AWS B1.11M/B1.11:2015
An American National Standard

Guide for the Visual Examination of Welds

American Welding Society®

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Guide for the Visual Examination of Welds

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Prepared by the
American Welding Society (AWS) B1 Committee on Methods of Inspection

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This guide contains information to assist in the visual examination of welds. Included are sections on fundamentals, surface conditions, and equipment. Sketches and full-color photographs illustrate weld discontinuities commonly found in welds.

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Foreword

This foreword is not part of AWS B1.11M/B1.11:2015, *Guide for the Visual Examination of Welds*, but is included for informational purposes only.

Visual examination (VT), as used in this guide, is a nondestructive method whereby a weldment, the related base metal, and particular phases of welding may be evaluated in accordance with applicable requirements. All visual examination methods require the use of eyesight to evaluate the conditions which are present; hence, the term *visual* examination.

The use of gauges and other tools is supplemental to the main method, and these are treated only as adjuncts to visual examination of weldments.

The *Guide for the Visual Examination of Welds* has been prepared by the AWS B1 Committee on Methods of Inspection to serve as a simple tutorial source of basic information concerning visual examination of welds. It is not the intent of this document to present the *only* approved methods for conducting visual examination. Some typical standards are listed in this document. It is intended that the material presented be useful to engineers, designers, educators, inspectors, and other welding personnel who need knowledge about basic visual examination attributes, which would be essential, or desirable, for a particular process. Included in this guide are fundamental prerequisites for performing visual examination, steps in performing visual examination at various stages of welding, and also typical examples of visual examination, discontinuities and conditions, equipment supplements and aids, records, and other reference sources which may be helpful. Terminology used throughout this guide has been established in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.

This guide is intended as an instructive reference. The codes or specifications applicable to any particular weldment always take precedence over the generalized material contained herein, should any conflict arise between the two. The text has been written in general terms and does not include all the conditions applicable to a specific instance. Examples given are general and are used only for the purpose of illustration.

This material can be used as a training text for inspectors. Although the information generally relates to the arc welding processes, most of it applies to weldments fabricated by other fusion welding processes, for which these methods may be required.

For the examination of resistance welded assemblies, refer to AWS C1.1M/C1.1, *Recommended Practices for Resistance Welding*, AWS C1.3, *Recommended Practices for Resistance Welding Coated Low Carbon Steels*, and AWS D8.7, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, published by the American Welding Society.

For the examination of brazed assemblies, refer to the *Brazing Handbook*, also published by the American Welding Society.

For those who need more detailed information than this guide provides, bibliographies or complete books on the subjects covered in each chapter may be found in good technical libraries. The many specifications and codes that are listed, and have been used as illustrative examples, may also be consulted for more detailed information.

Basic information on other nondestructive examination methods is contained in AWS B1.10M/B1.10, *Guide for Nondestructive Examination of Welds*, and in the *Welding Inspection Handbook*.

All revisions to the 2000 edition are identified by a vertical line in the margin next to the text.

Comments and inquiries concerning this standard are welcome. They should be sent to the Secretary, AWS B1 Committee on Methods of Inspection, American Welding Society, 8669 NW 36 St, # 130 Miami, FL 33166.

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Guide for the Visual Examination of Welds

1. General

1.1 Application. Information contained in this guide applies to the visual examination of weldments. This document is intended for those individuals that examine welds before, during, or after the weld is completed. Welders, examiners, engineers, supervisors, etc., that routinely examine welds will benefit from the information contained in this guide.

The individual examining the welds should be familiar with the principles and methods of visual examination. The qualification and certification of individuals may be required by the applicable welding standard or as a legal requirement stipulated by municipal, state, or federal statute. Current or past certification in accordance with AWS QC1, *Standard for AWS Certification of Welding Inspectors*, may be acceptable where an alternate certification scheme is not required.

Welding should not be initiated before the visual acceptance criteria are clearly defined. Clearly defined visual acceptance criteria will enable the visual examination to be effective and ensure the weldment is completed in accordance with the approved contract documents.

1.2 Scope. This guide essentially provides an introduction to visual examination of welding. These examinations fall into three categories based on the time they are performed, as follows: (1) prior to welding, (2) during welding, and (3) after welding. An extensive treatment is provided on weld surface conditions, including reference to frequently used terminologies associated with *preferred* and *non-preferred* conditions. Visual examination may be performed by different people or organizations. Personnel performing welding examination include welders, welding supervisors, the contractor's welding examiner, the purchaser's examiner, or the regulatory examiner. For the purpose of simplicity, these individuals are referred to as visual examiners in the remainder of this standard in that they perform visual examination. Fabrication documents, contract specifications, and regulatory agencies may specify who performs final examinations.

Also provided is a review of visual examination equipment routinely used, such as gauges and lighting equipment. Formal documentation of visual examination results is also discussed. Finally, the guide suggests additional reading or references, that may provide more detailed requirements for specific visual examination applications.

AWS A3.0M/A3.0 uses nondestructive examination (NDE) as the standard terminology for these examination methods. In other standards, literature, and industry usage, other expressions are commonly used. Among these are: nondestructive inspection (NDI) and nondestructive testing (NDT). It must be emphasized that all of these expressions are commonly used and may be considered equivalent.

1.2.1 Unit of Measurement. This standard makes use of both the International System of Units (SI) and U.S Customary Units. The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety and Health. Safety and health issues and concerns are beyond the scope of this standard and therefore are not addressed herein. Safety and health information is available from the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

U.S. Department of Labor Regulations:

CFR-29, Part 1910.107, *Spray Finishing using Flammable and Combustible Liquids*

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

2. Normative References

The standards listed below contain provisions which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS Documents:[1]

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

3. Qualification of Examination Personnel

3.1 General. Individuals assigned the task of performing formal visual examinations should be qualified. The three elements of qualification may include education, training, and experience. Since visual examination requires the ability to see small discontinuities or imperfections, good visual acuity is also desirable.

3.2 Visual Acuity. The individual should have sufficient visual acuity to perform an adequate examination. Consideration should be given to sufficient near and far vision with natural or corrected vision. A documented periodic visual acuity examination is a requirement of many codes and specifications, and is generally considered good practice.

3.3 Equipment. Visual examination may require the use of special tools or equipment. The tools or equipment depend upon the application and the degree of accuracy required. Some tools may need to be calibrated prior to use. Although this guide presents an outline of visual examination aids, there are many different concepts and other variations of equipment. As a general rule, those tools should be used that: (1) comply with the project requirements, (2) are adequate for the intended accuracy, and (3) satisfy the need of the examination.

3.4 Experience and Training. The visual examiner should have sufficient knowledge and skill to perform the examination successfully and meaningfully. Knowledge and skill can be imparted or obtained through the educational and training processes. Either method can be performed in a classroom or on the job. The variety of methods and processes of imparting or obtaining knowledge and skill are many, but the art of good judgment does not always come easily or readily. Sufficient time should be allowed for individuals to properly grasp key points pertaining to the following: (1) joint preparation, (2) welding preheat, (3) interpass temperature, (4) weldment distortion, (5) welding consumables, (6) base materials, and (7) workmanship standards.

[1] AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

3.5 Procedures. Development of standard or specialized procedures covering examination methodology and acceptance criteria produces consistent and accurate results. Such procedures are normally prepared by the employer and typically consist of detailed instructions that interrelate the various fabrication processes, the customer's detailed requirements, and examination criteria. Items such as *who* performs an examination, *when* to perform an examination, *how* to perform an examination, and *where* to perform an examination are typically included in the procedure. As a minimum the standard procedures should include the following: workmanship standards, check lists, and examination equipment requirements.

When written procedures are not available, examiners may be asked to work directly with relevant codes and specifications.

3.6 Certification Programs. To provide assurance that visual examiners are qualified it may be desirable to have visual examination personnel formally certified. Contract documents, fabrication standards, or regulatory agencies may require special qualifications for visual examiners. Several standards developers offer certification programs for visual examiners such as AWS QC1, *Standard for Certification of Welding Inspectors*.

4. Fundamentals of Visual Examination

4.1 General. Visual examination reveals surface discontinuities and is a valuable method for evaluating weld quality. It is a simple, accessible, low cost examination method, but it requires a trained examiner. Additionally, it can be an excellent process control tool to help avoid subsequent fabrication problems and improve workmanship.

Visual examination only identifies surface discontinuities. Consequently, any conscientious quality control program should include a sequence of examinations performed during all phases of fabrication. An examination plan should establish hold/witness points that allow for visual examination prior to subsequent operations.

A conscientious program of visual examination before and during welding may reduce costs by revealing surface defects early in the fabrication process.

4.2 Prior to Welding. Prior to welding, some typical action items requiring attention by the visual examiner should include the following:

(1) Review drawings and specifications

(2) Review material documentation

(3) Review procedure and performance qualifications

(4) Establish examination points if required

(5) Establish documentation plan

(6) Examine base material

(7) Examine fitup and alignment of joints

(8) Review storage of welding consumables

If the examiner pays particular attention to these preliminary items, many problems that might occur later can be prevented. It is important that the examiner review the governing documents to determine the job requirements. A system should be established to assure that accurate and complete records are produced. Users of this standard are encouraged to reference AWS D14.8M (ISO/TR 17844:2004 IDT), *Standard Methods for Avoidance of Cold Cracks*, as a means to prevent or correct conditions that contribute to weld cracking.

4.2.1 Review Drawings and Specifications. The examiner should either have copies of the drawings and specifications, or have access to them, and should review them periodically. Information to be gained, but not limited to, includes: weld details, material requirements, examination requirements, dimensions, and qualification requirements.

4.2.2 Review Material Documentation. The examiner should verify that the correct materials were ordered, received, and used during fabrication.

4.2.3 Review Procedure and Performance Qualifications. The examiner should review welding procedures and welder qualification records to assure the qualifications meet the requirements of the job specification.

4.2.4 Establish Examination Points. The examination plan should consider the sequence of construction and determine whether there is a need to establish examination points to ensure suitable access for examination is provided. A mandatory examination point permits work that may be concealed by subsequent work to be examined and accepted before additional manufacturing operations are resumed.

4.2.5 Establish Documentation Plan. The examiner should review the reporting requirements to establish what is to be reported and who will receive copies of the examination reports. It may also be beneficial to establish a means of marking the workpiece examined in order to identify defects and the need for repair. More serious quality problems such as cracking or excessively poor workmanship should be reported to the appropriate parties. The documentation will indicate the examination status.

4.2.6 Examine Base Materials. Prior to welding, the base materials should be examined for unacceptable discontinuities such as laminations, seams, laps, cracks, and other surface conditions that would prevent proper welding. The surfaces of cut edges, groove preparations, access holes, etc., should be evaluated using a surface roughness comparator such as the AWS C4.1 Surface Roughness Gauge as a guide.

4.2.7 Examine Fit-Up and Alignment of Joints. Joint fit-up and alignment are critical to the production of a sound weld. Items that may be considered prior to welding include:

(1) Groove angle

(2) Bevel depth

(3) Root opening

(4) Joint alignment and weld joint mismatch (see Figure 1)

(5) Backing

(6) Consumable insert

(7) Joint cleanliness

(8) Tack welds

(9) Preheat

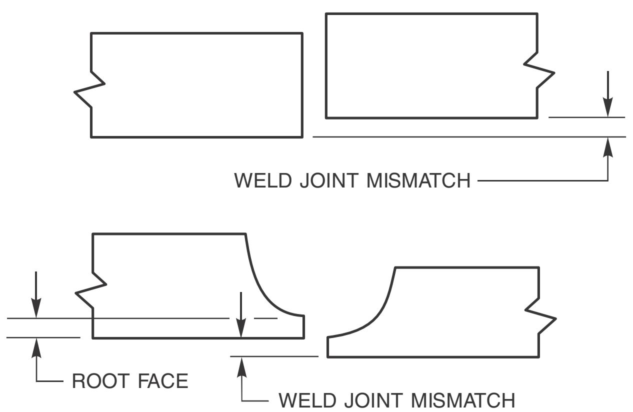

Figure 1—Weld Joint Mismatch

All of these factors could have a direct bearing on the resultant weld quality. If the fit-up is poor, it should be corrected before being tack welded. Extra care taken during the joint assembly can greatly improve the efficiency of the welding operation. Examination of the joint prior to welding can reveal irregularities that are within the limitation of the applicable standard, but may become areas of concern and require careful observation during subsequent operations. For example, if a T-joint exhibits the maximum root opening, the size of the required fillet weld may have to be increased by an amount equal to the measured root opening. Conditions such as an excessive root opening can be discovered only when a fit-up examination is performed before the joint is welded. The drawing or member should be marked indicating the problem so that the corrected weld size is verified during the final examination.

4.2.8 Review Storage of Welding Consumables. Welding consumables should be checked to ensure they are appropriate for the work and are as specified by the welding procedure specification. The procurement, storage, and handling of filler metals is crucial to producing welds that meet the mechanical properties and soundness requirements of the welding standard. Filler metals should be stored in a manner prescribed by the manufacturer and applicable welding standard.

Electrode manufacturers have established maximum atmospheric exposure limits for low-hydrogen electrodes. This is the maximum amount of time a low-hydrogen electrode can be out of heated storage before reconditioning is required. These limits have been incorporated into many welding codes. Exposure times start when the electrodes are removed from the electrode storage oven, portable storage oven, or their original, hermetically-sealed containers.

Filler metals should be checked during fabrication to ensure the welder is using the filler metal specified.

Filler metal control also includes the disposal of used or damaged filler metal in a manner that will ensure they are not used for production.

4.3 During Welding. During welding, some typical action items requiring attention by those responsible for weld quality should include the following:

(1) Verify conformance to Welding Procedure Specification (WPS),

(2) Verify preheat and interpass temperatures,

(3) Examine root bead,

(4) Examine weld layers, and

(5) Examine second side prior to welding.

Any of these factors, if ignored, could result in discontinuities that could cause serious quality degradation.

4.3.1 Verify Conformance with Welding Procedure Specification. Monitor the welding operation to ensure compliance with the applicable WPS. The specific welding variables to be verified will depend on the welding process and the WPS. However, they would typically include factors such as the consumable classification, joint design, electrical characteristics, and welding techniques.

4.3.2 Verify Preheat and Interpass Temperatures. When the temperature of the material is below a specified temperature, supplemental preheat may be required by the applicable welding standard or WPS. The goal is to heat the base metal to or above the minimum temperature specified. Preheat should be verified before any welding is begun.

Not all metals require preheat, but when preheat is specified by the welding standard, the location of the temperature measurement is usually specified. In the absence of a welding standard, preheat may be measured at a distance equal to the thickness of the thicker member from the edge of the joint to be welded. Preheat requirements may specify that the preheat extend through the thickness of the members being welded. If that is the case, the preheat temperature should also be verified on both the root and the face sides of the joint.

Some applications impose a maximum interpass temperature to ensure welding does not continue if a specified maximum temperature is exceeded. A cooling period is observed if the temperature approaches or exceeds the maximum specified interpass temperature.

Interpass temperature should be checked immediately before a weld bead is initiated when making a multi-pass weld. The applicable welding standard may specify that the interpass temperature be measured adjacent to the location where the next weld pass is to be initiated.

There are several temperature measuring tools used to measure preheat and interpass temperatures. Temperature sensitive crayons, contact thermometers, pyrometers, thermocouples, infrared thermometers, etc., are typically used to monitor preheat and interpass temperatures.

4.3.3 Examine Weld Root Bead. The first weld deposited in a multiple pass weld, called the root bead, is susceptible to a number of weld discontinuities such as cracks, incomplete fusion, incomplete joint penetration, etc. A thorough visual examination of the root bead can detect many unacceptable conditions that should be corrected before depositing additional weld metal.

4.3.4 Examine Intermediate Weld Beads. Examine intermediate weld beads as work progresses to ensure the weld beads are free of unacceptable conditions or discontinuities such as cracks, undercut, incomplete fusion, slag or oxides, etc., which if left uncorrected can result in unacceptable welds.

4.3.5 Examine Second Side Prior to Welding. Critical joint root conditions may exist on the second side of a double welded joint. This area should be examined after removal of slag and other irregularities. This is to assure that all discontinuities have been removed and that the contour and cleanliness of the excavation are suitable for subsequent welding.

4.4 After Welding. Following welding, some typical action items requiring attention by the visual examiner should include the following:

(1) Examine weld surface quality

(2) Verify weld dimensions

(3) Verify dimensional accuracy

(4) Review subsequent requirements

4.4.1 Examine Weld Surface Quality. Visually examine weld surface to verify the weld profile meets the acceptance criteria specified by the contract documents. Workmanship standards may address such items as surface roughness, weld spatter, and arc strikes. Most codes and specifications describe the type and size of discontinuities that are acceptable. Many of these discontinuities can be found by visual examination of the completed weld. The following are typical discontinuities found at the surface of welds:

(1) Porosity

(2) Incomplete fusion

(3) Incomplete joint penetration

(4) Undercut

(5) Underfill

(6) Overlap

(7) Cracks

(8) Metallic and nonmetallic inclusions

(9) Reinforcement

(10) Weld bead profile

(11) Root oxidation

4.4.2 Verify Weld Dimensions. All completed welds should be visually examined to verify the weld meets the drawing requirements for profile, size, length, and location. Fillet weld sizes can be determined by using one of several types of weld gauges to be discussed later. Groove welds should be filled to the full cross section of the joint, or as specified, and the weld reinforcement should not be excessive. Some conditions may require the use of special weld gauges to verify these dimensions.

4.4.3 Verify Dimensional Accuracy. Final examination of a fabricated weldment should verify that the dimensions are in accordance with the drawing.

4.4.4 Review Subsequent Requirements. Review the specification to determine if additional procedures are required. Such procedures may include postweld heat treatment, nondestructive testing, proof testing, or other operations.

5. Weld Surface Conditions

5.1 General. This clause is concerned only with discontinuities, which may or may not be classed as defects (rejectable) depending on requirements of individual specifications or codes. The intent is informational and instructional, and meant to assist in the identification of discontinuities. Discontinuities can occur at any location in the weld. Visual examination after welding is limited to the surface condition of the weld. Discovery of subsurface discontinuities requires the visual examination be supplemented by a volumetric nondestructive test method such as ultrasonic or radiographic examination.

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. Discontinuities are rejectable only if they exceed specification requirements in terms of type, size, distribution, or location. A defect is a discontinuity or discontinuities that by nature or accumulated effect (for example, total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. The term *defect* designates rejectability.

Weld and base-metal discontinuities of specific types are more common when certain welding processes and joint details are used. Attendant conditions, such as high restraint and limited access to portions of a weld joint, may lead to a higher than normal incidence of weld or base-metal discontinuities. For example, highly restrained weld joints are more prone to cracking.

Each general type of discontinuity is discussed in detail in this clause (see also Table 1 and Figures 2 through 7). Other documents may use different terminology for some of these discontinuities; however, whenever possible, the approved AWS terminology, as found in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, should be used to eliminate confusion. An example of additional terminology occurs in AWS D1.1/D1.1M, *Structural Welding Code—Steel*. There, *fusion-type discontinuity* is a general term which is used to describe a number of discontinuities, including: slag inclusions, incomplete fusion, incomplete joint penetration, and similar elongated discontinuities in fusion welds.

5.2 Porosity [see Table 1(1)].[2] Porosity is a cavity-type discontinuity formed by gas entrapment during solidification or in a thermal-spray deposit. The discontinuity formed is generally spherical and may be elongated. Two common causes of porosity are contamination and insufficient shielding during welding.

[2] The numbers in parenthesis in 5.2–5.13 refer to numbers in Table 1 and Figures 2–7.

Table 1
Common Types of Discontinuities

Type of Discontinuity	Subclause	Location	Remarks
(1) Porosity	5.2	WMZ	Porosity could also be found in the BM and HAZ if the base metal is a casting.
(a) Scattered	5.2.1		
(b) Cluster	5.2.2		
(c) Piping	5.2.3		
(d) Aligned	5.2.4		
(e) Elongated	5.2.5		
(2) Inclusion	5.11	WMZ, WI	
(a) Slag			
(b) Tungsten			
(3) Incomplete fusion	5.3	WMZ/WI	Fusion face or between adjoining weld beads.
(4) Incomplete joint penetration	5.4	BMZ	Weld root in a groove weld.
(5) Undercut	5.5	WI/HAZ	Adjacent to weld toe or weld root in base metal.
(6) Underfill	5.6	WMZ	Weld face or root surface of a groove weld.
(7) Overlap	5.7	WMZ	Weld toe or root surface.
(8) Lamination	5.8	BMZ	Base metal, generally located near midthickness of hot rolled members.
(9) Delamination	5.8	BMZ	Base metal, generally located near midthickness of hot rolled members.
(10) Seam and lap	5.9	BMZ	Base metal, surface generally aligned with rolling direction.
(11) Lamellar tear	N/A	BMZ	Base metal.
(12) Crack (includes hot cracks and cold cracks described in text)	5.10		
(a) Longitudinal	5.10.1	WMZ, HAZ, BMZ	Weld metal or base metal adjacent to WI.
(b) Transverse	5.10.1	WMZ, HAZ, BMZ	Weld metal (may propagate into HAZ and base metal).
(c) Throat	5.10.2.1	WMZ	Parallel to weld axis. Through the throat of a fillet weld.
(d) Face & Root	5.10.2.2	WMZ, WI	Face or root surfaces.
(e) Crater	5.10.2.3	WMZ	Weld metal at point where arc is terminated.
(f) Toe	5.10.2.4	WI, HAZ	Parallel to weld axis.
(g) Underbead and HAZ	5.10.2.5	HAZ	HAZ (may propagate into base metal).
(13) Concavity	5.13	WMZ	Weld face of a fillet weld.
(14) Convexity	5.13	WMZ	Weld face of a fillet weld.
(15) Weld reinforcement	5.12	WMZ	Weld face or root surface of a groove weld.

Legend:
WMZ—weld metal zone
BMZ—base metal zone
HAZ—heat-affected zone
WI—weld interface

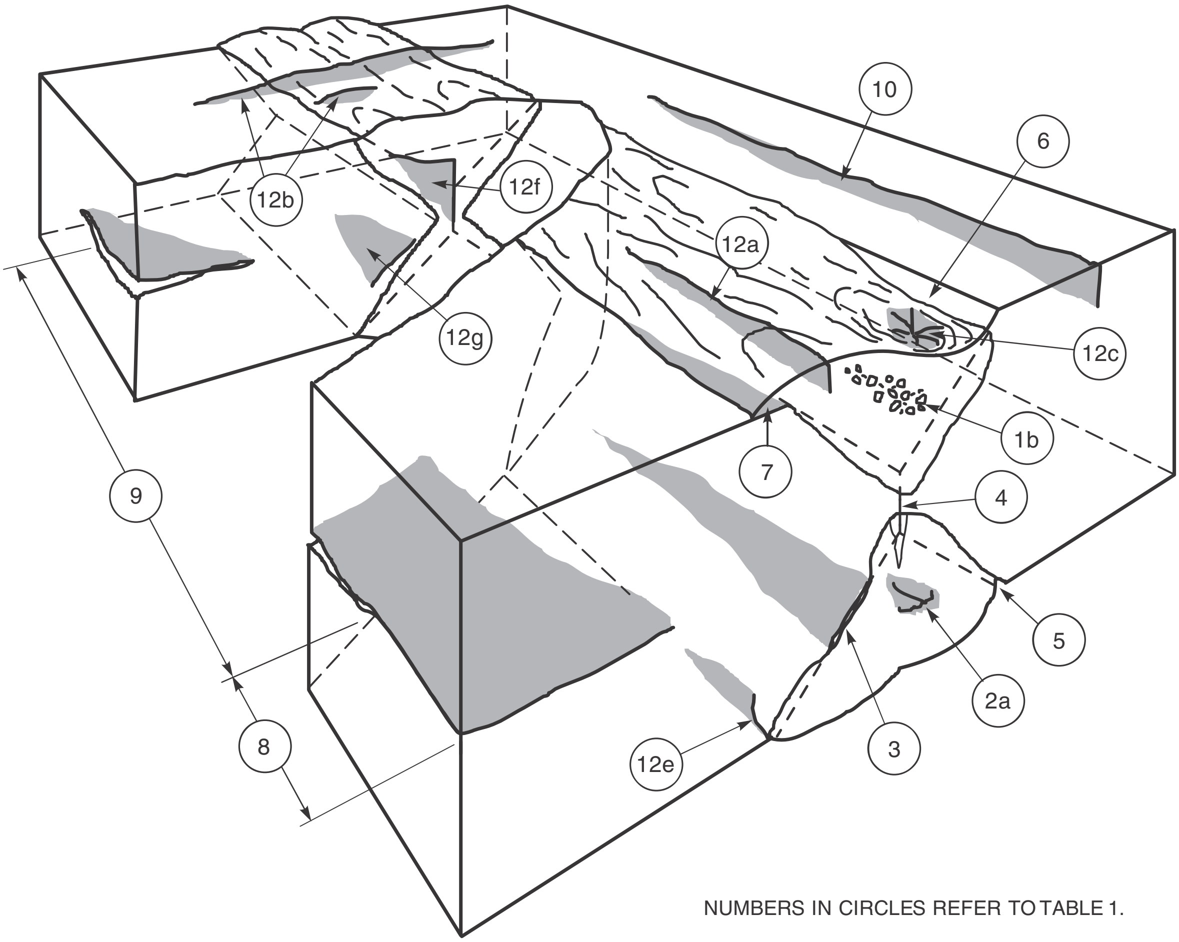

Figure 2—Double-V-Groove Weld in Butt Joint

Generally, porosity is not considered to be as detrimental as other discontinuities, due to its shape, since it doesn't result in the creation of a severe stress concentration. Porosity is an indication that the welding parameters, welding consumables, or joint fit-up were not properly controlled for the welding process selected or that the base metal is contaminated or of a composition incompatible with the weld filler metal being used.

Porosity is an indicator regarding the apparent quality of a weld, without being considered a severe discontinuity. Important information regarding the cause of the problem is provided by describing both the shape and orientation of individual pores or the geometric array of adjacent pores.

An example of this utility is the distinction between elongated porosity and piping porosity. Both have lengths greater than their width, but they differ because of their orientation with respect to the weld axis. They also differ in terms of how they were caused.

Providing this additional detail is more information than may be required, but it can be helpful in determining what corrective action is needed.

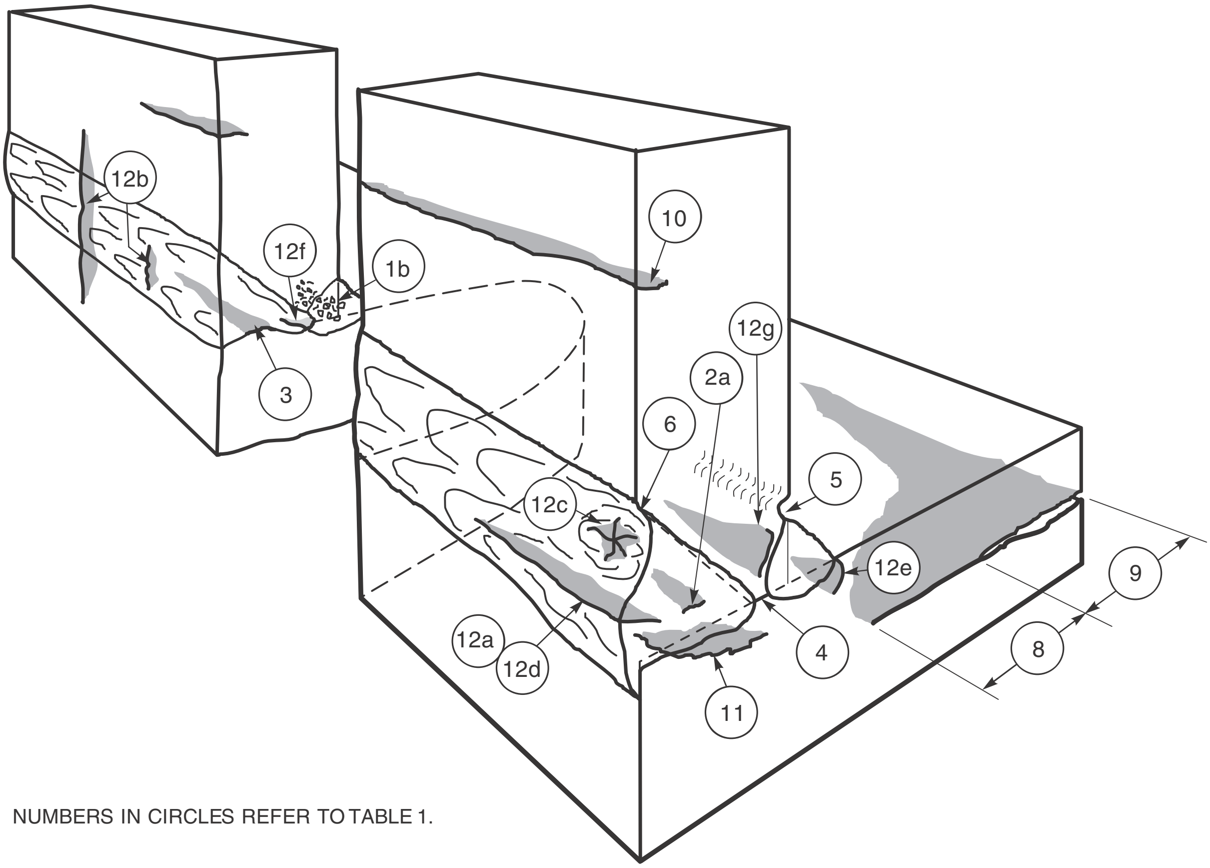

Figure 3—Single-Bevel-Groove and Fillet Welds in Corner Joint

5.2.1 Scattered Porosity [see Table 1(1)(a)]. Figure 8 illustrates scattered porosity which is uniformly distributed throughout the weld metal.

5.2.2 Cluster Porosity [see Table 1(1)(b)]. Cluster porosity is a localized array of porosity having a random geometric distribution.

5.2.3 Piping Porosity [see Table 1(1)(c)]. Figure 9 illustrates piping porosity which is a form of porosity having a length greater than its width that lies approximately perpendicular to the weld face. Piping porosity is also known by the nonstandard term "wormhole porosity."

5.2.4 Aligned Porosity [see Table 1(1)(d)]. Figure 10 illustrates aligned porosity which is a localized array of porosity oriented in a line. The pores may be spherical or elongated. Linear porosity is a nonstandard term when used for aligned porosity.

5.2.5 Elongated Porosity [see Table 1(1)(e)]. Figure 11 illustrates elongated porosity which is a form of porosity having a length greater than its width that lies approximately parallel to the weld axis. It shows elongated porosity formed between the slag and the weld metal surface. Such porosity could also be formed below the surface of the weld metal.

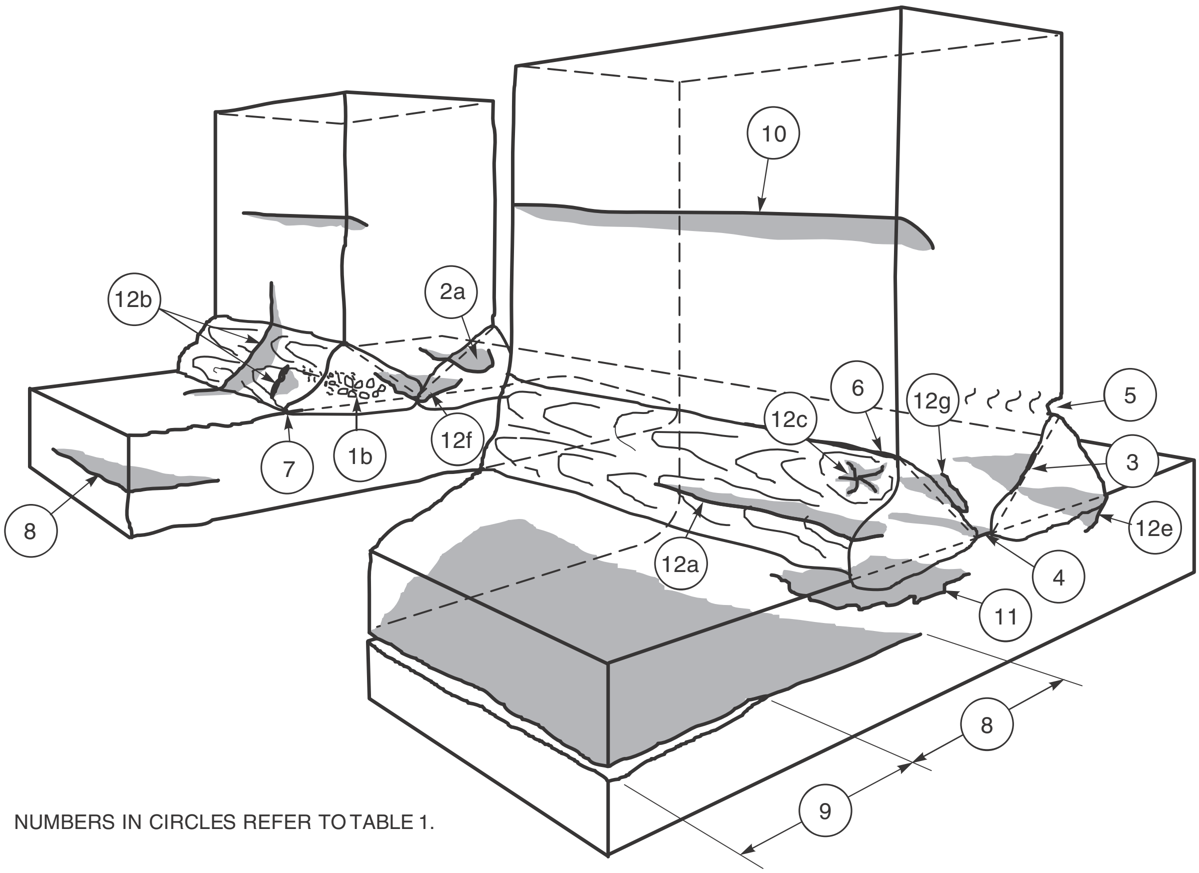

Figure 4—Double-Bevel-Groove Weld in T-Joint

5.3 Incomplete Fusion [see Table 1(3)]. Incomplete fusion is a weld discontinuity in which fusion did not occur between weld metal and fusion faces or adjoining weld beads. Examples of incomplete fusion are shown in Figures 12–16. It is the result of improper welding techniques, improper preparation of the base metal, or improper joint design. Deficiencies causing incomplete fusion include insufficient welding heat or lack of access to all fusion faces, or both. Unless the weld joint is properly cleaned, tightly adhering oxides can interfere with complete fusion, even when there is proper access for welding and proper welding parameters are used.

5.4 Incomplete Joint Penetration [see Table 1(4)]. Incomplete joint penetration is a joint root condition in which weld metal does not extend through the joint thickness. The unpenetrated and unfused area is a discontinuity described as incomplete joint penetration. Examples of incomplete joint penetration are illustrated in Figures 17–19. Incomplete joint penetration may result from insufficient welding heat, improper joint design (e.g., thickness the welding arc cannot penetrate), or improper lateral control of the welding arc.

Some welding processes have much greater penetrating ability than others. For joints welded from both sides, backgouging may be specified before welding the second side to ensure that there is no incomplete joint penetration. Pipe welds are especially vulnerable to this type of discontinuity, since the inside of the pipe is usually inaccessible. Designers may employ a backing ring or consumable inserts to aid welders in such cases. Welds that are required to have complete joint penetration may also be examined by other nondestructive methods in addition to visual examination.

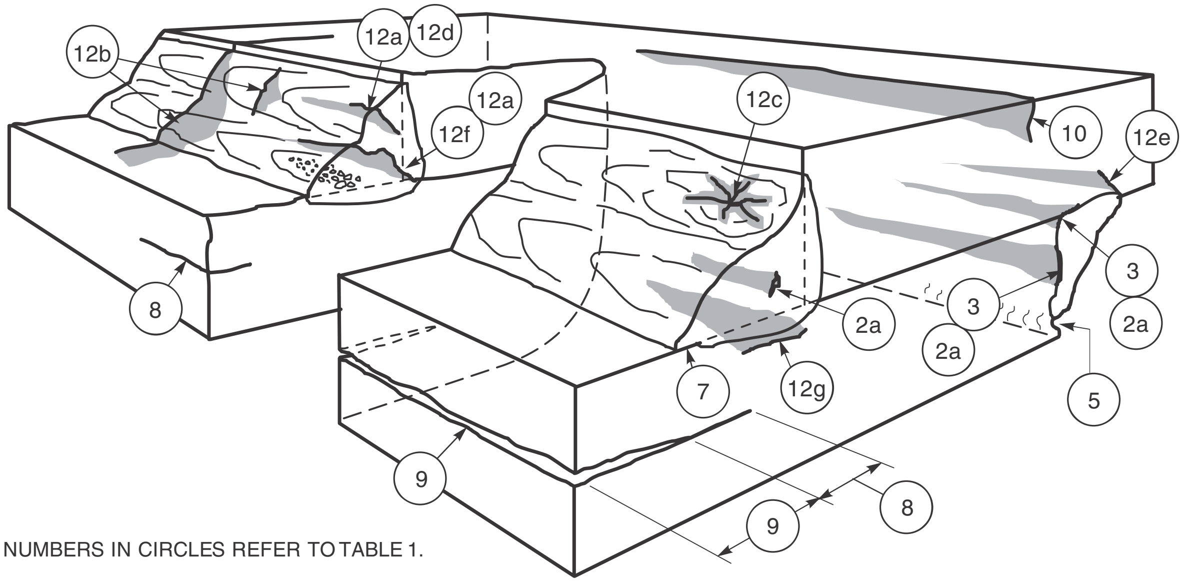

Figure 5—Double Fillet Weld in Lap Joint

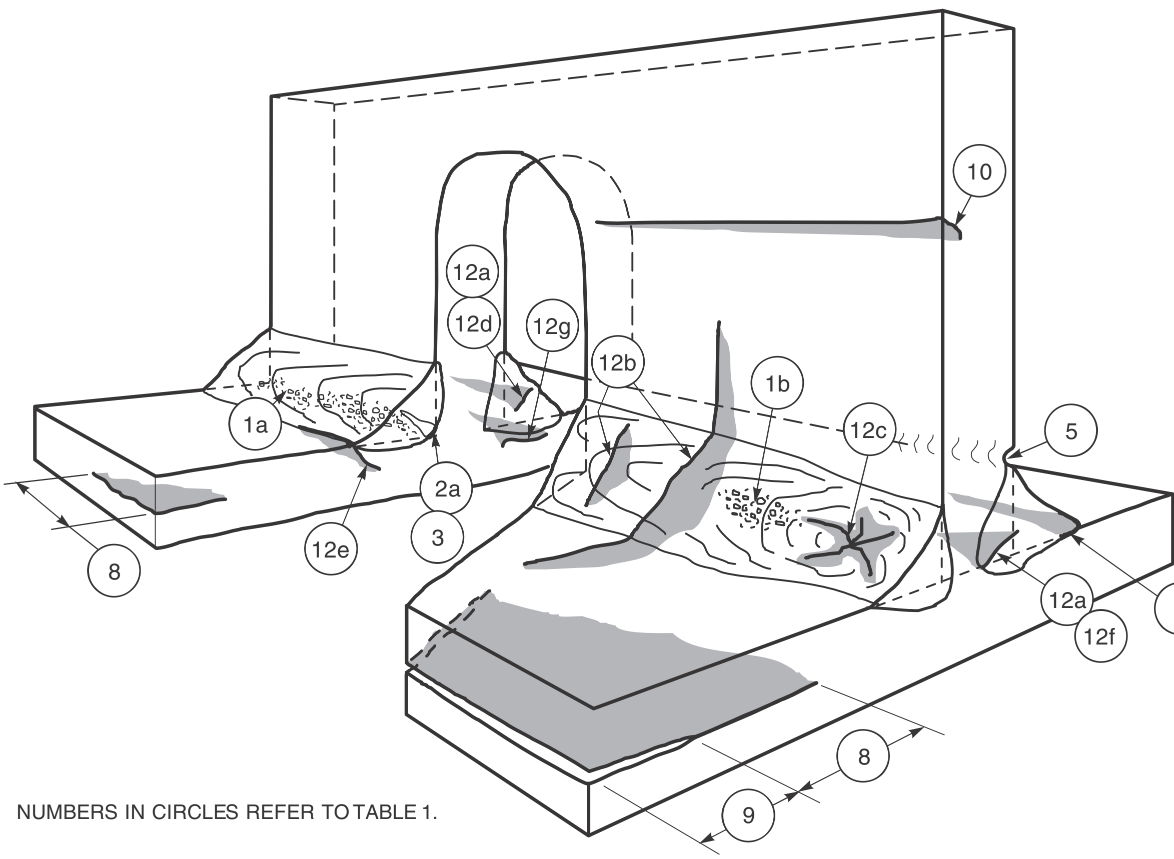

Figure 6—Single Pass Double Fillet Weld in T-Joint

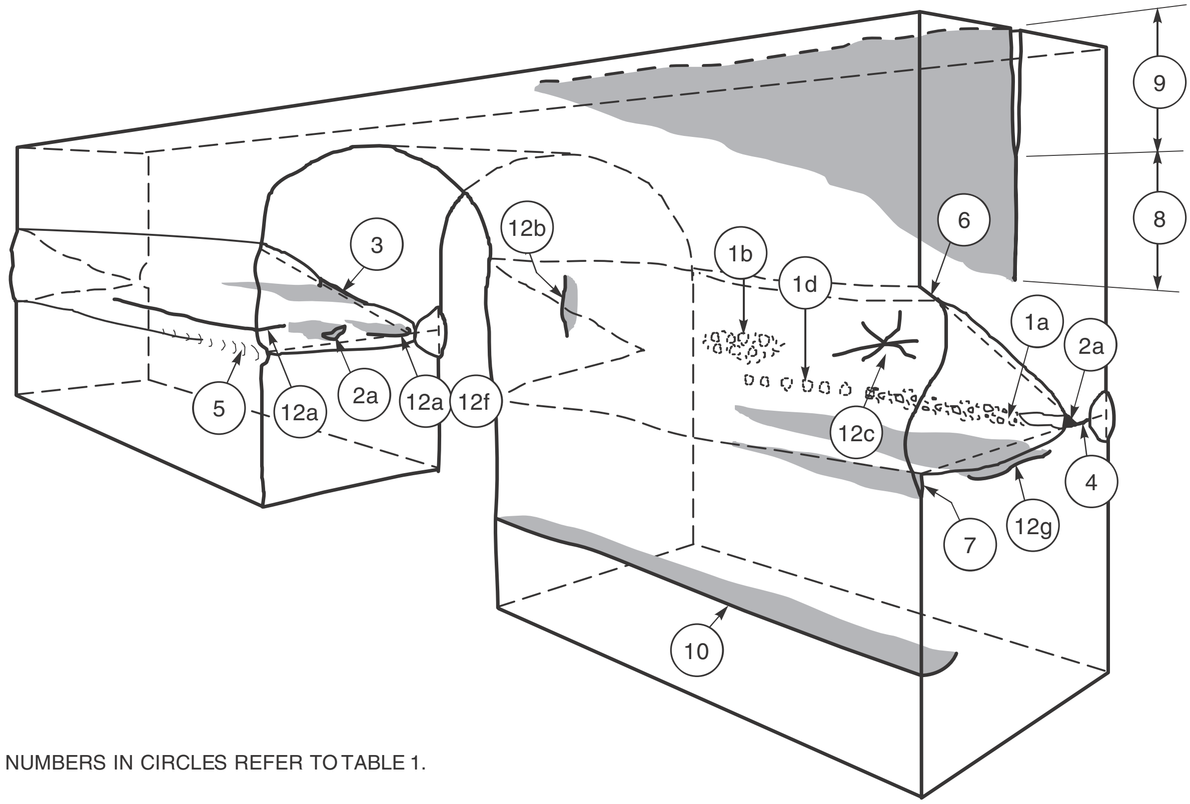

Figure 7—Single-Bevel-Groove Weld in Butt Joint

Figure 8—Scattered Porosity

Figure 9—Surface Appearance of Piping Porosity

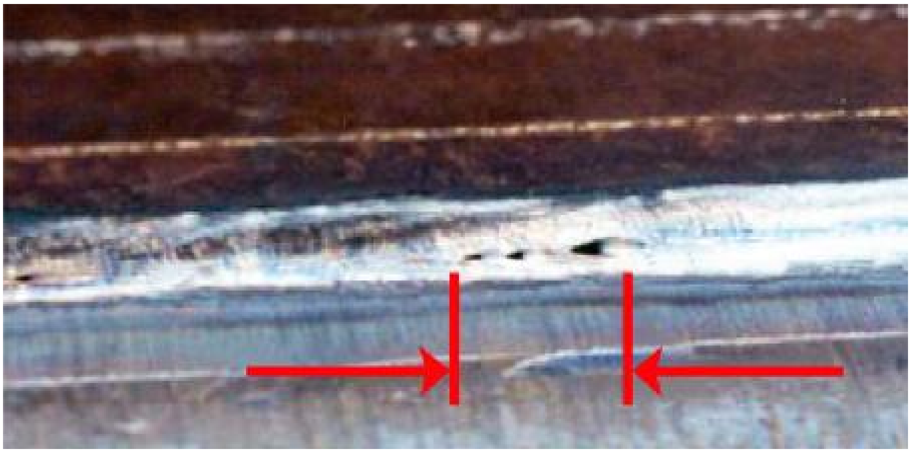

Figure 10—Aligned Porosity

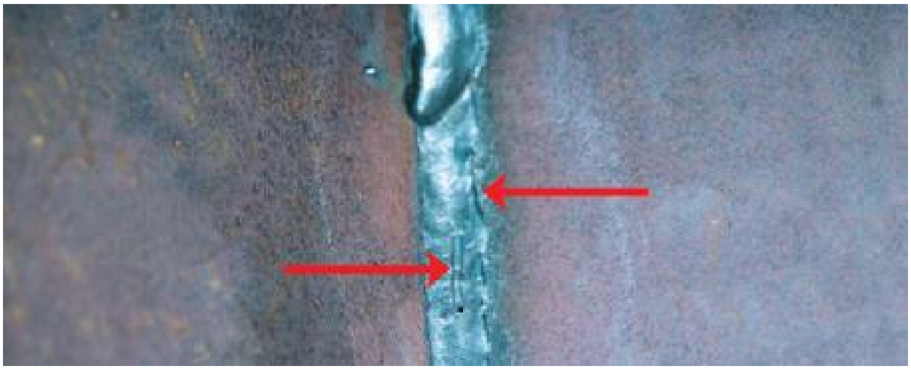

Figure 11—Elongated Porosity

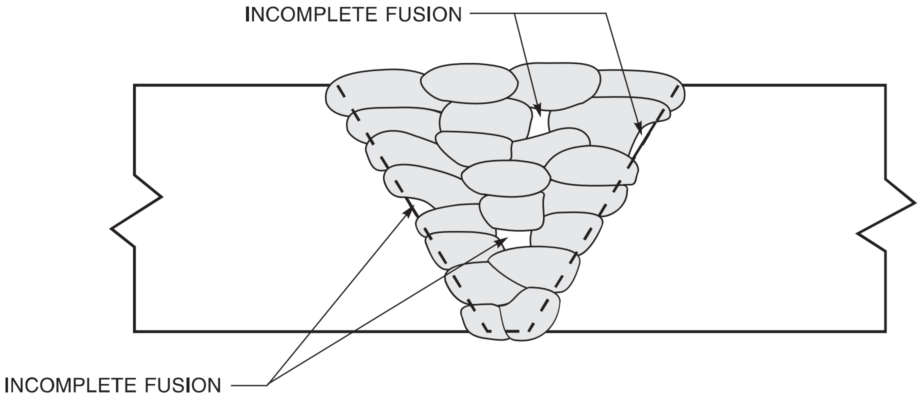

Figure 12—Various Locations of Incomplete Fusion

Note: View of the weld from the root side of an open root groove weld showing complete joint penetration with incomplete fusion. There is a "keyhole" toward the left side of the photograph.

Figure 13—Incomplete Fusion

Figure 14—Incomplete Fusion at the Groove Face

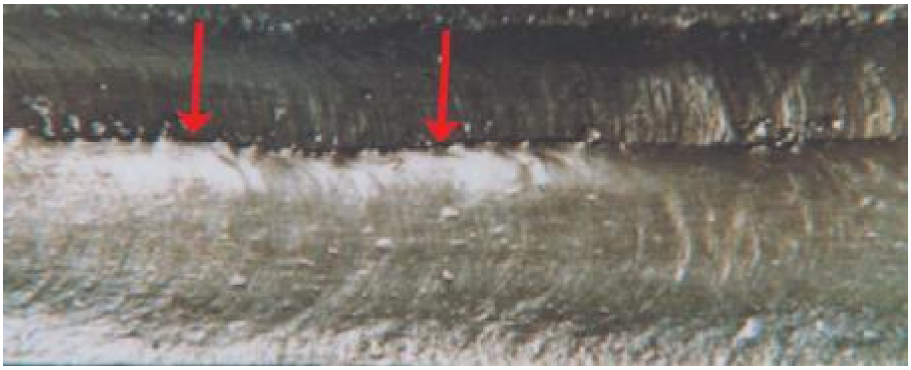

Figure 15—Incomplete Fusion Between Weld Beads

Figure 16—Incomplete Fusion Between the Weld and Base Metal

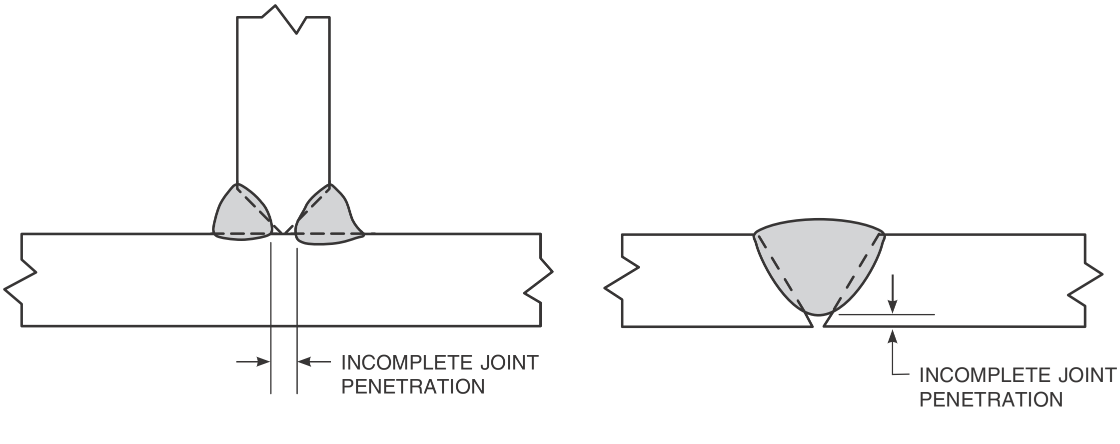

Figure 17—Incomplete Joint Penetration

Figure 18—Incomplete Joint Penetration with Consumable Insert

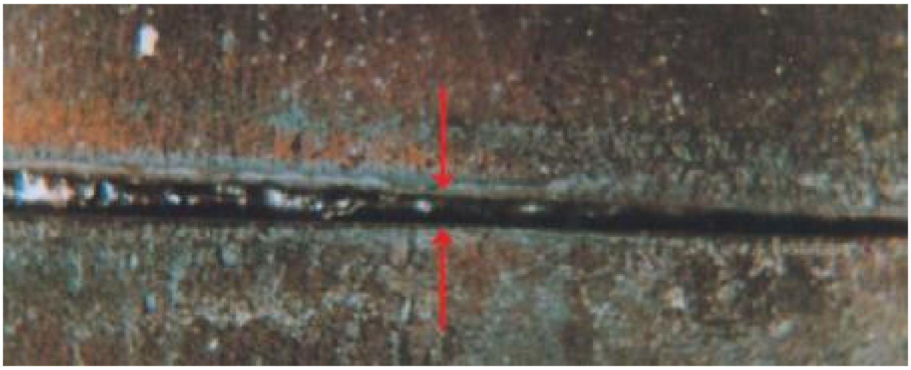

Figure 19—Incomplete Joint Penetration

5.5 Undercut [see Table 1(5)]. Undercut is a groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal. This groove creates a mechanical notch which is a stress concentrator. Examples of undercut are illustrated in Figures 20 and 21. When undercut is controlled within the limits of specifications it is not considered a weld defect. Undercut is generally associated with either improper welding techniques or excessive welding currents, or both.

5.6 Underfill [see Table 1(6)]. Underfill is a condition in which the weld face or root surface of a groove weld extends below the adjacent surface of the base metal. It results from the failure of the welder to completely fill the weld joint. Examples of underfill are illustrated in Figures 22 and 23.

5.7 Overlap [see Table 1(7)]. Overlap is the protrusion of unfused weld metal beyond the weld toe or weld root. Overlap is a surface discontinuity that forms a mechanical notch and is nearly always considered rejectable. Two common causes of overlap may be insufficient travel speed and improper preparation of the base metal. Examples of overlap are illustrated in Figures 24 and 25.

5.8 Lamination [see Table 1(8)]. Lamination is a type of base metal discontinuity with separation or weakness generally aligned parallel to the worked surface of a metal.

Laminations are formed when gas voids, shrinkage cavities, or nonmetallic inclusions in the original ingot, slab, or billet are rolled.

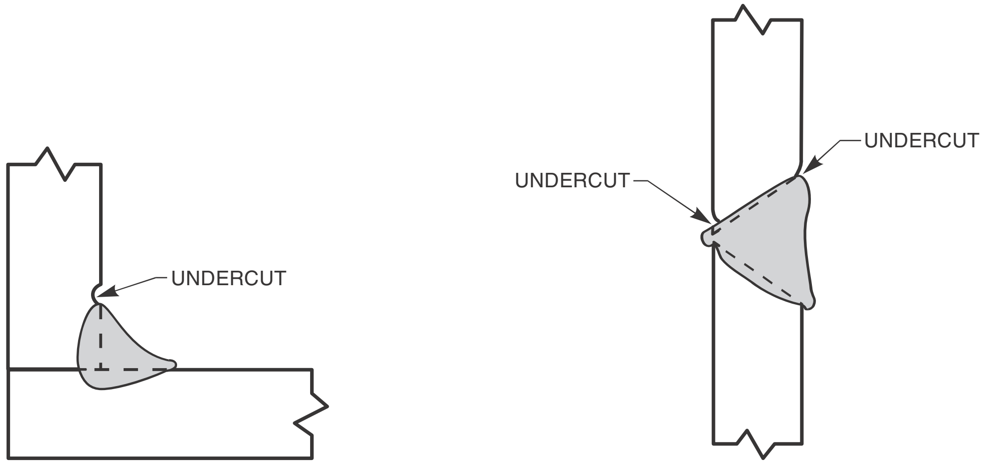

Figure 20—Examples of Undercut

Figure 21—Undercut at Fillet Weld Toe

Laminations may be completely internal and are usually detected nondestructively by ultrasonic examination. They may also extend to an edge or end, where they are visible at the surface and may be detected by visual, liquid penetrant, or magnetic-particle examination. They may be found when cutting or machining exposes internal laminations. A lamination exposed by oxyfuel gas cutting is shown in Figure 26. A delamination is the separation of a lamination under stress.

5.9 Seams and Laps [see Table 1(10)]. Seams and laps are base metal discontinuities that may be found in rolled, drawn, and forged products. They differ from laminations in that they appear on the surface of the worked product. The criticality of seams and laps depend on their orientation, size, and the application of the weldment. While seams and laps are surface discontinuities, they may only be detected after fabrication operations such as bending, rolling, or sand blasting. Welding over seams and laps can cause cracking, porosity, or both.

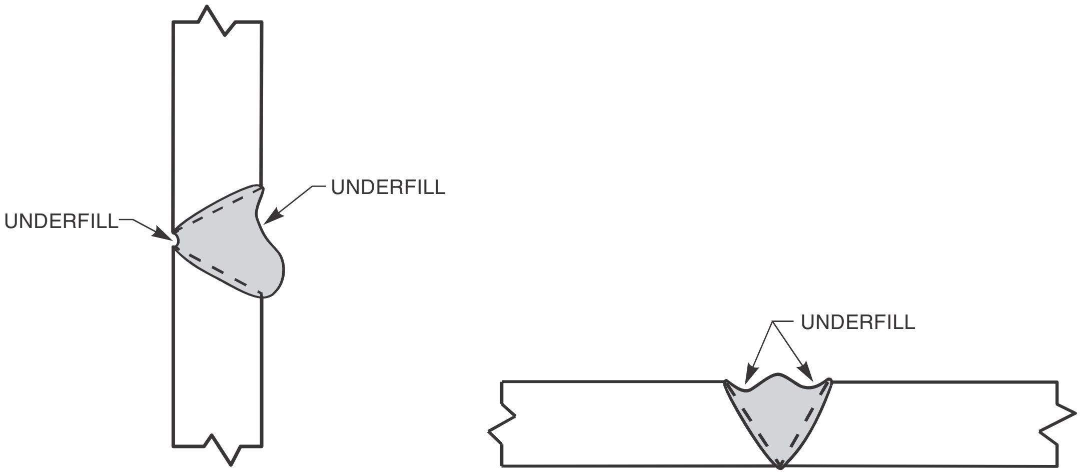

Figure 22—Underfill

Figure 23—Underfill in a Groove Weld Made Using GMAW

5.10 Cracks [see Table 1(12)]. Cracks are defined as fracture-type discontinuities characterized by a sharp tip and high ratio of length and/or width to thickness. They can occur in weld metal, heat-affected zone (HAZ), and base metal.

Cracking often initiates at stress concentrations caused by other discontinuities or near mechanical notches associated with the weldment design. Stresses that cause cracking may be either residual or service-induced. Residual stresses develop as a result of restraint provided by the weld joint and thermal contraction of the weld following solidification. Some crack types are illustrated in Figure 27.

If a crack is found during welding, it should be completely removed prior to additional welding. Welding over a crack rarely eliminates the crack.

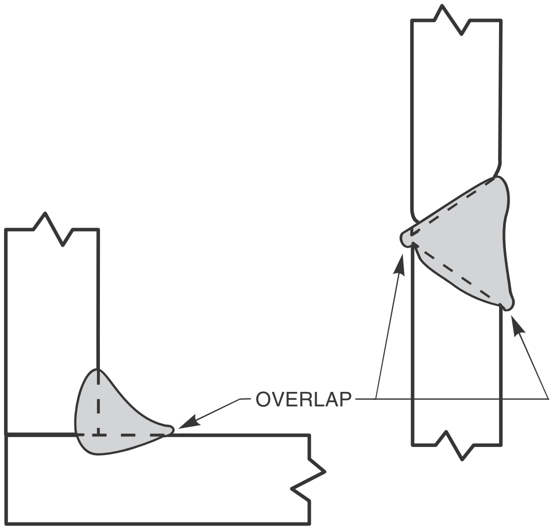

Figure 24—Overlap

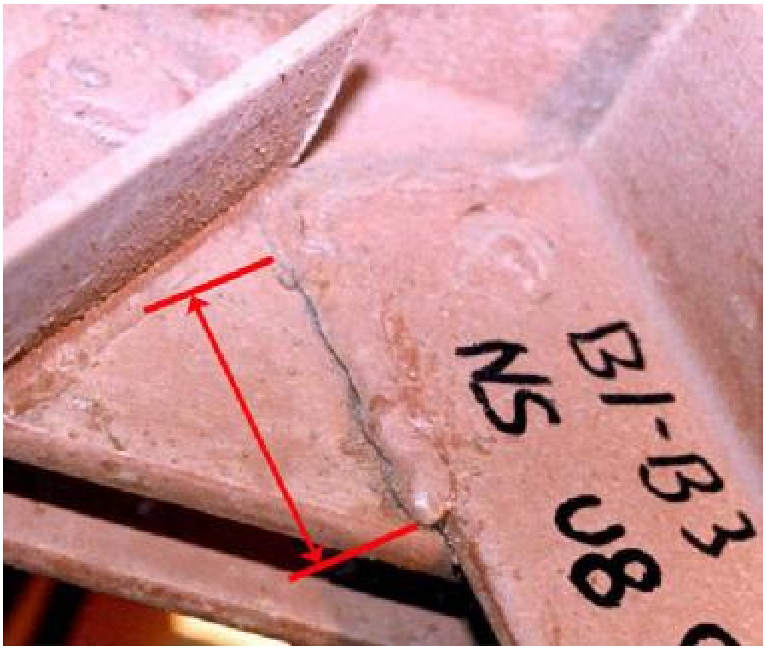

Figure 25—Overlap

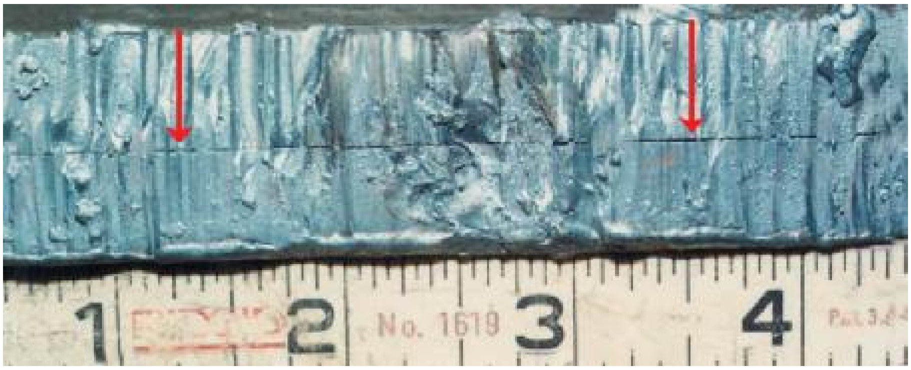

Figure 26—Laminations

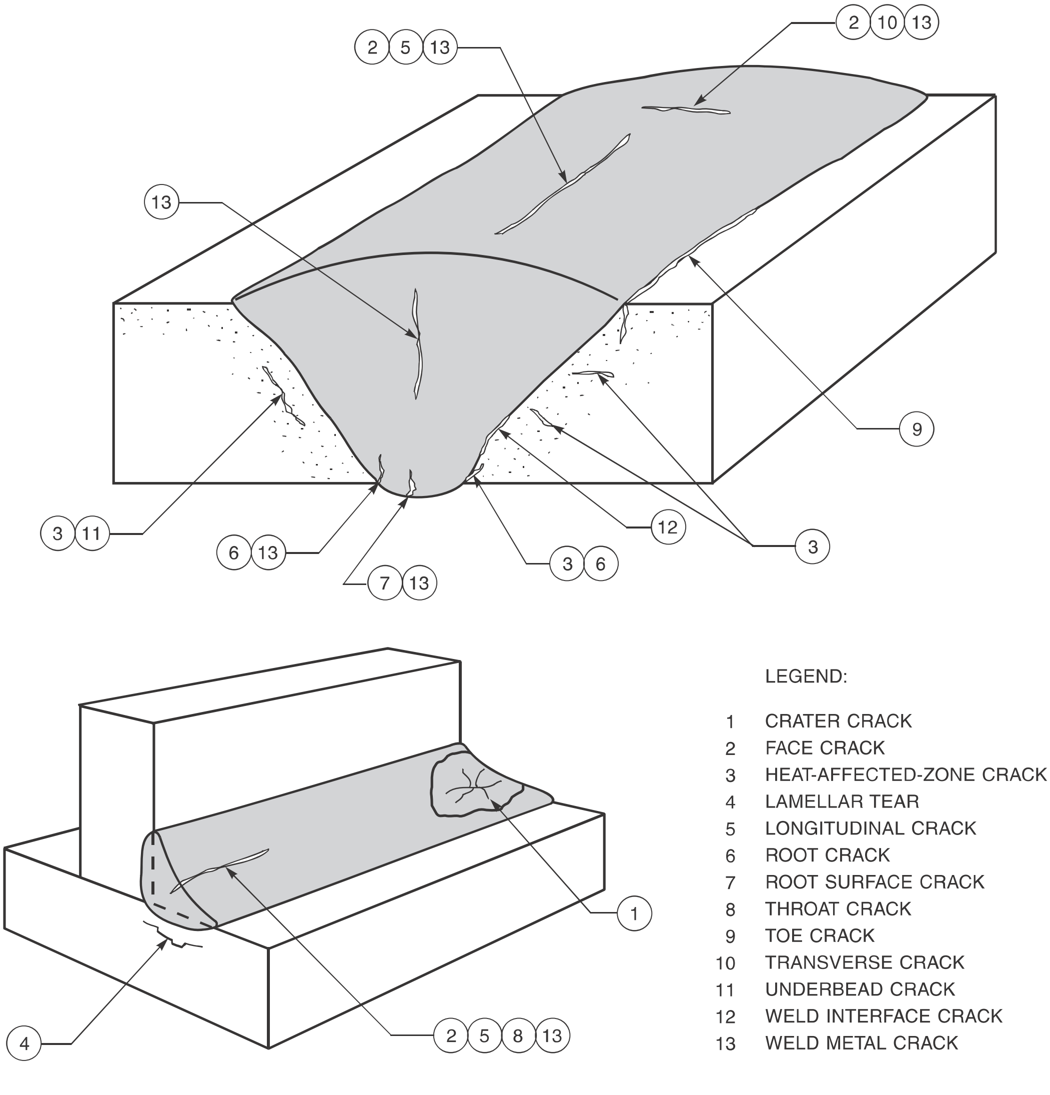

Figure 27—Types of Cracks

5.10.1 Orientation [see Table 1(12)(a) and (b)]. Cracks may be described as either longitudinal or transverse depending on their orientation.

When a crack is parallel to the weld axis it is called a *longitudinal crack* regardless of whether it is a centerline crack in weld metal or a toe crack in the base metal heat-affected zone.

Longitudinal cracks are illustrated in Figure 28 and shown in Figure 29. Longitudinal cracks in small welds between heavy sections are often the result of high cooling rates and high restraint. In submerged arc welding they are commonly associated with high welding speeds or may be related to porosity problems that do not show at the surface of the weld. Longitudinal heat-affected zone cracks are usually caused by diffusible hydrogen.

Transverse cracks are perpendicular to the axis of the weld. These may be limited in size and contained completely within the weld metal or they may propagate from the weld metal into the adjacent heat-affected zone and further into the base metal. In some weldments, transverse cracks will form in the heat-affected zone and not in the weld.

Transverse cracks may be the result of longitudinal residual stresses acting on weld metal with low ductility or they may be related to diffusible hydrogen and delayed cracking. Examples of transverse cracks are shown in Figure 30.

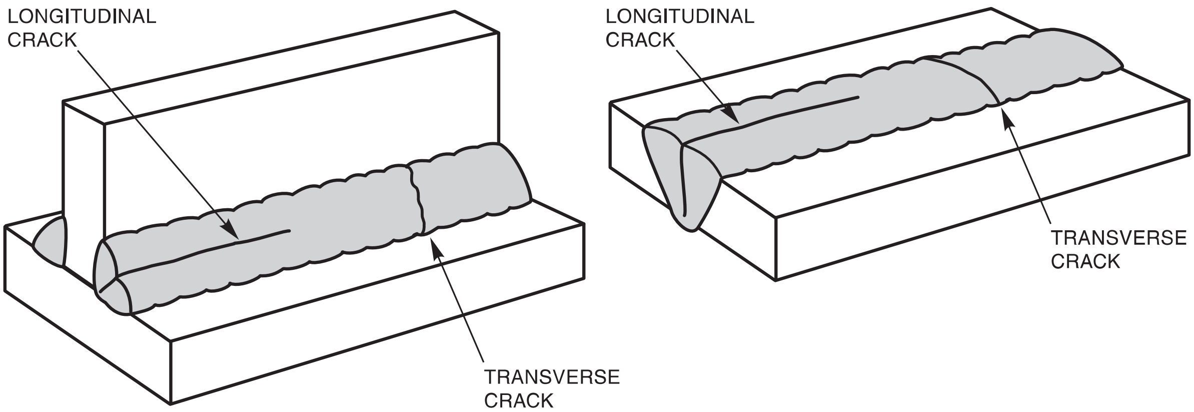

Figure 28—Longitudinal vs. Transverse Cracks

Figure 29—Longitudinal Crack and Aligned Porosity

Figure 30—Transverse Cracks

5.10.2 Crack Types. Cracks can generally be classified as either hot cracks or cold cracks. Hot cracks occur in a metal during solidification or at elevated temperatures. Hot cracks can occur in both heat-affected (HAZ) and weld metal zones (WMZ), and are the result of insufficient ductility at high temperature. Hot cracks propagate between grains in the weld metal or at the weld interface.

Cold cracks occur in a metal at or near ambient temperatures. Cold cracks can occur in base metal (BMZ), heat-affected (HAZ), and weld metal zones (WMZ). They may result from improper welding practices or service conditions. Cold cracks propagate both between grains and through grains.

5.10.2.1 Throat Cracks [see Table 1(12) (c)]. Throat cracks are longitudinal cracks oriented along the throat of fillet welds. A throat crack is shown in Figure 31. They are generally, but not always, hot cracks.

5.10.2.2 Face and Root Cracks [see Table 1(12)(d)]. Face cracks are cracks that occur on the face of the weld and that can be oriented longitudinally or transversely. Root cracks are longitudinal cracks at the weld root or in the root surface. They may be hot or cold cracks. Face and root cracks are illustrated in Figure 27 and a face crack is illustrated in Figure 29.

5.10.2.3 Crater Cracks [see Table 1(12)(e)]. Crater cracks occur in the crater of a weld when the welding is improperly terminated. They are sometimes referred to as *star cracks*, though they may have other configurations. A

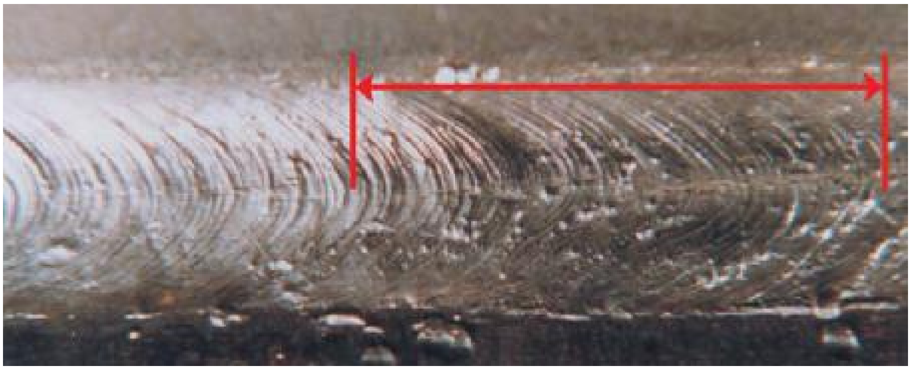

Figure 31—Throat Crack

crater crack is shown in Figure 32. Crater cracks are hot cracks usually forming a pronged starlike network. Crater cracks are found most frequently in materials with high coefficients of thermal expansion, for example austenitic stainless steel and aluminum. However, the occurrence of any such cracks can be minimized or prevented by filling the crater to a slightly convex shape prior to terminating the arc. Longitudinal cracks may initiate from a crater crack. Such a crack is shown in Figure 33.

5.10.2.4 Toe Cracks [see Table 1(12)(f)]. Toe cracks (Figures 34 and 35) are generally cold cracks. They initiate and propagate from the weld toe where shrinkage stresses are concentrated. Toe cracks initiate approximately normal to the base-metal surface. These cracks are generally the result of thermal shrinkage stresses acting on a weld heat-affected zone. Some toe cracks occur because the ductility of the base metal cannot accommodate the shrinkage stresses that are imposed by welding. Figures 34 and 35 depict a toe crack at the toe of a fillet weld.

5.10.2.5 Underbead and Heat-Affected Zone Cracks [see Table 1(12)(g)]. Carbon and low alloy steels are susceptible to cracks due to the presence of diffusible (atomic) hydrogen. Since this type of cracking may not occur until after the welding is completed, a hold time may be required prior to examination. The cracks are also known as delayed cold cracks, underbead cracks, heat-affected zone cracks (HAZ cracks), hydrogen-induced cracks, and hydrogen-assisted cracks. Diffusible hydrogen can be introduced into the weld puddle by moisture in the flux covering, by the decomposition of the flux components in FCAW or SAW consumables, and the presence of hydrocarbons such as grease, oil, cutting fluids, paint, finger prints, etc. Underbead cracks are depicted in Figure 36. These are unlikely to be detected by visual examination.

Figure 32—Crater Crack

Figure 33—Longitudinal Cracks Propagating from Crater Crack

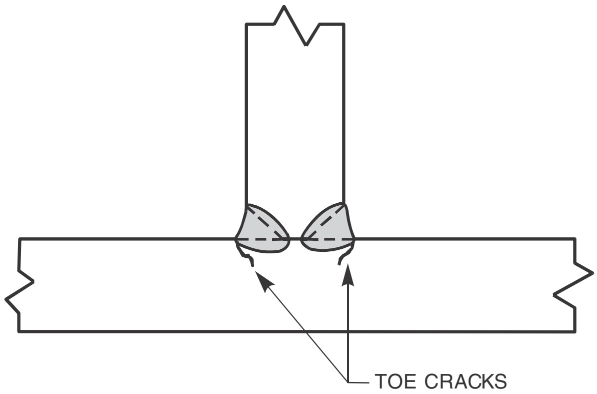

Figure 34—Toe Cracks

Figure 35—Toe Cracks

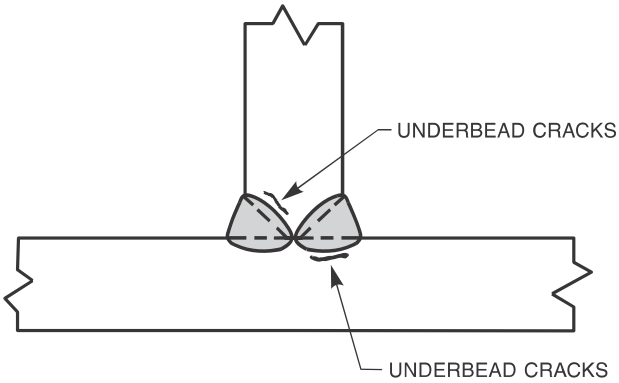

Figure 36—Underbead Cracks

Hydrogen cracks take time to incubate and to propagate to a detectable size. Many welding standards include a requirement to delay the final examinations for 24 hours to 48 hours to allow sufficient time for the cracks to initiate, propagate and become detectable during the course of the visual examination. Even with the delayed examination, hydrogen-induced cracks may not propagate to the surface, and therefore could remain undetected during a visual examination.

5.11 Slag Inclusions [see Table 1(2)(a)]. Slag inclusions are nonmetallic products resulting from the mutual dissolution of flux and nonmetallic impurities in some welding and brazing processes. A slag inclusion is shown in Figure 37.

Slag inclusions as shown in Figure 37 can be found in welds made with any arc welding process that employs flux as a shielding medium. In general, slag inclusions result from improper welding techniques, the insufficient access for welding the joint, or improper cleaning of the weld between passes. Due to its relatively low density and melting point, molten slag will normally flow to the surface of the weld pass. Sharp notches in the weld interface or between passes often cause slag to be entrapped under the molten weld metal. The release of slag from the molten metal will be expedited by any factor that tends to make the metal less viscous or retard its solidification, such as high heat input.

5.12 Weld Reinforcement [see Table 1(15)]. In groove welds, weld reinforcement is weld metal in excess of the quantity required to fill a joint. Weld reinforcement can be located at either the weld face or weld root surface, and is called face reinforcement and root reinforcement, respectively. Examples of weld reinforcement are illustrated in Figure 38. Excessive weld reinforcement is undesirable because it creates high stress concentrations at the toes of the weld. This condition results from improper welding technique or insufficient welding current.

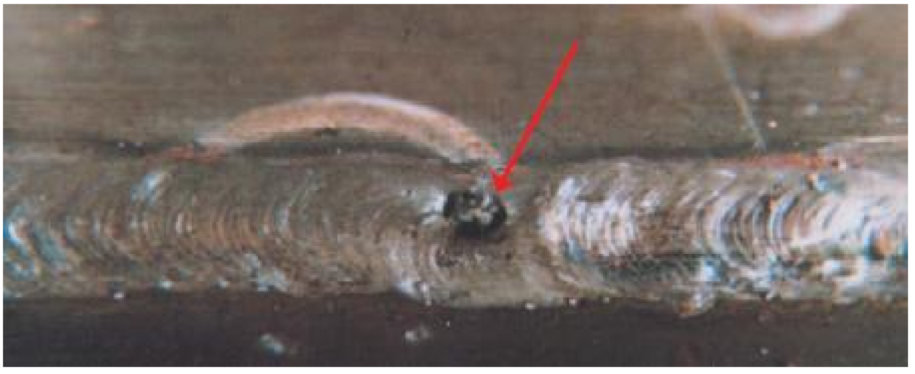

Figure 37—Slag Inclusions

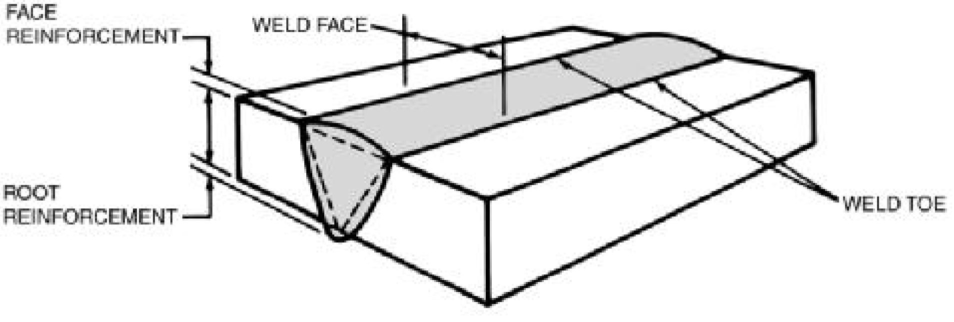

Figure 38—Weld Reinforcement

5.13 Concavity and Convexity [see Table 1(13) and (14)]. Concavity, illustrated in Figure 39, is the maximum distance from the face of a concave fillet weld perpendicular to a line joining the weld toes. The size of a concave fillet weld is related to its throat dimension. The measured leg size will be greater than the true weld size.

Convexity, illustrated in Figure 40, is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes. Excessive convexity, like excessive weld reinforcement, can introduce undesirable stress concentrations at the weld toes.

5.14 Arc Strikes. An arc strike is a discontinuity consisting of any localized remelted metal, heat-affected metal, or change in the surface profile of any part of a weld or base metal resulting from an arc. Arc strikes result when the arc is initiated on the base-metal surface away from the weld joint, either intentionally or accidentally. When this occurs, there is a localized area of the base-metal surface that is melted and then rapidly cooled due to the massive heat sink created by the surrounding base metal. Arc strikes are not desirable because they contain metallurgical discontinuities and they are potential sites for crack initiation. An example of an arc strike is shown in Figure 41.

5.15 Spatter. Spatter consists of metal particles expelled during fusion welding that do not form a part of the weld. Normally, spatter is not considered to be a serious discontinuity unless its presence interferes with subsequent operations, especially nondestructive examination, or the serviceability of the part. Excessive spatter is usually associated with

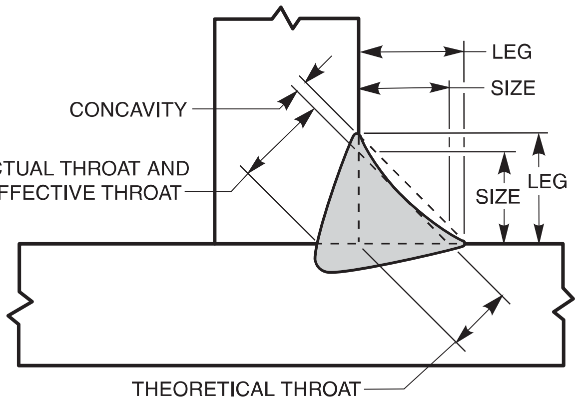

Figure 39—Concave Fillet Weld

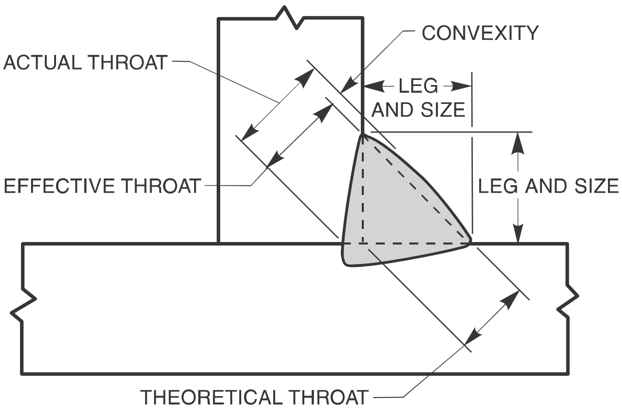

Figure 40—Convex Fillet Weld

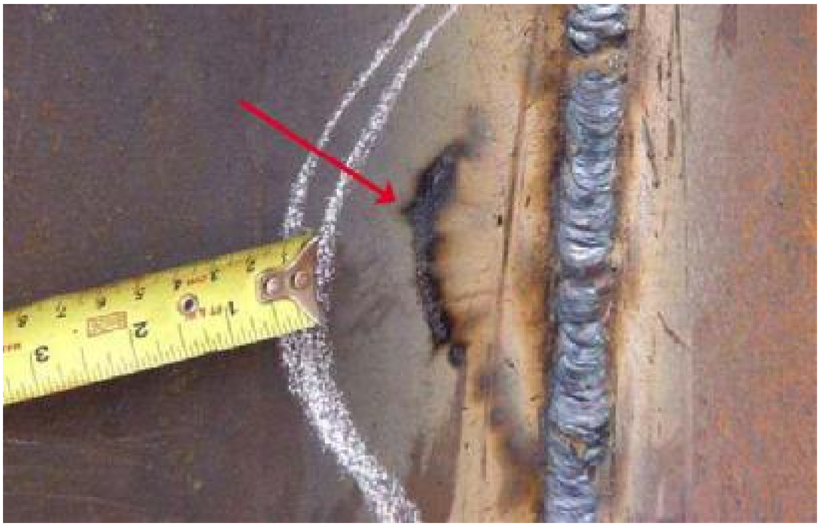

Figure 41—Arc Strike

excessive amperage, excessive arc length, incorrect polarity, or other parameters that are not properly controlled. An example of spatter is shown in Figure 42.

5.16 Melt-Through. Melt-through is visible root reinforcement produced in a joint welded from one side. An example of melt-through is illustrated in Figure 43. Melt-through is generally acceptable unless it results in excessive root reinforcement. Excessive melt-through is known by other nonstandard terms such as "root protrusion."

5.17 Weld Size. Weld size is a measure of a critical dimension, or a combination of critical dimensions of a weld. The required weld size should be shown on the detail drawings. Weld size for various welds are defined and illustrated in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.

Figure 42—Spatter

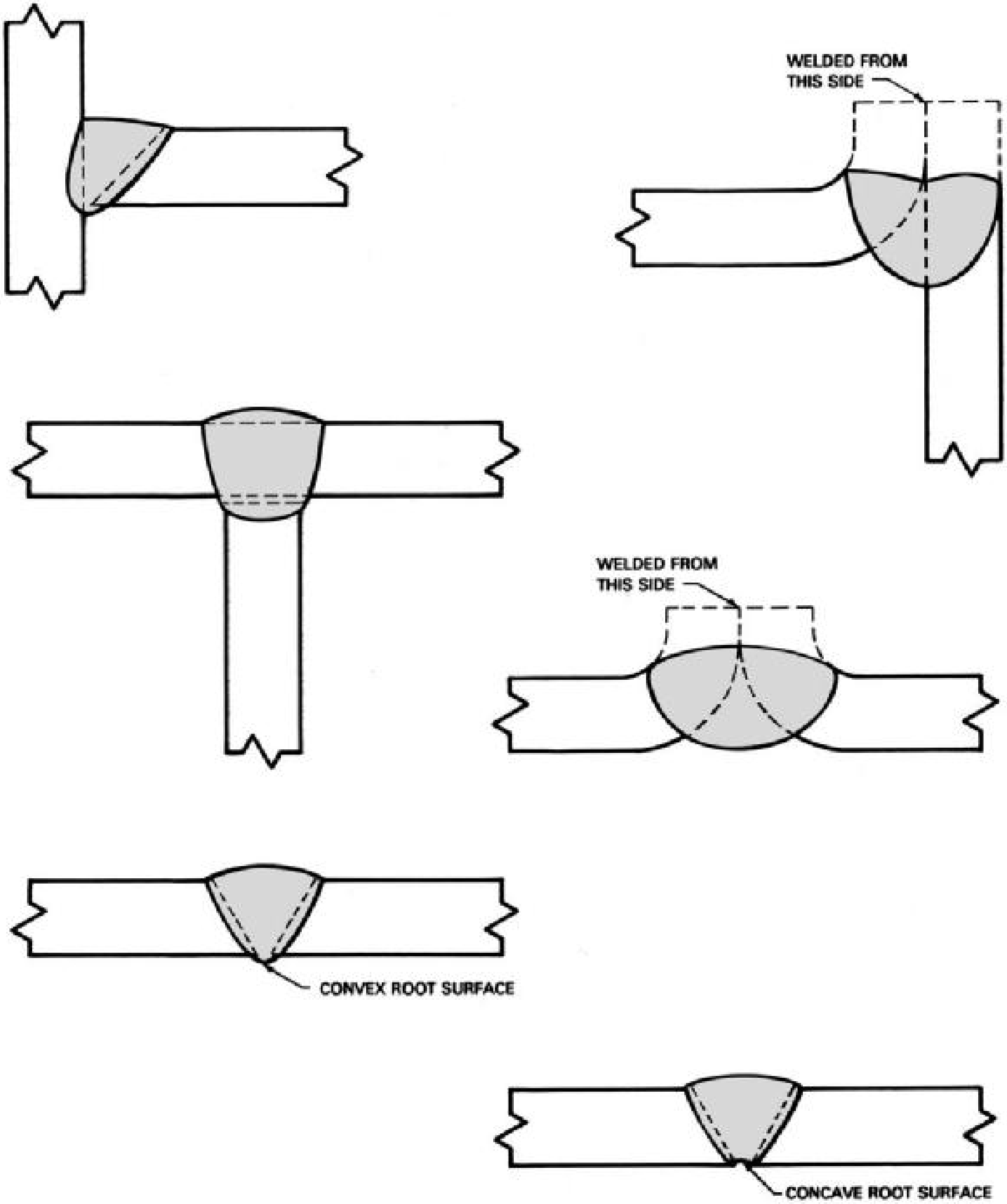

Figure 43—Melt-Through

5.18 Surface Oxidation. Surface oxidation occurs when heated metals are exposed to atmospheric gases; this may be the result of insufficient shielding. It is also known by non-standard terms such as *sugaring*, *carburizing*, or *decarburizing*. Surface oxidation of stainless steels and nickel alloys can vary from iridescent colors of light straw, red, or blue when exposed to the atmosphere at temperatures above 540°C [1000°F]. When titanium and zirconium are exposed to the atmosphere at high temperature, they may develop discoloration from straw color to blue to black. Any discoloration darker than slight yellowing indicates extreme contamination of the base metal. These conditions may be avoided by keeping these metals protected by an inert gas anytime they are heated above 430°C [800°F]. In piping, this is called purging, and specific direction on how to do purging of piping is covered in AWS D10.11M/D10.11, *Guide for Root Pass Welding of Pipe Without Backing*. Surface oxidation occurs during gas shielded arc welding when the gas shield is lost or inadequate. Excessive surface oxidation, sometimes called sugaring, is shown in Figure 44.

6. Examination Equipment

6.1 Introduction. There are numerous examination devices that may be used in welding examination. This clause surveys some of the tools and gauges most frequently used in visual welding examination. The tools covered by this clause are the following:

(1) Linear measurement devices

(2) Temperature-indicating materials

(3) Surface contact and non-contact thermometers

(4) Weld gauges

(5) Fiberscopes and borescopes

(6) Ferrite gauges

(7) Light sources

(8) Ammeters/voltmeters

6.2 Calibration and Handling of Examination Equipment. Some industries require the use of calibrated measuring instruments. Calibration is the comparison of a measuring instrument with a reference standard of a closer tolerance and known accuracy. This comparison is generally made to a standard whose accuracy is traceable to the National Institute for Standards and Technology.

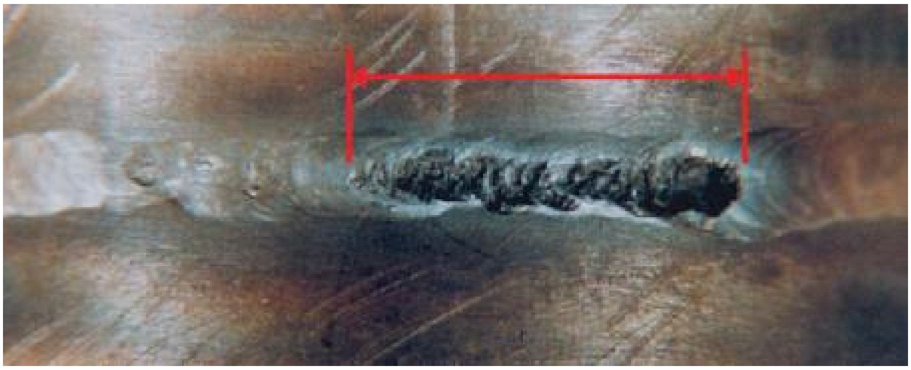

Figure 44—Surface Oxidation Due to Insufficient Shielding in a Gas Tungsten Arc Weld

Calibration is generally documented on a permanent record, and a calibration label may be attached to the instrument indicating the date the instrument is again due to be calibrated.

An effective calibration system should assure the recall and calibration of all precision measuring devices under its control on a pre-established periodic schedule. Prior to using a controlled measuring device, the examiner should assure that the calibration is current. Any gauge whose calibration date has expired should be calibrated prior to use.

To assure continued accuracy it is important to avoid careless or abusive treatment of examination equipment.

Care should be exercised to avoid scratches or nicks on contact surfaces, dial faces, and graduations. Instruments should be kept free of dust, moisture, or fingerprints, and, therefore, should be wiped off before being put away. Equipment should be handled and stored in accordance with manufacturers recommendations.

6.3 Linear Measuring Devices. Devices such as tape measures, micrometers, calipers, and rulers are used for measuring weldment dimensions.

6.4 Temperature Measuring Devices. Temperature measuring devices are used for a variety of conditions which may include monitoring preheat, interpass, aging, or postweld heat treatment temperatures. Only some of the devices are described below but others can be used which may be equally satisfactory. When measuring the temperature with these devices, it is recommended the measurement point should be in accordance with the applicable welding standard. The thickness of the weld joint should be considered when determining the appropriate measurement point.

6.4.1 Temperature Indicating Materials. Temperature indicating materials typically include a crystalline material that melts and leaves a liquid smear upon reaching the prescribed temperature. The temperature indicating materials are available in the form of crayon type markers, pellets, and paint-on liquids.

Crayon-type temperature indicating materials are used by rubbing the end of the marker across the area to be monitored, but not on the area to be welded or on the weld itself. The resulting dry chalk type mark will turn to a liquid smear when the prescribed temperature is reached. An example of a temperature sensitive crayon is shown in Figure 45.

The pellet type temperature indicating material is placed on the surface to be monitored. The pellet melts at the prescribed temperature. The paint-type temperature indicating material is swabbed onto the surface to be monitored and allowed to dry. The dried mark will turn to a liquid smear when the prescribed temperature is reached.

Figure 45—Temperature Sensitive Crayon

6.4.2 Surface Contact Thermometers. The surface thermometer provides a direct indication of the surface temperature of the workpiece. The magnet of the surface thermometer holds fast to ferromagnetic base metals. A surface contact thermometer is shown in Figure 46.

6.4.3 Surface Contact Pyrometers. The electrical pyrometer is an instrument which offers direct indication of temperature. It is often used when the temperature measured might exceed the limits of mercury or other type thermometers. The point of the probe is placed on the work, and the temperature is read from the scale. Some devices have a button that can be depressed to hold the reading, if desired. These types of instruments give a more accurate indication than either the surface thermometer, or temperature indicating materials discussed previously. Figure 47 illustrates the use of an electrical thermocouple.

6.5 Weld Gauges

6.5.1 Fillet Weld Gauge. The fillet weld gauge offers a quick means of measuring most fillet welds, of 3 mm–25 mm [1/8 in–1 in] in size. Both legs of fillet welds should be measured. Fillet weld gauges measure both convex and concave fillet welds.

To measure a convex fillet weld, the blade representing the specified fillet weld size with the single curve should be selected. As shown in Figure 48, the lower edge of the blade is placed on one of the base plates with the tip of the blade moved to the other member.

To measure a concave fillet weld, the blade representing the specified fillet weld size with the double curve should be selected, as shown in Figure 49. After placing the lower edge of the blade on the base plate with the tip touching the upright member, the projection formed by the double curve should just touch the center of the weld face. This will measure throat size for the specified weld size. However, if the center portion of the gauge does not touch the weld, the weld has insufficient throat size.

6.5.2 Multipurpose Gauge. There are numerous multipurpose welding gauges available. A multipurpose gauge is capable of performing many measurements, such as measuring convex and concave fillet welds, weld reinforcement, and root opening. The use of numerous and various gauges available cannot all be detailed here; therefore, the instructions packed with each gauge should be carefully followed. Figure 50 illustrates one of these gauges.

Figure 46—Surface Contact Thermometer

Figure 47—Electrical Thermocouple

Figure 48—Evaluating a Convex Fillet Weld

Figure 49—Evaluating a Concave Fillet Weld

6.5.3 Taper Gauge. The taper gauge is inserted into the opening of a joint to measure root opening (gap). The root opening measurement is taken from the gauge at the point where the gauge becomes snug in the joint as illustrated in Figure 51.

6.5.4 Hi-Lo Gauge. The Hi-Lo gauge is a multi-purpose tool capable of measuring the internal alignment of pipe, weld reinforcement, root opening when backing is not used, and several other dimensions of the weld or groove preparation. After the gauge has been inserted and adjusted, the thumb screw is tightened, and the tool is removed for measurement of misalignment. This is shown in Figure 52.

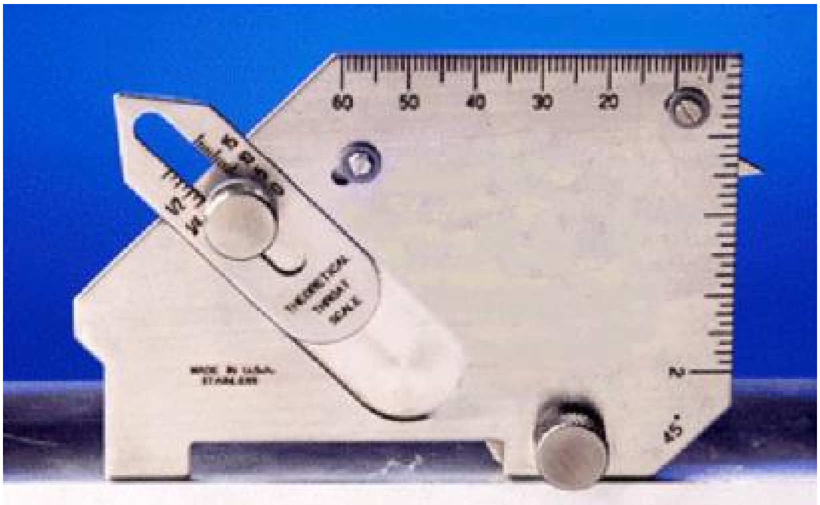

Figure 50—Multipurpose Gauge

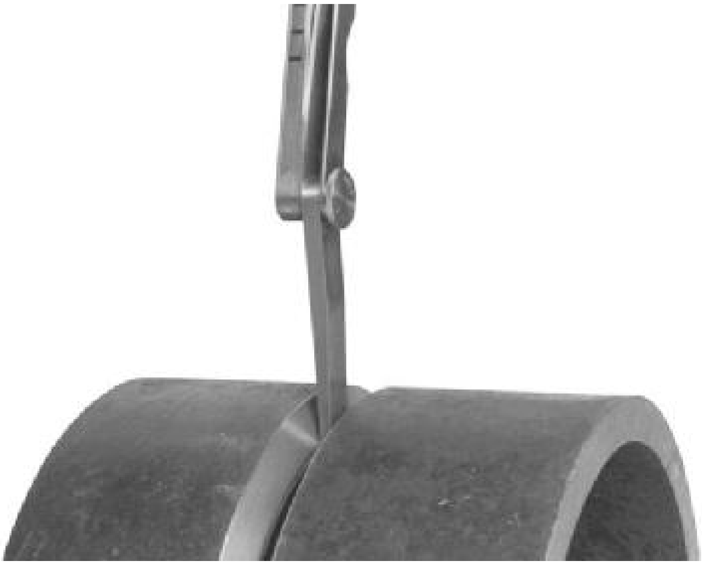

Figure 51—Taper Gauge

6.5.5 Undercut Gauge. The undercut gauge can be used to measure the depth of undercut and to measure the height of weld reinforcement. It also has comparators for estimating the size of an individual pore and can be used for measuring the amount of porosity per linear inch of weld. This is shown in Figure 53.

6.6 Fiberscopes and Borescopes. These are optical instruments ideal for weld examination where there is restricted access. A fiberscope has a flexible construction, and a borescope is rigid. These instruments allow the examiner to look into small holes or around corners. These units may be combined with lenses and cameras, allowing the images to be projected and recorded. Figure 54 illustrates the use of a fiberscope.

6.7 Ferrite Gauges. Austenitic stainless steel weld metal forms microcracks when it does not contain a sufficient amount of a magnetic phase known as delta ferrite. The amount of delta ferrite can be predicted if the chemical composition of the weld metal is known. This methodology is discussed in detail in AWS A5.4/A5.4M, *Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding*. In addition, ferrite in production welds can be measured using one of several magnetic comparator devices, (ferrite gauges) some of which are rugged and highly portable. Ferrite is measured in Ferrite Numbers (FN), and the gauges can be calibrated in accordance with AWS A4.2M (ISO 8249 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*. Typically, a minimum of 3 FN is adequate to preclude microcracking, although the specific requirements should be provided in the contract documents for the work. A ferrite gauge is shown in Figure 55.

6.8 Light Source. The examiner should have adequate illumination, either natural or artificial, while performing visual examination. Minimum lighting may be specified by the applicable code. For example, ASME Section XI has a brightness discrimination vision requirement which requires that a black line approximately 0.8 mm [1/32 in] in width, drawn on a 18% neutral-gray card should be distinctly visible for the lighting to be adequate. Other codes specify minimum illumination levels that are required while performing visual examination; for example, 160 lux [15 fc] for general examination, and a minimum of 540 lux [50 fc] for the detection of small discontinuities. If ambient light conditions are inadequate, auxiliary lighting such as a flashlight should be used.

6.9 Electrical Meters. Electrical meters are used to monitor the welding arc voltage and amperage to verify the electrical parameters are within the prescribed ranges listed in the welding procedure specification. The meters may be multipurpose with the appropriate attachments or single purpose.

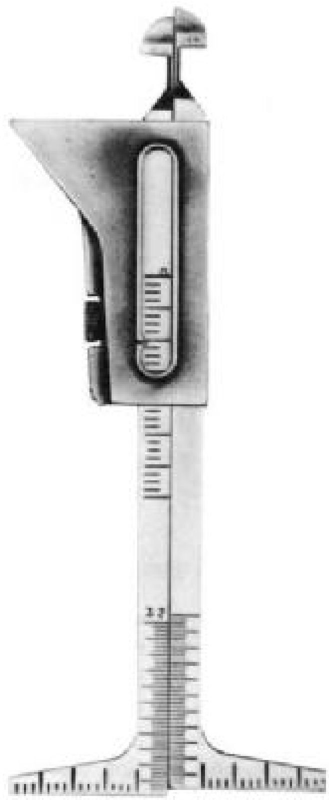

Figure 52—Hi-Lo Mismatch Gauge

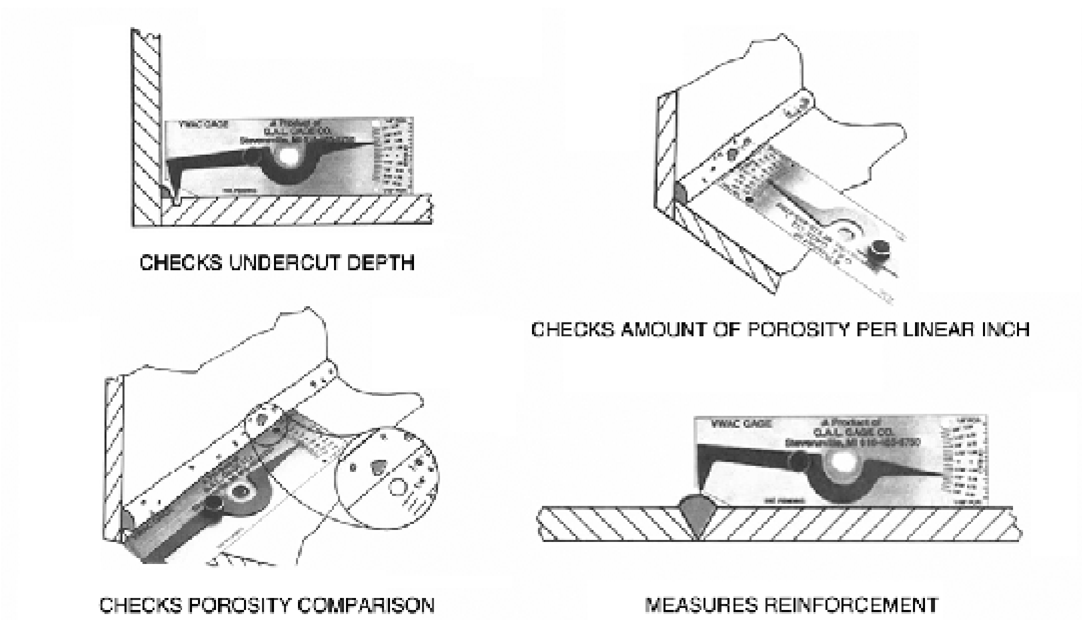

Figure 53—Undercut Gauge

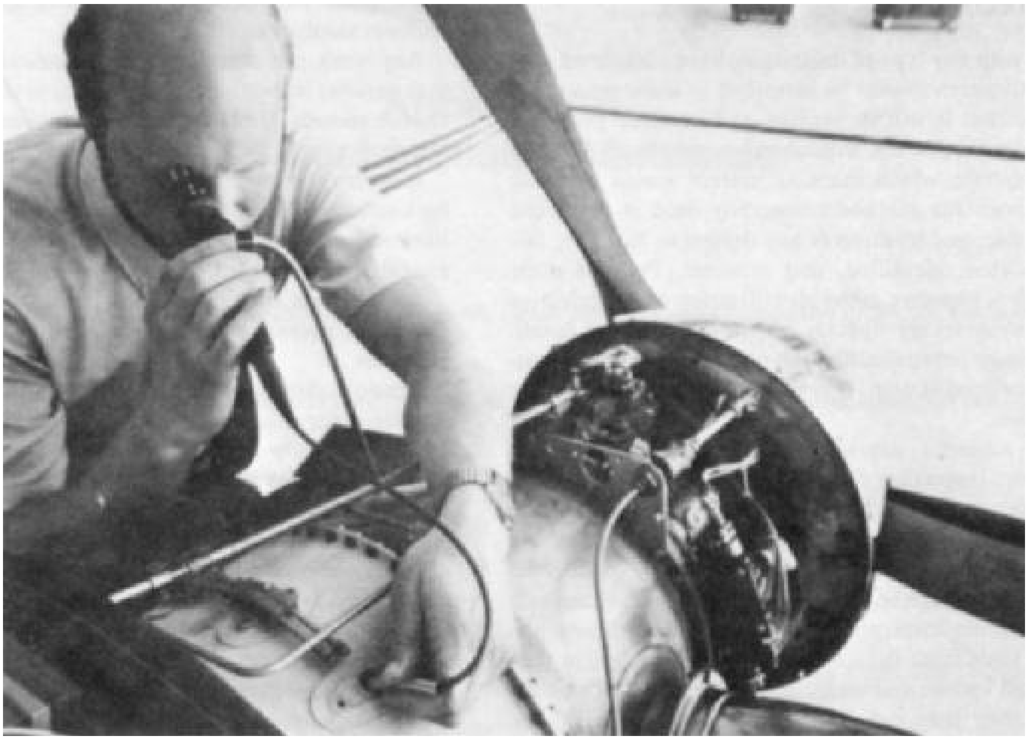

Figure 54—A Fiberscope in Use

Figure 55—Ferrite Gauge

The voltmeter should be connected as close to the welding arc as practical to eliminate errors due to voltage drops from long welding cables, loose connections, etc. One lead from the voltmeter is connected to the electrode cable and the other meter lead is connected to the work piece as shown in Figure 56.

The ammeter must be appropriate for the current being used, i.e., alternating current or direct current. The clamp on type ammeter can obtain an amperage reading by placing the clamp (tong) around one of the welding leads as shown in Figure 57.

7. Records

A written report may be required when a code or contract requires visual examination. The content of the report should contain sufficient details to provide the reader a clear, concise, yet complete understanding of the test results. The report should contain sufficient details that the extent of the examination and the findings can be reconstructed.

It may be beneficial to develop and adopt a report form that will ensure basic information is recorded. It is easy to get distracted while performing a test or examination. The preprinted report format can provide the individual with a checklist of information that should be gathered and recorded. There are numerous attributes that need to be checked or verified when performing an examination. A report form can include these important attributes to ensure they are not inadvertently overlooked.

Written reports and test records should include the printed name, signature and date indicating who performed the test or examination and when it was performed.

A method of identifying parts or components that have been examined should be established. The method of identifying nonconforming material should identify the specific defect so that repairs can be accomplished.

A filing system to archive reports should be established and maintained. It may be necessary to retrieve past reports to verify the required tests and examinations were performed as per the contract or code.

An example of a report format is located in Annex C. The report form, listing the weld attributes to be examined, should be tailored to suit the reporting requirements of the project.

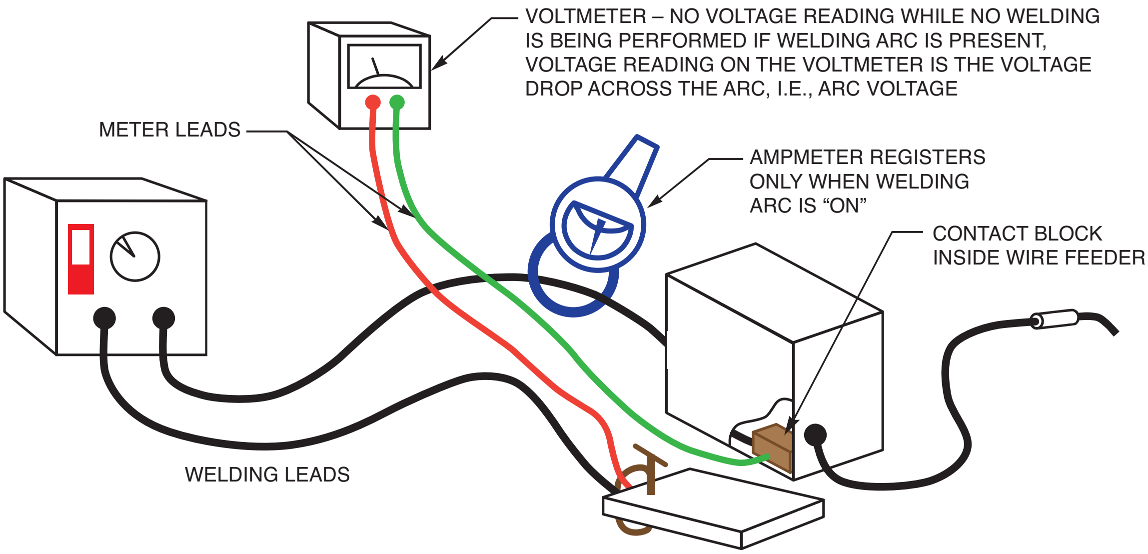

Figure 56—Voltmeter Arrangement

Figure 57—Tong Test Ammeter

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Annex A (Informative)

List of Standards Commonly Used in the Welding Industry

This annex is not a part of AWS B1.11M/B1.11:2015, *Guide for the Visual Examination of Welds*, but is included for informational purposes only.

Listed below are some of the standards used in the welding industry for fabrication and examination. They are listed here by name of category and society.

Category	Society	Title
Pressure Vessel	American Society of Mechanical Engineers (ASME) Three Park Avenue New York, NY 10016-5990 https://www.asme.org	*Boiler and Pressure Vessel Code*, Section V, Nondestructive Examination
Piping	American Society of Mechanical Engineers (ASME) Two Park Avenue New York, NY 10016-5990 https://www.asme.org	B31.1, *Power Piping* B31.3, *Chemical Plant and Petroleum Refinery Piping* B31.4, *Liquid Petroleum Transportation Piping Systems*
	American Petroleum Institute (API) 1220 L Street N.W. Washington, DC 20005 http://www.api.org	Standard 1104, *Standard for Welding of Pipelines and Related Facilities* API-RP-2X, *Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Technicians*
Structural	American Welding Society (AWS) 8669 NW 36 St, # 130 Miami, FL 33166	D1.1/D1.1M, *Structural Welding Code—Steel* D1.2/D1.2M, *Structural Welding Code—Aluminum* D1.3/D1.3M, *Structural Welding Code—Sheet Steel* D1.4/D1.4M, *Structural Welding Code—Reinforcing Steel* D1.5/D1.5M, *Bridge Welding Code* D1.6/D1.6M, *Structural Welding Code—Stainless Steel* D1.7/D1.7M, *Guide for Strengthening and Repairing Existing Structures* D1.8/D1.8M, *Structural Welding Code—Seismic Supplement* D1.9/D1.9M, *Structural Welding Code—Titanium*

(Continued)

Category	Society	Title
Structural (Cont'd)	American Welding Society (AWS) 8669 NW 36 St, # 130 Miami, FL 33166	D9.1/D9.1M, *Sheet Metal Welding Code* D3.6M, *Specification for Underwater Welding* D14.3/D1.43M, *Specification for Welding Earthmoving, Construction, and Agricultural Equipment* D15.1/D15.1M, *Railroad Welding Specification—Cars and Locomotives* QC1, *Standard for AWS Certification of Welding Inspectors* QC2, *Recommended Practice for Training, Qualification, and Certification of Welding Inspector Specialist and Welding Inspector Assistant*
	American Institute of Steel Construction (AISC) One East Wacker Drive, Suite 700 Chicago, IL 60611-1802 http://www.aisc.org	Quality Criteria and Inspection Standards, 2nd Edition, *Specifications for the Designing, Fabrication, and Erection of Safety Related Structures for Nuclear Facilities*
Shipbuilding	American Bureau of Shipping (ABS) 16855 Northcase Drive Houston, TX 77060 http://www.eagle.org	*Rules for Building and Classing Steel Vessels*, Section 43
Military	Naval Publication and Forms Center 5801 Taber Avenue Philadelphia, PA 19120	Navy NAVSEA S9074-AQ-GIB-010/248, *Requirements for Welding and Brazing Procedure and Performance Qualification* Navy NAVSEA S9074-AR-GIB-010/278, *Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels* Navy NAVSEA T9074-AS-GIB-010/271, *Requirements for Nondestructive Testing Methods* MIL STD 2035, *Nondestructive Testing Acceptance Criteria* MIL STD 1689, *Fabrication, Welding and Inspection of Ships Structure* NAVY NAVSEA T9074-AD-GIB-010/1688, *Requirements for Fabrication, Welding and Inspection of Submarine Structure*

Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not a part of AWS B1.11M/B1.11:2015, *Guide for the Visual Examination of Welds*, but is included for informational purposes only.

B1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS *Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex C (Informative)

Sample Form

This annex is not a part of AWS B1.11M/B1.11:2015, *Guide for the Visual Examination of Welds,* but is included for informational purposes only.

The following form is an example of a typical Visual Examination Report.

Visual Examination Report

Client/Owner:	
Project:	
Serial / Part / Spool Number:	
Job or Contract Number:	
Drawings/Approval Date:	

Examiner's Signature

Examination Method			
Examination Procedure			
Examiner & ID Stamp			
Date of Examination			
Joint Identification:			
Joint Design:			
Service Class / Weld Class			
Base Metal (1) Specification			
Heat / Lot Number			
S Number			
Base Metal (2) Specification			
Heat / Lot Number			
S Number			
Welding Procedure Spec.			
Filler Metal			
Heat / Lot Number			
Preheat/Interpass			
Post Weld Heat Treatment			
Welder Stamp (ID number)			

Fitup						
Root Opening/Clearance						
Root Face / Pull-Back						
Groove Angle						
Alignment						
Welding Attributes						
Reentrant Angle						
Fillet – Convexity/Concavity						
Groove Face/Root Reinforcement						
Length / Size						
Cracks						
Burn-through						
Melt-through						
Incomplete Fusion						
Crater Pit						
Oxidation						
End or Corner Melt						
Undercut						
Porosity						
Spatter / Arc Strike						
Surf. Cond. – paint, grinding/gouges						

Figure C.1—Sample Visual Examination Form

Annex D (Informative)

Informative References

This annex is not a part of AWS B1.11M/B1.11:2015, *Guide for the Visual Examination of Welds*, but is included for informational purposes only.

ASM International Documents:[3]

Nondestructive Evaluation and Quality Control, *Metals Handbook*, 9th Edition, Volume 17.

AWS Documents:[4]

AWS B1.10M/B1.10, *Guide for the Nondestructive Examination of Welds*

AWS A4.2M (ISO 8249:2000MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*

AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*

AWS D10.11M/D10.11, *Guide for Root Pass Welding of Pipe without Backing*

AWS QC1, *Standard for AWS Certification of Welding Inspectors*

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

AWS *Welding Handbook*, 9th Edition, Volume 1, Welding Science and Technology; American Welding Society, Miami, FL

AWS *Welding Handbook*, 9th Edition, Volume 2, Welding Processes, Part 1; American Welding Society, Miami, FL

AWS *Welding Handbook*, 9th Edition, Volume 3, Welding Processes, Part 2; American Welding Society, Miami, FL

AWS *Welding Handbook*, 8th Edition, Volume 3, Materials and Applications, Part 1; American Welding Society, Miami, FL

AWS *Welding Handbook*, 8th Edition, Volume 4, Materials and Applications, Part 2; American Welding Society, Miami, FL

AWS *Welding Inspection Handbook*, American Welding Society, Miami, FL

AWS *Welding Metallurgy, Carbon and Alloy Steels*; Volume 1, Fundamentals; American Welding Society, Miami, FL

ASNT Document:[5]

Nondestructive Testing Handbook, 2nd Edition, Volume 8; Visual and Optical Testing; The American Society for Nondestructive Testing, Columbus, OH

[3] ASM International documents may be obtained from ASM International, 9639 Kinsman Road, Materials Park, OH 44073.
[4] AWS documents and ANSI Z49.1 may be obtained from American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.
[5] ASNT documents may be obtained from the American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, OH 43228-0518.

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List of AWS Documents on Welding Inspection

Designation	Title
B1.10M/B1.10	*Guide for the Nondestructive Examination of Welds*
B1.11M/B1.11	*Guide for the Visual Examination of Welds*
WI	*Welding Inspection Handbook*

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