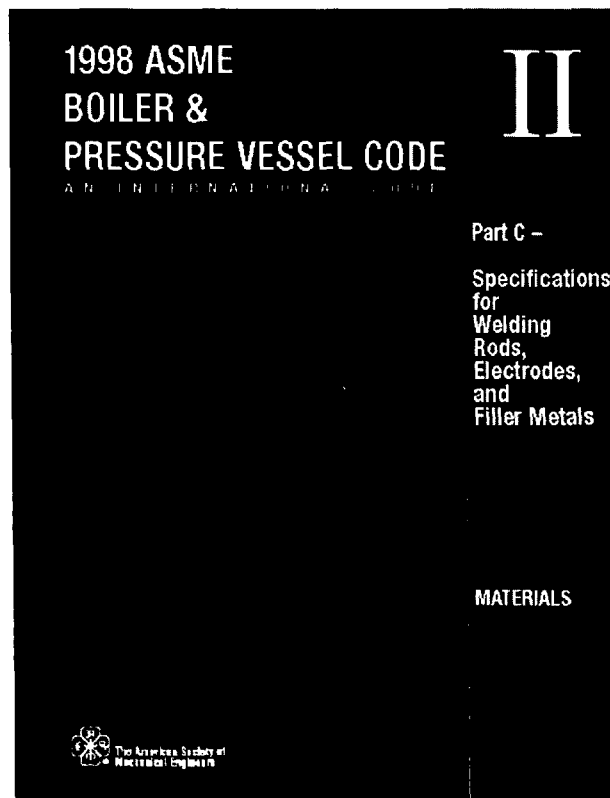


Figure 6. ASME Section II, Part C, covering filler metals. The AWS Filler Metal Specifications were adopted for use in Part C.

marking is taken for use and this requires the remarking of the “drop” or remainder. Inspectors should, and often do, play a role in this remarking. Other items such as forgings, castings, or subassemblies may require bar coding, stamping, tagging, or segregation to maintain their identity.

Welding Procedure Qualification

Once the base materials have been received, confirmed, and stored properly, the next item requiring attention for fabrication of pressure containment equipment is the qualification of welding procedures. (This step may be the initial step in the entire process if the fabricator has little or no experience with the materials to be used.) A welding process is selected and a preliminary Welding Procedure Specification is usually prepared. However, these procedures can be qualified in several different

ways depending on the code requirements in effect for the project. In some codes, test weldments must be made and tested to qualify a procedure. Other codes may permit the use of “canned” welding procedures or the use of mockups. The inspector must be familiar with the procedure qualifications and ensure they are met completely and satisfactorily.

Two of the more common procedure qualification approaches are those found in the AWS standard B2.1:1998, and the ASME Boiler and Pressure Vessel Code, Section IX (see Figures 7 and 8). Either may be acceptable but if an ASME Code fabrication is being produced, Section IX is required for procedure qualification.

Too often, once a welding procedure has been qualified, it disappears into the dark corners of some office and is never seen again except during formal audits. While a master list of procedures with current copies should be maintained in an office,

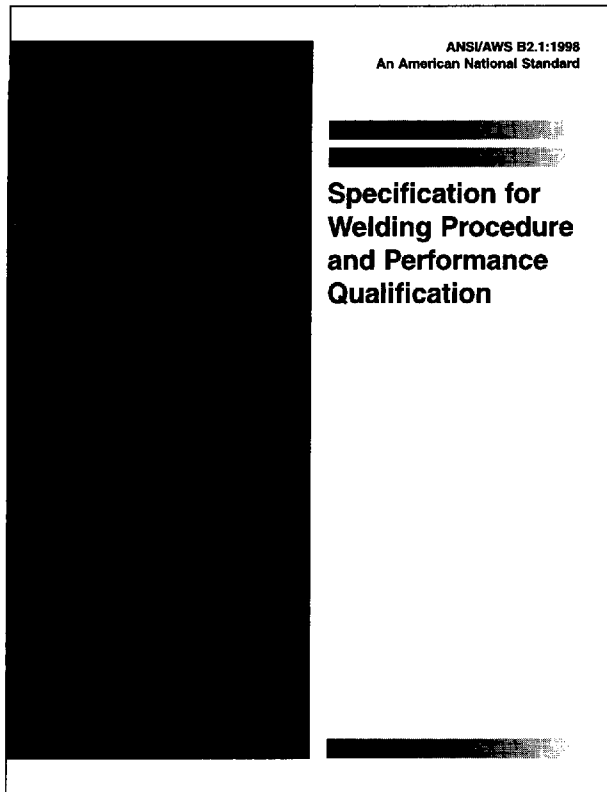


Figure 7. ANSI/AWS B2.1:1998 can be used for welding procedure and personnel qualification.

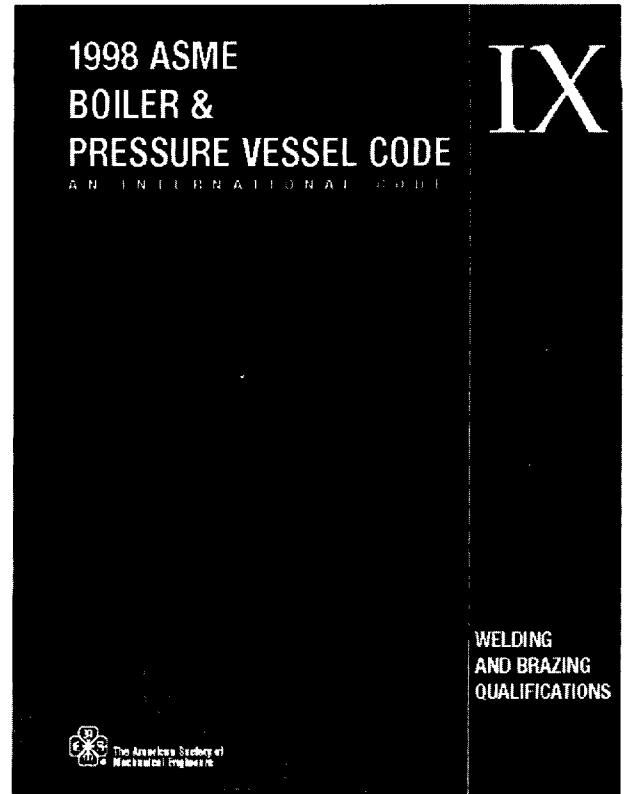


Figure 8. ASME Section IX also covers qualification of procedures and personnel for welding.

copies of those welding procedures should also be placed in binders or protected with plastic covers and made readily available at the shop floor to the welding and inspection personnel. This simple step often eliminates many procedural mistakes during fabrication.

Personnel Qualification

Once the necessary welding procedures have been qualified, the next step is to qualify the welders and welding operators to the applicable code. The inspector has a key role to play in this activity; many codes require the witnessing and documentation of both the welder performance tests and the mechanical testing of the resulting welded test specimens by an inspector. Most codes and other standards cover both the procedure qualification and the welder performance testing.

The inspector should be familiar with the period of validity for the welder to remain qualified; this period is usually noted in the applicable code. Most welder qualifications are valid for a six-month period, meaning that the qualification is valid as long as the welder performs the same welding process to which he or she qualified. If a welder does not perform any documented welding with the qualified welding process in the specified time period, the welder is no longer considered qualified. Some companies adhere strictly to the code qualification requirements; other retest their welders once a year regardless of the code requirements or continuing use of the process. There are several software programs available that aid the tracking of welder qualifications. Central certification of welders is another option that allows a company to maintain records on qualification. Independent third party certifications of welders can provide value by introducing rigorous standardized procedures for