

AWS API-M:2008



Study Guide

for

API Standard 1104 Welding of Pipelines and Related Facilities

TWENTIETH EDITION



American Welding Society

Study Guide

for

API Standard 1104 Welding of Pipelines and Related Facilities

TWENTIETH EDITION

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Abstract

This study guide contains information on the use of API Standard 1104, Twentieth Edition, which will assist the student in preparing for using the standard as well as preparing for code-related examinations. Material is provided for each of the 13 sections of the standard and both appendices. Exercise questions and answers are provided for each topic.



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Study Guide for API Standard 1104, Twentieth Edition

Foreword

AWS Education Services has published this AWS Study Guide to assist quality professionals—inspectors and supervisors—and quality-conscious engineers and managers in reading, understanding, and learning to apply the American Petroleum Institute’s API Standard 1104, *Welding of Pipelines and Related Facilities*, Twentieth Edition.

API 1104 applies to welding of piping used in the compression, pumping, and transmission of petroleum products, fuel gases, carbon dioxide, and nitrogen. The standard’s purpose is to present methods for the production and inspection of high-quality welds through the use of qualified personnel using approved procedures, materials, and equipment. It applies to new construction and in-service welding, and is voluntary.

This API 1104 Study Guide consists of an introduction and 15 sections, each covering a specific code section or appendix.

For each section exercise questions and answers are provided at the end of this document. Answering them provides a valuable review of the section contents. These questions also illustrate the types of questions you’re likely to encounter in practice.

The authors of this book want you to write in this book and in *API Standard 1104* to clarify your understanding of the figures, tables, and text in both volumes.

The book provides a commentary on the code; it does not repeat the contents of the code.

As you read this book, open the code to the corresponding page.

Remembering excerpts from the code is neither necessary nor desirable. You need not memorize the code; just learn how to use it.

The American Welding Society appreciates feedback from participants in its education programs. Please send comments or questions to:

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or contact AWS Education Services by email: education@aws.org. Additional information on AWS products and services may be found on our website: www.aws.org.

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INTRODUCTION: HOW TO USE API 1104

Definitions of Documents

All codes, standards, specifications, and guides are conceptually similar, but each has a specific application and purpose. API 1104 is a good example of the concept, so learning to use this standard will help you learn to use others as well.

A **CODE** is a body of laws arranged systematically for easy reference and use. Because a code has a legal status, it is by definition mandatory, and uses words such as shall, will, and must to express certain conditions and requirements, and to verify that those requirements are being met. Examples of codes include AWS D1.1, *Structural Welding Code—Steel*, AASHTO/AWS D1.5, *Bridge Welding Code*, and ASME B31.1, *Power Piping Code*.

A **STANDARD** is established for use as a rule or basis of comparison in measuring quality, quantity, content, relative value, etc. API 1104, *Welding of Pipelines and Related Facilities*, is an example. So are AWS A3.0, *Standard Welding Terms and Definitions*, and AWS QC1, *Standard for AWS Certification of Welding Inspectors*.

A **SPECIFICATION** is a detailed description of the parts of a whole; a statement or enumeration of particulars, as to actual or required size, quality, performance, terms, etc. Thus, a specification describes all pertinent technical information for a material, product, system, or service, and indicates how to determine that the requirements have been met. Examples include AWS Filler Metal Specifications A5.1 through A5.34.

A **RECOMMENDED PRACTICE** is a nonmandatory description of generally accepted industrial methods and techniques. One of the most common examples is *Recommended Practice No. SNT-TC-1A*, ASNT's guideline to personnel qualification and certification in nondestructive examination.

A **GUIDE** provides information on proven methods to accomplish certain tasks. It is not mandatory but should reflect best practices. An example is AWS B1.11, *Guide for the Visual Examination of Welds*.

Less Than or Greater Than?

In many codes and standards, including API 1104, the rules vary depending on the size of a part, intended service and manufacturing requirements. Often these rules are differentiated symbolically. Most people know that = means “equal to” but the symbols for “less than” and “greater than” can cause confusion. Here's an easy way to keep them straight:

- < The symbol for less than points to the left. Example: 5 < 9 means five is less than nine.
- > The symbol for greater than points to the right. Example: 9 > 5 means nine is greater than 5.
- ≤ is the symbol for less than or equal to.
- ≥ is the symbol for greater than or equal to.

Other Definitions

API 1104 Section 3, Definition of Terms, presents a list of definitions of welding terms based upon *AWS 3.0, Standard Welding Terms and Definitions*. Section 3 of this Study Guide provides additional key terms and definitions that users of the standard should know.

The Meaning of Quality

Quality is measurable conformance to specifications. To establish **product quality**, purchasers invoke or mandate certain codes, standards, and specifications that state the requirements to which the product must conform. Thus, quality professionals must be able to read, understand, and apply the provisions of the governing documents cited in a contract, job specification, or purchase order.

To facilitate working with a code, you should attach an index tab to the first page of each section, and to significant tables and figures that you will use frequently. API 1104 has 13 sections and two appendices. See Study Guide Figure A.

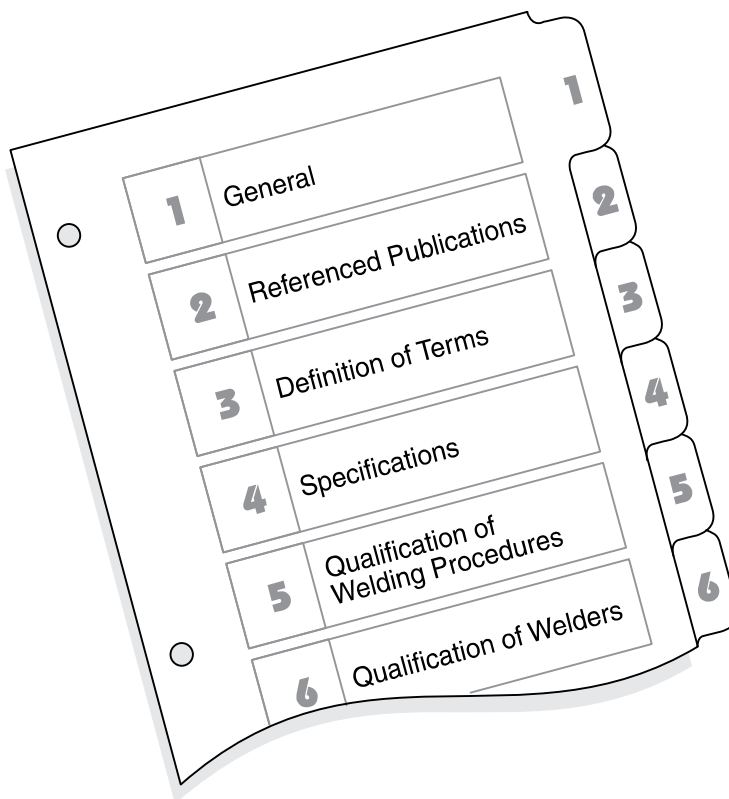


Figure A—Section ID ‘Tabs’

Many codes make extensive use of notes (which may be footnotes, or general notes incorporated into the text) to explain something, or to cover special cases and particular circumstances. Every time you apply a code, look up the information, be thorough,

and pay close attention to any notes. Carefully review the tables and figures, being attentive to superscripts and their corresponding footnotes, which can modify the effect of the information in the table or figure.

You will see three types of footnotes:

- Global footnote—Appears at the top of a figure, list, or table, and influences everything therein.
- Regional footnote—Appears at the top of a column, subsection, or row in a figure, list, or table, and influences only that portion of the material.
- Local footnote—Applies only to the specific item being footnoted.

For example, turn to page 8 in your copy of API 1104. Note the small superscript letters that follow certain Filler Metal Group Numbers in Table 1. Each superscript refers to a footnote, which changes some aspect of the provisions of the table.

As you work with a code, check periodically for applicable Errata Sheets. If any exist, mark the changes in the code. Errata may result from printing errors or advances in knowledge and practice.

Typically, codes are revised periodically according to a regular schedule. API generally updates its standards every five years, though up to two additional years may be added to a review cycle. See the foreword of API 1104 for information on ascertaining the status of the Twentieth Edition.

Finding Code Provisions

Codes typically use the multiple decimal numbering system. See Study Guide Figure B.

```

1.  -----
    1.1 -----
        1.1.1 -----
        1.1.2 -----
    1.2 -----
        1.2.1 -----
        1.2.2 -----
2.  -----
  
```

Figure B—Multiple Decimal Numbering System

A **code provision** is the specific text contained within a numbered section or subsection of a code.

When you use a code, identify the key term or phrase that best describes the issue or requirement of interest, and then locate the code provision that best addresses that issue or requirement.

Although you might find a particular provision by thumbing through the code, a more systematic approach is to convert the information you seek into a question, then analyze the question to identify key words or expressions. Look for those key words or expressions in the table of contents to locate the applicable provisions by section or subsection number. Those numbers are called **references**. Then locate those reference numbers in the code.

Code Reference Exercise

When the company requests a radiographic test method, how long after processing shall the images still be interpretable?

Key Words: a) radiographic test method

b) processed, handled, and stored

Check Contents: Section 11 Procedures for Nondestructive Testing (**page vi**) and subheading 11.1, Radiographic Test Methods.

Look it up: Find reference **11.1.11**, Image Processing (**page 33**), left column.

Provision: When requested by the company, film or other imaging media shall be processed, handled, and stored so that the images are interpretable for at least 3 years after they are produced.

API 1104 Contents

API 1104 contains 13 sections and two appendices:

1. General
2. Referenced Publications
3. Definition of Terms
4. Specifications
5. Qualification of Welding Procedures for Welds Containing Filler-Metal Additives
6. Qualification of Welders
7. Design and Preparation of a Joint for Production Welding

8. Inspection and Testing of Production Welds
9. Acceptance Standards for Nondestructive Testing
10. Repair and Removal of Defects
11. Procedures for Nondestructive Testing
12. Mechanized Welding with Filler Metal Additions
13. Automatic Welding Without Filler-Metal Additions

Appendix A—Alternative Acceptance Standards for Girth Welds

Appendix B—In-Service Welding

This Study Guide follows the structure of API 1104. Therefore, the sections and subsections in this book correspond to those in API 1104.

The API 1104 **Contents** list begins on page v. It contains:

- A list of standard provisions by section and subsection number and title, i.e., 1.1 Scope. The page on which a given section or subsection begins is to the right of that subsection's title. (For the appendices, the numbering system is alphanumeric, i.e., A.1 General.)
- A list of figures. A figure is an illustration of a pictorial nature. Figures are listed by number, title, and the page on which they appear in the text.
- A list of tables. A table is a systematic arrangement of data, typically in rows and columns. Tables are listed by number, title, and the page on which they appear in the text.

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SECTION 1—GENERAL

API 1104 provides a list of permitted welding processes, and does not allow for substitutions without formal consideration by the API 1104 Committee.

The following list, in the same order as in Section 1, gives common industry abbreviations and nonstandard names for the permitted processes:

- Shielded metal arc welding (SMAW), also called stick welding.
- Submerged arc welding (SAW), also called subarc.
- Gas tungsten arc welding (GTAW), also called tungsten inert gas (TIG) and heliarc welding.
- Gas metal arc welding (GMAW), also called metal inert gas (MIG) welding.
- Flux-cored arc welding (FCAW).
- Plasma arc welding (PAW).
- Oxyacetylene welding (OAW), also called gas welding.
- Flash butt welding (FW).

API 1104 also discusses the use of manual, semiautomatic, mechanized, or automatic welding techniques. For definitions of these techniques, see Section 3 of API 1104. Study Guide Table 1.1 indicates which of the permitted welding processes you may perform using each technique.

API 1104 covers procedures and acceptance standards for various kinds of non-destructive testing. The following list, in the same order as in Section 1, gives common industry abbreviations and nonstandard names:

- Radiographic testing (RT) (x-ray and gamma radiation testing).
- Magnetic particle testing (MT).
- Liquid penetrant testing (PT).
- Ultrasonic testing (UT).
- Visual testing (VT).

API 1104 contains values stated in U.S. Customary (inch-pound) Units and SI (metric) Units. The U.S. Customary values appear first, followed by the SI Units in parentheses, but the SI Units are an approximation of the corresponding U.S. Customary Units. API 1104 emphasizes that you must use one system or the other, and not combine them.

Table 1.1
Processes and Techniques

Process	Manual	Semi-automatic	Mechanized	Automatic
Shielded metal arc welding (SMAW)	1			
Submerged arc welding (SAW)		2	1	
Gas tungsten arc welding (GTAW)	1		2	
Gas metal arc welding (GMAW)		1	2	2
Flux-cored arc welding (FCAW)		1	2	
Plasma arc welding (PAW)	1		2	
Oxyacetylene welding (OAW)	1			
Flash butt welding (FW)				1

1. Common applications used in industry.
2. Nontypical applications requiring additional equipment.

SECTION 2—REFERENCED PUBLICATIONS

Section 2 of API 1104 lists the standards, codes, and specifications referenced throughout the standard. The footnotes provide contact information for the organizations that publish these documents.

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SECTION 3—DEFINITION OF TERMS

The definitions of welding terms in this section of API 1104 are based on definitions in AWS A3.0, *Standard Welding Terms and Definitions*, with additions and modifications. Additional key terms and definitions *not* included in this section of the code appear below:

Bend test. A soundness test in which the individual performing the test places the specimen across the shoulders of a die with the surface to be tested facing down. A plunger positioned above the area of interest is forced toward the die, causing the specimen to bend into a U shape.

butt weld. A nonstandard term for a weld in a butt joint, which is a joint between two members aligned approximately in the same plane.

classification number. A number in an AWS numbering system that identifies electrodes and filler metals according to their chemical composition and operating characteristics. Examples include for SMAW—E7018, for GMAW—ER70S-6, and for GTAW—EWh-2.

defect. A rejectable imperfection that impairs the suitability of a structure for its intended purpose. See API 1104 Section 9 for a list of types of imperfections.

destructive testing. Testing that renders the material or part useless for service, performed to obtain information on material properties and soundness.

discontinuity. An irregularity in an otherwise uniform structure. See API 1104 Section 9 for a list of types of imperfections and the criteria that may allow them in a weldment. API 1104 does not use the word discontinuity but rather calls them indications or imperfections. Not all discontinuities, imperfections, or indications are rejected.

essential variable. A component of a welding procedure specification that requires requalification if changed beyond certain limits specified in the applicable code.

face reinforcement. A weld metal build-up, raised above the surface of the parent metal in excess of what is required to fill a groove joint on the side of the base metal from which welding was done.

faying surface. The mating surfaces of two parts that are to be welded together.

filler metal. The metal or alloy to be added in making a brazed, soldered, or welded joint.

fillet weld. A weld of approximately triangular cross section joining two surfaces approximately at right angles.

fisheye. A discontinuity attributed to the presence of hydrogen in the weld, observed on the fracture surface of a weld in steel that consists of a small pore or inclusion surrounded by a round bright area.

flux. A substance that hinders or prevents oxide formation in molten metal or dissolves or otherwise facilitates the removal of such substances.

image quality indicator (IQI) (previously referred to as a penetrameter in API 1104). A device used to measure the quality of radiographic images. It is placed on the weldment prior to radiography and must be verified to exist on the film when looking at the resulting film. See Study Guide Figure 3.1.



Figure 3.1—Wire-Type IQI

lineup clamp. An external or internal device used to bring two pipe segments into acceptable alignment for preweld tacking or for welding.

nick-break test. A destructive test that judges the soundness of a weld by fracturing the specimen through the weld so the fractured surface can be examined for the presence of discontinuities.

postheat. The heat applied after completion of welding.

preheat. The heat applied to a base metal immediately before welding.

procedure qualification record (PQR). A document containing all of the actual values recorded during welding of a test weldment and the test requirements necessary to comply with a given code or standard.

shielding atmosphere. A protective gas or vacuum envelope surrounding the welding arc to prevent or reduce contamination of the workpiece by the ambient atmosphere.

socket weld. A fillet weld joining two pipes or pipe fittings, one of which is inserted into the other. See Study Guide Figure 3.2.

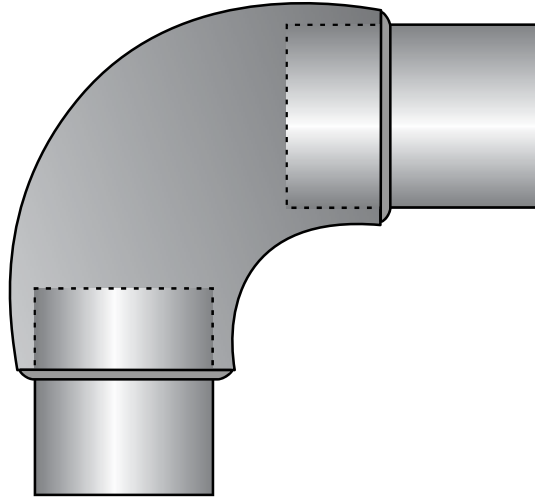


Figure 3.2—Socket Weld

soundness. Freedom from imperfections.

soundness testing. See bend, nick-break, and fillet-weld break test (destructive soundness tests) and RT and UT (nondestructive soundness tests). API 1104 does not use the fillet-weld break test.

specification number. The number assigned to a document that describes the attributes of some item or operation. Examples include AWS A5.1, *Specification for Covered Carbon Steel Arc Welding Electrodes*, ASTM A 514, *Standard Specification for High Yield Strength, Quenched and Tempered Alloy Steel Plate*, and AWS D14.4, *Specification for Welded Joints in Machinery and Equipment*.

speed of travel. The rate of welding progression along the weld joint.

tensile-strength test (also called tension test). A test in which the specimen is subjected to a pulling load until failure occurs. Test results are expressed in pounds per square inch (psi) or megapascals (MPa).

trepanning. A process (using a hole saw) for removing a specimen from a weld for examination of the weld metal. The hole is cut so the inspector can look inside the pipe to verify the degree of penetration. Trepanning is generally not permitted for production piping applications. See Study Guide Figure 3.3.

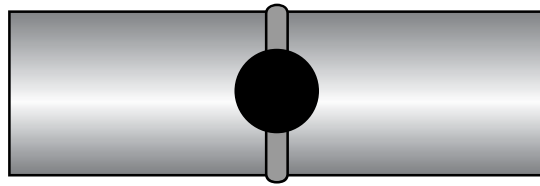


Figure 3.3—Trepan

underfill. Weld metal that is insufficient in meeting the full thickness of the parent metal due to inadequate filling of a groove joint from the side of the base metal from which welding was done.

welder qualification test report (WQTR). A document that identifies the essential variables of a welding procedure specification (WPS) and the test requirements necessary to verify a welder's ability to perform a procedure.

welding procedure. An activity undertaken according to a set of specific instructions provided in a welding procedure specification (WPS).

welding procedure specification (WPS). A document providing the welding variables required for a specific application to assure repeatability by properly trained welders and welding operators.

yield strength. The amount of strength necessary to make a metal exhibit a specified permanent deformation under load, expressed in API 1104 in pounds per square inch (psi) or megapascals (MPa).

SECTION 4—SPECIFICATIONS

4.1 Equipment

This section calls for good judgment, sound engineering, suitable operating practices, and attention to safety. A measure of suitability is to ensure that the right equipment to realize all of the variables of the welding procedure is being used in a safe manner.

4.2 Materials

4.2.1 Pipe and Fittings

API 1104 says that pipe and fittings must conform to API Spec 5L or any applicable ASTM specifications, but it then states that chemically and mechanically similar materials also are acceptable. This means you must identify the chemical and mechanical properties of any material not included in those specifications to ensure its compatibility.

4.2.2 Filler Metal

4.2.2.1 Type and Size

All filler metals must conform to one of the AWS filler metal specifications, or must be qualified for use according to the requirements of API 1104, Section 5.

API 1104 Table 1, in Section 5 on page 8, divides filler metals into nine groups, based on electrode characteristics and the processes that employ those electrodes. The columns in Table 1 list:

- Group numbers for filler metals, electrodes, and fluxes.
- AWS specification numbers.
- Electrodes and filler metals by classification number.
- Fluxes by classification number.

Be attentive to the footnotes, which modify the requirements for use of certain electrodes, filler metals, or fluxes under particular circumstances.

4.2.2.2 Storage and Handling of Filler Metals and Fluxes

API 1104 requires protection of filler metals and fluxes from deterioration and excessive changes in moisture. Low-hydrogen electrodes (classification number ending in 5, 6, or 8) must remain moisture-free. Although it is not mentioned in great detail in API 1104, electrode manufacturers recommend that low hydrogen electrodes be stored in a heated, vented oven at a prescribed temperature after opening their container.

4.2.3 Shielding Gases

4.2.3.1 Types

By definition, an inert gas does not combine chemically with other materials. An active gas does. Inert gases include argon and helium. Active gases include carbon dioxide and oxygen. Gases must be pure and dry, and the gas or mixture of gases for a given procedure must be of welding quality.

4.2.3.2 Storage and Handling

A crucial prohibition with respect to shielding gases involves field intermixing. Never try to force one kind of gas into a cylinder containing another, or bring gases to the arc in multiple hoses.

SECTION 5—QUALIFICATION OF WELDING PROCEDURES FOR WELDS CONTAINING FILLER-METAL ADDITIVES

5.1 Procedure Qualification

Section 3 of this Study Guide defined a welding procedure as an activity undertaken according to a set of specific instructions provided in a welding procedure specification (WPS). Section 3 of this Study Guide also defined a WPS as a document providing the welding variables required for a specific application to assure repeatability by properly trained welders and welding operators.

These definitions are repeated here to set the stage for a detailed discussion of procedure qualification, which involves:

- Developing a welding procedure specification (WPS).
- Establishing a procedure qualification record (PQR) by identifying the essential variables of that WPS.
- Implementing welder testing to verify that the welders are capable of performing the procedure.

API 1104 Section 5.1 also requires destructive testing to determine the quality of the welds, unless the company specifically authorizes a different method.

5.2 Record

API 1104 Section 5.2 requires the company to record the complete details of each qualified procedure, and to keep that record as long as the procedure is in use. The section provides sample forms for this purpose. Figure 1 is a sample WPS. Figure 2 is a sample that can be used as a PQR, a WQTR, or both. The welder who initially qualifies a procedure is also qualifying himself to perform that procedure. Other welders then may qualify to perform the same procedure.

5.3 Procedure Specification

This section of API 1104 lists the components of a WPS:

- **Process** (5.3.2.1)—State the welding process or processes to be used in the welding procedure application and indicate whether they are manual, semiautomatic, or automatic.
- **Pipe and Fitting Materials** (5.3.2.2)—Identify material specification numbers and groupings. To qualify an entire group, you must qualify on the material with the highest specified minimum yield strength in the group.
- **Diameters and Wall Thicknesses** (5.3.2.3)—Provide a range of outside diameters and wall thicknesses with the corresponding diameter and wall thickness groups. API 1104 divides diameters and wall thicknesses into three groups. The code refers you to Section 6.2.2 to learn the characteristics of these groups. You may want to tab page 14, where these groups appear.

- **Joint Design (5.3.2.4)**—Identify the joint type you are using and other characteristics associated with it.
- **Filler Metal and Number of Beads (5.3.2.5)**—Identify the filler metal by its size and classification numbers. Also identify the number and sequence of beads and layers that comprise the weldment.
- **Electrical Characteristics (5.3.2.6)**—Designate the current (AC or DC), the polarity (DC positive or DC negative), and the amperage and voltage range for each electrode, rod, or wire. Typically, amperage and voltage ranges reflect the proven minimum and maximum amperage and voltage that produces an acceptable weld. The inspector should always verify that variables are within manufacturer's recommendations.
- **Flame Characteristics (5.3.2.7)**—Designate the type of flame being used in oxyacetylene welding. Three possibilities exist:
 - Carburizing (also called reducing), in which an excess of fuel gas results in a carbon-rich flame.
 - Oxidizing, in which an excess of oxygen results in an oxygen-rich flame.
 - Neutral, in which the mixture being burned contains equal parts of fuel gas and oxygen.

Also specify the size of the orifice in the torch tip for each size of rod or wire. The inspector should always verify that tip sizes and gas pressures are within manufacturer's recommendations.

- **Position (5.3.2.8)**—Designate whether the pipe is rolled or stationary during welding.
- **Direction of Welding (5.3.2.9)**—Designate whether welding is to be performed uphill from the bottom of the pipe up to the top or downhill from the top of the pipe down to the bottom.
- **Time Between Passes (5.3.2.10)**—Document time between passes, making allowances for cleaning of beads, cooling of base material, and other interpass considerations.
- **Type and Removal of Lineup Clamp (5.3.2.11)**—Document whether a lineup clamp is required, and if so, what kind (external or internal), and how much welding must be done before the clamp is removed. Typically a prescribed amount of tacking or welding must be performed to ensure the stability of the joint before removing the clamp to finish welding.

- **Cleaning and/or Grinding** (5.3.2.12)—Document what tools (grinder, file, descaler, etc.) are to be used for interpass cleaning of weld beads.
- **Pre- and Postheat Treatment** (5.3.2.13)—Document any heat treatment activities involved with the welding process. Heat-treatment temperatures and methods are derived from base metal thickness, alloy chemistry, and in-service requirements. Preheating equalizes the temperature of work pieces to create a larger heat-affected zone (HAZ), reduces the amount of heat necessary to make a weld, reduces the cooling rate, and enhances mechanical properties by diffusing hydrogen. Postheating reduces residual stress, and tempers hardness and brittleness caused by cooling or quenching.
- **Shielding Gas and Flow Rate** (5.3.2.14)—Document the type(s) of gas used, the composition of any mixture, and the range of flow rates. Typically, the range of flow rates are measured in cubic feet per hour (cfh) and are based on the proven minimum and maximum flow rates that produce an acceptable weld.
- **Shielding Flux** (5.3.2.15)—Specify the type of shielding flux in use.
- **Speed of Travel** (5.3.2.16)—Specify the range for speed of travel, in inches per minute (ipm) or millimeters per minute (mm/m), for each pass. Typically, the range for speed of travel reflects the proven minimum and maximum travel speeds that produce an acceptable weld.

5.4 Essential Variables

API 1104 Section 5.4 lists the essential variables. Review each of these essential variables. You should build the WPS around the essential variables because they dictate the extent of change the standard allows for each variable before you must requalify the procedure.

Nonessential variables (those elements of a procedure specification that aren't explicitly listed in Section 5.4) can be adjusted without having to requalify the procedure, but of course you must use sound engineering judgment in any adjustment of nonessential variables. When making any change to a previously released document, essential or nonessential, a revision change is required.

5.5 Welding of Test Joints—Butt Welds

Using the WPS, a joint will be made to test the combination of variables comprising the butt weld procedure.

5.6 Testing of Welded Joints—Butt Welds

With a test weld joint completed, conduct destructive testing according to the provisions of API 1104 Section 5.6.

5.6.1 Preparation

Cut the joint into sections. See API 1104 Table 2 on page 10 and API 1104 Figure 3 on page 11.

API 1104 Table 2 identifies the type and number of test specimens required, based on diameter and wall thickness, to evaluate the welded joint. Be attentive to the footnotes, which change the requirements for specific sizes of pipe.

API 1104 Figure 3 illustrates the location of test butt-weld specimens for procedure qualification testing. It contains four pipe illustrations, each representing a different group of pipe diameters. Think of each illustration as a clock face. In the largest of the pipes, you'll cut the pipe at the two, four, eight, and 10 o'clock positions. The arrows outside the pipes point to locations where you'll take specimens for particular kinds of destructive testing. Subsequent subsections of API 1104 Section 5.6 discuss these tests in detail, describing the preparation of test specimens, the test method, and the requirements to qualify the specimen. The discussion refers you to API 1104 Figures 4 through 7. When viewing these figures, pay close attention to notes and dimensions.

The smaller diameters have relatively less surface area in which to make cuts, and will yield fewer specimens. Thus, for pipes under 2.375 in in diameter, you may need to weld an additional joint to obtain the proper number of test specimens.

The diameter of the pipe governs whether one test weld or two is required. If the pipe diameter is less than 2.375 in [60.3 mm], two test welds must be performed to obtain the required number of test specimens—unless the pipe is less than or equal to 1.315 in [33.4 mm], in which case one full section tensile test is acceptable. However, if tensile testing of a smaller pipe is impractical, the alternative is to weld two pipes and test them using the nick-break and root bend methods.

Footnote 2 in Figure 3 and footnotes a and b in Table 2 specify the rules governing whether you need one test weld or two when qualifying pipe under 2.375 in [60.3 mm].

5.6.2 Tensile-Strength Test

In a tensile-strength test (also called tension test), the specimen is subjected to a pulling load until failure occurs. In other words, a machine pulls the specimen apart until it breaks. Test results are expressed in pounds per square inch (psi) or megapascals (MPa). The formula for calculating tensile strength is load of failure divided by the area of the specimen. API 1104 Figure 4, in Section 5 on page 12, illustrates a tensile-strength test specimen. Note that weld reinforcement is not removed when testing a tensile specimen and the API 1104 tensile specimen is full width and not a reduced section specimen.

5.6.3 Nick-Break Test

The nick-break test is a test that judges the soundness of a weld by fracturing the specimen through the weld so the fractured surface can be examined for the presence of discontinuities. The term “nick-break” refers to the saw-cut notch that initiates fracture, making the specimen easier to break by any convenient method, which may include pulling it apart in a tensile machine, or hitting one end with a hammer while holding the other end firm.

API 1104 Figure 5 on page 12 illustrates a nick-break test specimen with instructions on how to prepare the nick. Figure 8 on page 14 illustrates the exposed surface of such a specimen after breaking.

5.6.4 Root- and Face-Bend Test

The root- and face-bend test is a soundness test in which the individual performing the test places the specimen across the shoulders of a die with the surface to be tested facing down. A plunger positioned above the area of interest is forced toward the die, causing the specimen to bend into a U shape. See API 1104 Figure 9 on page 15 which illustrates the guided bend test jig. It should be noted that the diameter of the plunger and die are specified and not determined by material strength as in other codes. Causes of failure may include brittleness, inclusions, incomplete fusion or penetration, porosity, and/or trapped slag. The root- and face-bend test is for pipes with a wall thickness less than or equal to 1/2 in [12.7 mm].

API 1104 Figure 6 on page 13 illustrates a root- and face-bend test specimen. Note that weld reinforcement must be removed prior to testing.

5.6.5 Side-Bend Test

The side-bend test is similar to the root- and face-bend test, except that the bending occurs on the cross section surface of the specimen. The side-bend test on pipe wall thicknesses over 1/2 in [12.7 mm].

API 1104 Figure 7 on page 13 illustrates a side-bend test specimen. Note that the weld reinforcement must be removed.

5.7 Welding of Test Joints— Fillet Welds

Using the WPS, a joint will be made to test the combination of variables comprising the procedure.

5.8 Testing of Welded Joints—Fillet Welds

With a fillet-weld test joint completed, conduct destructive testing according to the provisions of API 1104 Section 5.7–5.8, pages 9 and 10, and Figures 10 and 11, page 16.

API 1104 Figure 10 on page 16 illustrates two possible configurations of fillet weld joints. One option is a multiple qualification for welders called a branch-on-pipe

connection (see Study Guide Figure 5.1), assembling two pipes in the form of a T (see Study Guide Section 6.3); the other is a fillet weld qualification (see Study Guide Figure 5.2), where two pipes are assembled so they overlap (with one pipe tightly sleeved over the other to create a lap joint).

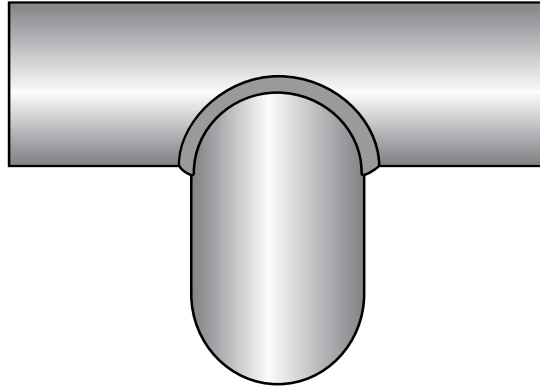


Figure 5.1—Branch-on-Pipe Connection

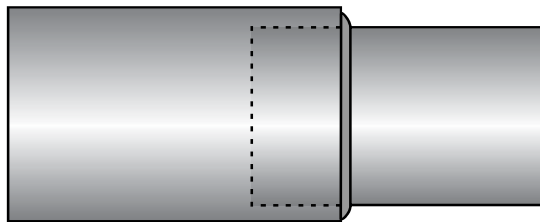


Figure 5.2—Fillet Weld Qualification

5.8.1 Preparation

Testing requires four specimens from the fillet welded pipes, cut at 90° intervals (see API 1104 Figure 10) beginning at the bottom of the pipe, which in the T-joint is also called the crotch.

As with the butt joints, if the pipe is smaller than 2.375 in [60.3 mm], two pipe joints must be welded to obtain the required number of specimens. In this case, two specimens will be cut 180° apart in each of the two pipes.

5.8.2 Method

Note that the specimens cut from the pipe must be long enough so they can be clamped effectively for breaking. They may be broken by any convenient method.

5.8.3 Requirements

The exposed surfaces of all specimens cut from a test weld must show complete penetration (i.e., the weld must extend through the full thickness of the base metal) and complete fusion (i.e., the weld must extend beyond the faying surfaces) for a fillet weld.

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SECTION 6—QUALIFICATION OF WELDERS

6.1 General

Welders must pass a qualification test to show that they can use a given welding procedure. The test should employ the same manipulative techniques that welders will use in production. The welder who qualifies the PQR is also qualified as long as the welder qualification requirements detailed in API 1104 Section 6 are met.

Welders may be tested in any position. A welder who qualifies in the 6G position (see API 1104 Section 6.2.2.f. on page 14) automatically qualifies to weld butt joints and lap fillet welds in all positions. A welder who qualifies in any other position has qualified only for that particular position.

Read the essential variables for welder qualification that appear in API 1104 Section 6.2.2 and Section 6.3.2 carefully. They are different from the essential variables of a PQR and they vary depending on whether the welder is taking one test or two (single vs. multiple qualification). Be sure you understand the differences.

6.2 Single Qualification

Single qualification allows a welder to make fillet or groove welds on pipe in the position tested.

6.2.1 General

In the single qualification test, the welder will weld a test joint consisting of two sections of pipe or pipe nipples. The relationship between the axis of the pipe and the position is important. If the axis of the pipe is:

- Horizontal, and the pipe is rotated, the position is 1GR (note, these are AWS positions, not in API 1104).
- Horizontal, and the pipe is fixed, the position is 5G.
- Vertical, the position is 2G (whether the pipe is fixed or rotated).
- 45° inclined from the horizontal, and the pipe is fixed, the position is 6G.

6.2.2 Scope

This section lists the essential variables for single qualification of welders. Review them carefully. You should build the welder qualification test record (WQTR) around these essential variables because they dictate the extent of change the standard allows for each variable before you must requalify the welders.

Nonessential variables (those elements of a WQTR that aren't explicitly listed in Section 6.2.2.) may be adjusted without having to requalify the welders only to revise the document.

6.3 Multiple Qualification

Multiple qualification allows a welder to weld in all positions, on all wall thicknesses, joint designs, and fittings, and on all (or most) pipe diameters.

6.3.1 General

Multiple qualification requires the welder to complete two test weld joints:

- A butt joint fixed in the 5G or 6G position on pipe with a minimum outside diameter of 6.625 in [168.3 mm] and a minimum wall thickness of 0.250 in [6.4 mm].
- A branch-on-pipe connection, which requires the welder to lay out, cut, and fit two pipes together in the form of a T (see Study Guide Figure 5.1), with all welding performed almost entirely in the overhead position.

6.3.2 Scope

This section lists the essential variables for multiple qualification of welders. Review them carefully, because they differ from the essential variables for single qualification. You should build the welder qualification test record (WQTR) around these essential variables because they dictate the extent of change the standard allows for each variable before you must requalify the welders.

Nonessential variables (those elements of a WQTR that aren't explicitly listed in Section 6.3.2.) can be adjusted without having to requalify the welders.

Testing on pipes 12.750 in [323.9 mm] in diameter or larger qualifies a welder to work on pipes and fittings of any size. Testing on pipes smaller than 12.750 in [323.9 mm] qualifies a welder to work only on pipes equal to or smaller than those on which he qualifies. Thus, a welder qualifying on 10 in [254 mm] pipe may work on pipes 10 in [254 mm] or smaller.

6.4 Visual Examination

Visual examination of the test weld by a qualified inspector must precede any preparation of samples for mechanical testing. If the visual examination discloses that the weld lacks a commonly acceptable weld profile or contains an inherently unacceptable defect or discontinuity, rejection is automatic and another test weld must be prepared. This section also states that, in addition to the objective criteria for rejection, an inspector may reject the weldment at his discretion based on poor workmanship or if too much filler wire protrudes into the interior of the pipe (also called whiskers).

6.5 Destructive Testing

Beware of confusion between the requirements for procedure qualification in Section 5 and those for welder qualification in Section 6. API 1104 presents this information in figures and tables that are similar enough to cause such confusion. Make sure you are on the appropriate table or figure depending on whether you are qualifying a procedure or a welder.

6.5.1 Sampling of Test Butt Welds

Note the differences in requirements for type of testing and sampling locations between API 1104 Figure 3 (procedure qualification) on page 11 and API 1104 Figure 12 (welder qualification) on page 18.

Also note the differences in requirements for the type and number of test specimens between API 1104 Table 2 (procedure qualification) on page 10 and API 1104 Table 3 (welder qualification) on page 19.

API 1104 Table 3 identifies the type and number of test specimens required, based on diameter and wall thickness, to evaluate the welded joint. Be attentive to the footnotes, which change the requirements for specific sizes of pipe.

API 1104 Figure 12 illustrates the location of test butt-weld specimens for welder qualification testing. It contains four pipe illustrations, each representing a different group of pipe diameters. Think of each illustration as a clock face. In the largest of the pipes, you'll cut the pipe at the two, four, eight, and 10 o'clock positions. The arrows outside the pipes point to locations where you'll take specimens for particular kinds of destructive testing. Section 6 refers you back to various subsections of API 1104 Section 5.6 for detailed discussion of these tests, describing the preparation of test specimens, the test method, and the requirements to qualify the specimen. That discussion refers you to API 1104 Figures 4 through 7. When viewing these figures, pay close attention to notes and dimensions.

The smaller pipe diameters have relatively less surface area in which to make cuts, and will yield fewer specimens. Thus, for pipes under 2.375 in in diameter, you may need to weld an additional joint to obtain the proper number of test specimens.

The diameter of the pipe governs whether one test weld or two is required. If the pipe diameter is less than 2.375 in [60.3 mm], two test welds might be needed to obtain the required number of test specimens—unless the pipe is less than 1.315 in [33.4 mm]—in which case one full section tensile test is acceptable. However, if tensile testing of a smaller pipe is impractical, the alternative is to weld two pipes and test them using the nick-break and root bend methods.

Footnote 2 in Figure 12 and footnote a in Table 3 specify the rules governing whether you need one test weld or two when qualifying pipe under 1.315 in [33.4 mm].

6.5.2 Tensile-Strength, Nick-Break, and Bend-Test Procedures for Butt Welds

Prepare tensile-strength, nick-break, and bend-test specimens and conduct the tests in the same manner as for procedure qualification (see API 1104 Section 5.6). For welder qualification, however, you're testing just for soundness, not tensile strength. You may even omit the tensile-strength test for welder qualification as long as you use the nick-break test.

6.5.3 Tensile-Strength Test Requirements for Butt Welds

The goal of the tensile-strength test is to verify that the weld and the parent material are properly fused. The break may occur in the parent material, in the weld, or at the junction of the weld and the parent material. If it occurs in the weld or at the junction, the fractured surface must meet the soundness requirements of API 1104 Section 5.6.3.3.

6.5.4 Nick-Break Test Requirements for Butt Welds

The nick-break test for welder qualification follows the same guidelines as for procedure qualification. See API 1104 Section 5.6.3.3.

6.5.5 Bend Test Requirements for Butt Welds

Under normal conditions, the bend test for welder qualification follows the same guidelines as for procedure qualification. See API 1104 Section 5.6.4.3. However, welds in high-test pipe (pipe made of high-strength materials) may break before they bend to a full U shape. If that happens, the exposed surfaces must meet the requirements for the nick-break test in API 1104 Section 5.6.3.3.

6.5.6 Sampling of Test Fillet Welds

6.5.7 Test Method and Requirements for Fillet Welds

For instructions on cutting, preparing, and testing the specimens from a complete circumferential test weld, see API 1104 Section 5.8 and Figures 10 and 11 on page 16. If the test weld consists of segments of pipe nipples, each segment must supply the same number of specimens.

6.6 Radiography Butt Welds Only

For welder qualification of butt welds, the company may elect to use radiography instead of mechanical testing, but radiography can't be used to choose good or bad portions of the pipe for mechanical testing to qualify or disqualify a welder.

6.7 Retesting

If a welder fails a test but it was determined that he wasn't at fault, he may be allowed to try again. If he fails the second time, he must submit acceptable proof of additional welder training before taking the test again.

6.8 Records

The contractor must maintain records of test results for each welder, and must keep a list of welders and the procedures for which they have qualified. See API 1104 Section 5.2 and Figure 2 on page 6. If the abilities of a welder come into question, he may be required to requalify.

SECTION 7—DESIGN AND PREPARATION OF A JOINT FOR PRODUCTION WELDING

The purpose of API 1104 Section 7 is to establish requirements for production welding and fabrication.

Compared to welding in a test environment, production welding is much more difficult to control. It requires constant attention to the specifics of the welding procedure, which is why it must be performed only by welders who have qualified for that procedure.

7.1 General

API 1104 Section 7 applies the welding procedure specification (WPS) that has been qualified by a procedure qualification record (PQR) to production welding. Welders who have been qualified (WQTR) for that procedure can perform welding on production weldments.

7.2 Alignment

Ideally, the openings at the mating ends of adjoining pipe lengths should line up precisely. In reality, this may not happen, so API 1104 allows for no more than 1/8 in [3 mm] of offset (high/low) between adjoining pipe lengths. Larger variations are acceptable if the pipe you bought meets your purchase specifications. In such cases, any offset must be distributed evenly around the outside of the joint. API 1104 allows a minimal amount of hammering on pipes to obtain proper lineup.

7.3 Use of Lineup Clamp for Butt Welds

In production and fabrication, the use of a clamping device or fixture is a common practice to help bring adjoining pipe lengths into proper alignment. If external clamps are to be removed before completion of the root bead, at least half of the root bead must be in place, uniformly distributed around the outside of the joint. If internal clamps are to be used and removing them before completion of the root bead would be impractical, the internal clamps shall remain until the root pass is complete.

7.4 Bevel

Pipe ends may be beveled by any convenient machine method, except that the company must approve the use of manual oxygen cutting. The design and dimensions of such bevels must conform to the welding procedure specification.

7.5 Weather Conditions

Weather conditions (moisture, wind, and temperature) have a significant effect on the quality of welding. In inclement weather, a temporary shelter may protect the weld and its immediate surroundings. Responsibility for determining how or whether to conduct welding operations lies with the company.

7.6 Clearance

Welding on pipe above ground requires that the joint be free from obstructions inhibiting the welder's ability to move around the pipe for at least 16 in [400 mm] in all directions. Welding on pipe in a trench requires an excavation large enough to give the welder working space.

7.7 Cleaning Between Beads

Beads must be cleaned, using any convenient method allowed by the welding procedure. Semiautomatic or mechanized welding requires grinding between passes to remove surface discontinuities. When silicon in the weld puddle forms heavy glass deposits (primarily in GMAW) the company may request the removal of these deposits between passes.

7.8 Position Welding

In position welding, the pipe is stationary and the welder works around it. In roll welding, the pipe is rotated while the welder works at or near the top of the joint. The company decides which method to use.

7.9 Roll Welding

Both methods have the same weld profile requirements, with face reinforcement and underfill limited to 1/16 in [1.6 mm]. The face of the completed weld should be about 1/8 in [3 mm] wider than the groove opening.

In position welding, don't start two beads in the same location. Instead, sequence the individual layers of a multipass weld to avoid creating poor fusion where multiple starts occur.

7.10 Identification of Welds

Typically, the contractor supplies a stamp or engraving tool that welders use to identify their work. API 1104 requires such identification.

7.11 Pre- and Postheat Treatment

Preheating may be necessary to weld high-strength or thick materials or when welding is done in wet and/or cold weather. Postheating may be necessary to control distortion and relieve stress in high-strength materials. The welding procedure will specify the circumstances for use of either or both techniques.

SECTION 8—INSPECTION AND TESTING OF PRODUCTION WELDS

The company may dictate what kind of inspection will occur, when, and how often, and may require that inspectors demonstrate the effectiveness of the inspection procedures being used, and their ability to use those procedures. The company must keep detailed records of inspections and the certification of the personnel conducting them.

If radiographic inspection is used, the welds may be evaluated according to API 1104 Section 9 or Appendix A. The latter is for girth welds only, and requires more extensive interpretation. The certification of nondestructive testing personnel must be to the American Society for Nondestructive Testing (ASNT), Recommended Practice No. SNT-TC-1A or the ASNT Central Certification Program. API 1104 also recognizes other nationally recognized programs for qualification and certification with company approval. ASNT requires inspectors to have specified levels of education and training, experience, and performance on qualification exams.

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SECTION 9—ACCEPTANCE STANDARDS FOR NONDESTRUCTIVE TESTING

Nondestructive testing does not hurt the serviceability or function of a part. When performing a nondestructive examination, the inspector may find imperfections or discontinuities which may or may not require rejection of the part in question. To determine the disposition of a part, the inspector must compare the discontinuities he has found in that part with the criteria established in API 1104 Section 9.

To find discontinuities for evaluation, the inspector must understand how they present themselves using the inspection method(s) required by the company.

9.1 General

Section 9 presents acceptance standards for radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing methods to find defects and discontinuities. Each has a source of probing energy or a medium that, upon encountering a defect in the part, changes in some detectable way.

Radiographic testing (RT) is based on the distinction between transmission and absorption of x-ray and gamma radiation, producing images captured on film. Areas where material is thinner or less dense will transmit more radiation to the film, producing darker images; areas where material is thicker or denser will transmit less radiation to the film, producing lighter images. Defects and discontinuities cause unexpected patterns of lightness or darkness, which radiographic inspectors are trained to interpret and evaluate. Their training enables them to accept or reject an item being inspected.

Magnetic particle testing (MT) employs magnetizing current and iron powder to locate defects and discontinuities in ferromagnetic materials. Unlike water currents in a stream that flow around obstructions, currents in a magnetic field bump against obstructions and then leak into the atmosphere. This leakage attracts the particles of iron powder. Sound materials that do not contain defects or discontinuities and do not leak magnetic current do not attract magnetic particles. In MT, the inspector seeks places where particles accumulate. Depending on their nature and size, the defects and discontinuities may cause the item to be rejected or explored further.

Liquid penetrant testing (PT) relies on the ability of certain types of liquids to enter into surface voids and crevices by capillary action, and remain there when the surface liquid is removed. Then a contrast medium reveals the penetrant remaining in the voids and crevices by blotting or a reverse capillary action. The contrast medium may be a nonaqueous liquid, powder, or ultraviolet light.

Ultrasonic testing (UT) involves the propagation of sound waves through materials, and capture of the reflected echo from density changes in the material being inspected. These changes appear on a display screen as peaks and valleys. The inspector compares them to a reference standard to determine acceptability.

Visual inspection (VT), as practiced by trained personnel, is the basic element of any quality control system. It involves examining materials, with or without magnification

or remote examination devices such as mirrors or fiber optics. VT should precede other inspection methods. An effective VT program—performed before, during, and after welding operations to ensure adherence to relevant standards and correct procedures—should find most defects that a more costly nondestructive test method later may disclose.

9.2 Rights of Rejection

A weld that passes nondestructive testing may still be rejected by the company if in their opinion the imperfection can be detrimental to the weld.

9.3 Radiographic Testing

9.3.1 Inadequate Penetration without High-Low (IP)

9.3.2 Inadequate Penetration Due to High-Low (IPD)

High-low refers to misalignment of adjoining pipe sections. Inadequate penetration, also called incomplete joint penetration, can occur with or without high-low. IP and IPD are joint root conditions where the weld metal does not extend entirely through the thickness of a groove joint. Causes of IP include improper technique, improper joint configuration, or excessive contamination. Radiographic images of IP and IPD typically appear as a dark area with well defined straight edges that follow the root face down the center of the weldment. See API 1104 Figure 13 on page 22 for IP, and API 1104 Figure 14 on page 24 for IPD.

9.3.3 Inadequate Cross Penetration (ICP)

Inadequate cross penetration occurs when welding is being performed from both sides of the joint and the two beads don't meet within the joint. Causes of ICP include improper technique and improper joint configuration. The radiographic image of ICP typically appears as a dark straight line in the center of the weld, because it has less material there. See API 1104 Figure 15 on page 24. Also see Study Guide Figure 9.1.

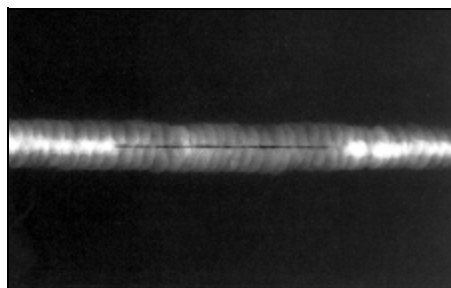


Figure 9.1—Inadequate Cross Penetration

9.3.4 Incomplete Fusion (IF)

9.3.5 Incomplete Fusion Due to Cold Lap (IFD)

Incomplete fusion is a weld discontinuity in which fusion does not occur between weld metal and fusion faces or adjoining weld beads. API 1104 differentiates between

IF (incomplete fusion open to the surface) and IFD (incomplete fusion below the surface). In both cases, the most common causes include improper manipulation of the electrode by the welder and improper joint configuration. Radiographic images of IF and IFD typically appear as a dark line or lines oriented in the direction of the weld.

9.3.6 Internal Concavity (IC)

Internal concavity, also called suckback, is a root surface condition in which the weld bead surface is somewhat below the inside surface of the pipe wall. Causes of IC include improper technique, and excessive heating and melting of the root pass during the welding of the second pass. The radiographic image of IC typically appears as a darker area with irregular edges and is quite wide in the center of the image.

9.3.7 Burn-Through (BT)

A burn-through is a localized collapse of the molten pool leaving a depression or crater type discontinuity in the root area of the weld. Causes of BT include improper technique, excessive amperage, and improper joint configuration. The radiographic image of BT typically appears as dark spots often surrounded by light areas.

9.3.8 Slag Inclusions (ESIs and ISIs)

A slag inclusion is an entrapment of a nonmetallic solid in the weld metal or between the weld metal and the parent material. Two kinds of slag inclusions exist: elongated (ESI) and isolated (ISI). ESIs typically appear at the fusion zone. They are linear and may be continuous, broken, or repetitive. ISIs have an irregular round shape and may appear anywhere in the weld. Causes of SI include improper technique, improper manipulation of the electrode, and insufficient cleaning of weld beads. The radiographic image of SI typically appears as dark jagged asymmetrical shapes within the weld or along the weld joint areas.

9.3.9 Porosity

Porosity is the result of gas entrapment in the solidifying metal. It takes many shapes on a radiograph but often appears as dark round or irregular spots or specks appearing singularly, in clusters or rows. Porosity can be elongated and may have the appearance of having a tail. API 1104 Section 9.3.9 distinguishes between individual or scattered porosity (P), cluster porosity (CP), and hollow bead porosity (HB). Causes of porosity include contaminants or moisture in the weld zone, improper shielding of the welding arc, and improper travel speed.

9.3.10 Cracks (C)

A crack, either longitudinal or transverse, is a linear discontinuity with sharp end conditions. Cracks are the most critical discontinuity because of their tendency to grow and propagate under stress. Cracks are characterized by their location within the weld,

and whether they are hot or cold (i.e., whether they developed during welding or after cooling). In API 1104, the only cracks that may be acceptable after further evaluation and repair are shallow star or crater cracks that appear at the end of a weld bead and are less than 5/32 in. API 1104 considers all other cracks as irreparable defects. Causes of cracks in general include improper heating and cooling, residual stress, and improper selection of procedures for the materials involved in the weld. Causes of star and crater cracks in particular include improper termination of the weld bead, and poor choice of filler metals. The radiographic image of a crack typically appears as jagged and often faint irregular dark lines.

9.3.11 Undercutting (EU and IU)

Undercutting is a groove melted into the base metal during welding. Internal or root undercut is in the base metal next to the root of the weld. In the radiograph it will appear as a dark irregular line offset from the centerline of the weldment. Undercut is not as straight edged as lack of penetration because it does not follow a ground or prepared edge. External undercut is found in the base metal next to the face of the weld. In the radiograph it appears as a dark irregular line along the outside edge of the weld area. Causes of undercutting include improper manipulation of the electrode by the welder, excessive amperage, and improper travel speed. You should not find external undercut with a radiograph; it should be found visually before radiography occurs. Use the length criteria in API 1104 Section 9.3.11 in conjunction with the depth criteria in API 1104 Table 4 on page 30 to determine whether an instance of undercutting is acceptable or rejectable.

9.3.12 Accumulation of Imperfections (AI)

API 1104 allows the inspector to add the dimensions of all defects and discontinuities except incomplete penetration due to high-low and undercut to determine acceptability or rejection.

9.3.13 Pipe or Fitting Imperfections

If radiography discloses defects or discontinuities in pipe or fittings, they must be reported to the company.

9.4 Magnetic Particle Testing

When using magnetic particle inspection, the inspector should be careful to distinguish between relevant accumulations of particles due to defects and irrelevant accumulations due to inherent characteristics of the part. If the inspector isn't sure what an indication is, he must condition the surface and re-examine it. The inspector must ascertain which imperfections are linear and which are rounded, because linear indications are more prone to propagation. If magnetic particle inspection gives ambiguous results, other nondestructive testing methods may be used to determine the disposition of the part. If magnetic particle testing discloses imperfections in pipe or fittings, they must be reported to the company.

9.5 Liquid Penetrant Testing

When using liquid penetrant inspection, the inspector should be careful to distinguish between relevant indications due to defects and irrelevant indications due to characteristics of the part. If the inspector isn't sure what an indication is, he must condition the surface and re-examine it. The inspector must ascertain which imperfections are linear and which are rounded, because linear indications are more prone to propagation. If liquid penetrant inspection gives ambiguous results, other nondestructive testing methods may be used to determine the disposition of the part. If liquid penetrant testing discloses imperfections in pipe or fittings, they must be reported to the company.

9.6 Ultrasonic Testing

When using ultrasonic inspection, the inspector should be careful to distinguish between relevant indications due to defects and irrelevant indications due to the geometry of the part. If the inspector isn't sure what an indication is, he must condition the surface and re-examine it. The inspector must distinguish between linear, transverse, and volumetric indications, because linear indications are the most prone to propagation. If ultrasonic inspection gives ambiguous results, other nondestructive testing methods may be used to determine the disposition of the part. If ultrasonic testing discloses imperfections in pipe or fittings, they must be reported to the company.

9.7 Visual Acceptance Standards for Undercutting

As noted above in API 1104 Section 9.3.11, use the length criteria in that section in conjunction with the depth criteria in API 1104 Table 4 on page 30 to determine whether an instance of undercutting is acceptable or rejectable.

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SECTION 10—REPAIR AND REMOVAL OF DEFECTS

10.1 Authorization for Repair

10.1.1 Cracks

As noted in API 1104 Section 9.3.10, the only cracks that may be acceptable after further evaluation and repair are shallow star or crater cracks that do not exceed 5/32 in.

Cracks other than shallow star or crater cracks may be repaired if the total length of the crack is less than 8% of the weld length, the repair is authorized by the company, and an approved and qualified *repair* welding procedure is used.

10.1.2 Defects Other Than Cracks

The company must authorize repair of defects in the root and filler beads, but need not authorize repair of cover pass defects. Two conditions require a qualified repair welding procedure: when the repair employs a welding process different from that of the original weld, and when a previously repaired area is repaired again.

10.2 Repair Procedure

A qualified repair procedure must include the minimum requirements listed in API 1104 Sections 10.2.1 through 10.2.6, and destructive testing is necessary to prove that the procedure works. The extent of testing is up to the company.

Once a weld is repaired, it must be inspected in the same manner as the original weld and meet the requirements of API 1104 Section 9. Deciding whether to have just the repaired area or the entire weld inspected is up to the company. The welder performing the repairs must be qualified, and the technician supervising the welder must have repair experience.

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SECTION 11—PROCEDURES FOR NONDESTRUCTIVE TESTING

Some of the technologies involved in nondestructive testing of welds—especially radiography and ultrasound—are well-known in medicine and other fields, and they have similar applicability to welding. Just as welding and destructive testing require the writing of qualified procedures, so does nondestructive testing.

11.1 Radiographic Test Methods

The many subsections of API 1104 Section 11.1 explain how to produce radiographic images using low-energy nonparticulate radiation (x-rays or gamma rays).

11.1.1 General

API 1104 Section 11.1.1 discusses film characteristics (appropriate density, clarity, and contrast) and the use of specific quality criteria to evaluate images using an image quality indicator (IQI), also called a penetrameter—a device that measures film quality using the image of a reference standard.

Film quality is a vital prerequisite to determining the quality of the part. You need a good film with a clear image to determine whether you have a good part.

11.1.2 Details of Procedure

API 1104 Section 11.1.2 gives the details of procedures for film radiography, and for other imaging media. When you write radiographic testing procedures, they must include the items listed in this section for film, or for the alternative imaging medium.

11.1.3 Exposure Geometry

Exposure geometry is the relationship between the radiation source, the part being inspected, and the film or other medium.

11.1.4 Type of Image Quality Indicators

The IQI used for radiographic testing must conform to either of two standards—ASTM E 747 or ISO 1027—and must be radiographically similar to the material being welded. The company must choose which type of IQI to use.

11.1.5 Selection of Image Quality Indicators

IQIs are chosen for a particular application based on the thickness of the weld, plus any weld reinforcement or melt through. Knowing the weld thickness and the required IQI type, the inspector can use API 1104 Tables 5 and 6 on page 33 to determine the essential wire diameter for the application. The essential wire diameter indicates which of the wires on the IQI must appear clearly across the entire area of interest.

11.1.6 Placement of Image Quality Indicators

Three different IQI placement options exist. The first, and most common, is to place the IQI across the weld, spaced equally around the pipe on the source side or film side of the pipe. When placing IQI across the weld is impractical due to weld reinforcement or profile, a separate block of similar material (also called a shim) is used to elevate the IQI to a height equal to the top of the weld reinforcement. The third location option, placing the IQI on a heat shield, is used primarily to radiograph hot materials.

11.1.7 Production Radiography

Technicians interpreting radiographic images must be certified as Level II or Level III according to the requirements of the ASNT Recommended Practice SNT-TC-1A or equivalent. Unless the company requests reporting of all imperfections, the inspector must report only defects that are rejectable according to API 1104 Section 9.6.

11.1.8 Identification of Images

Lead letters or numbers must be placed on the part being inspected to identify the image. This is particularly important when a single weld is represented by multiple radiographs because the identification markers will distinguish between the end of one radiograph and the start of the next.

11.1.9 Storage of Film and Other Imaging Media

Improper storage can damage unexposed film. API 1104 Section 11.1.9 provides the requirements for film storage and the recognizable characteristics of film damaged due to improper storage.

11.1.10 Film Density

The light area representing the image of a weld on a film must provide enough contrast from the dark area representing the image of the base metal. API 1104 Section 11.1.10 provides the requirements for determining that adequate density exists to ensure proper viewing of the film's image. The best way to view radiographic film is with equipment that transmits light through the film to help the inspector see the image of the part being inspected. API 1104 Section 11.1.10.2 gives the requirements for film viewing equipment; Section 11.1.10.3 describes the characteristics of suitable film viewing facilities.

11.1.11 Image Processing

The company may request that the film be readily viewable for at least three years.

11.1.12 Image Processing Area

All of the radiographic testing equipment and the area where image processing occurs must be kept clean.

11.1.13 Radiation Protection

The radiographer is responsible for all aspects of radiation safety. Because the gamma ray and x-ray radiation used in radiographic testing is nonparticulate electromagnetic radiation unaffected by gravity, effective shielding requires lead or a significant thickness of concrete or steel. RT work areas must be properly posted and cleared of all nonessential personnel.

11.2 Magnetic Particle Test Method

A procedure for magnetic particle testing must be written, qualified by demonstration, and accepted by the company prior to use. API 1104 states that the MT procedure must comply with ASTM E 709, *Standard Guide for Magnetic Particle Examination*, published by the American Society for Testing and Materials.

ASTM E 709 is a tutorial that supports ASTM E 1444, *Standard Practice for Magnetic Particle Testing*. Although API 1004 doesn't mention the latter document, both are necessary for comprehensive guidance on the methods and quality control requirements for magnetic particle examination.

11.3 Liquid Penetrant Test Method

A procedure for liquid penetrant testing must be written, qualified by demonstration, and accepted by the company prior to use. API 1104 states that the PT procedure must comply with ASTM E 165, *Standard Test Methods for Liquid Penetrant Examination*, published by the American Society for Testing and Materials.

ASTM E 165 is a guideline for penetrant processing that supports ASTM E 1417, *Standard Practice for Liquid Penetrant Testing*. Although API 1104 doesn't mention the latter document, both are necessary for comprehensive guidance on the methods and quality control requirements for liquid penetrant testing.

11.4 Ultrasonic Test Methods

API 1104 Section 11.4 applies to new and in-service circumferential butt welds (groove welds in a butt joint). A detailed procedure must be developed, qualified by demonstration, and agreed upon by the contractor and company. The pipe being inspected with UT must be uncoated and the inspector should be aware of surface conditions that can interfere with scanning.

11.4.2 Details of Procedure

API 1104 Section 11.4.2 gives the details of written procedures for ultrasonic testing of welds. When you write ultrasonic testing procedures, they must include all of the application details listed in this section.

11.4.2.1 General

The procedures furnished to the company should include all of the variables for ultrasonic inspection and should be represented by sketches for such things as joint design, scanning patterns, and inspection results.

11.4.2.2 Ultrasonic Procedure

The following details comprise the ultrasonic testing procedure:

- a. Distinguish between welds and joints. Types of welds include fillet, groove, spot, plug, seam, etc. Types of joints include butt, lap, tee, edge, and corner.
- b. List the base materials according to the requirements of API 1104 Section 4. Identify materials by their ASTM or API specification number.
- c. The ultrasonic scanning tool (transducer) must slide freely across the base material, so the surfaces of materials subject to UT must be free from such things as spatter or weld reinforcement.
- d. Welding and fabrication involve many steps where UT may be called for. The procedure must define clearly the stage of the welding or fabricating operation.
- e. Identify the manufacturer and list the specifications of all UT instruments and accessories. Scanning tools for various types of materials and for different angles at which sound can be projected through the part are available from a number of UT equipment manufacturers.
- f. Specify whether the UT process is manual (where the operator has full control of scanning) or automatic (where the operator applies no manual scanning techniques). An example of automatic UT is the immersion method in which parts are tested under water.
- g. Identify the manufacturer and product number of the couplant, the gel-like substance that lubricates the surface of the material to be scanned and provides an airtight bond between the transducer and the surface.
- h. In the manual mode of UT inspection, a part may be scanned in many ways. Describe the specific characteristics of the scanning process necessary to ensure scanning of the entire surface so the returning echo can be evaluated. These characteristics include angle and frequency of sound waves, the temperature of the test part, scanning patterns, the speed at which the part is scanned, and reference points or markings identifying the geometric characteristics of the joint or part.
- i. Use reference standards of similar material and geometry to qualify techniques and calibrate the UT process, and provide sketches and cross-sectional views of these standard blocks.

- j. Calibration of UT equipment is essential, to verify that the UT equipment and procedures are working properly, and to provide standard points of reference to compare echoes from actual inspections to those performed on reference standards during calibration. The UT procedure must specify when to calibrate, what calibration reference standards to use, sensitivity-level requirements to achieve, and the required steps involved with calibration.
- k. The amount of sensitivity (sound is measured in decibels) above what was used on the reference standard must be recorded.
- l. Establish and record acceptable and rejectable height levels for a return echo peak. Sound waves projected into a part will bounce back to their source from different portions of the part at different times, and these return echoes depict geometric differences in the part. The return echoes appear on the equipment screen as peaks, which will vary in screen height depending on their strength, differences within portions of a part, and the instruments' sensitivity settings.
- m. Identify the method of recording the inspection results.
- n. Include a sample inspection reporting form.

11.4.3 Ultrasonic Testing Personnel Requirements

Only Level III UT inspectors are qualified to develop application techniques and procedures, which must include qualification by demonstration.

Level II and Level III UT inspectors are qualified to calibrate equipment, follow a procedure to perform testing at the company's request, and interpret test results by determining acceptability of circumferential welds according to the criteria for defects provided in API 1104 Section 9.6.

11.4.4 Demonstration of the Testing Procedure

Prior to a UT procedure being used, it must be demonstrated and accepted by the company. The demonstration involves creation of reference weldments similar to production welds, using an approved welding procedure. These reference welds, specifically designed with defects and geometrical differences such as joint configuration and repaired areas, are then used to demonstrate that the UT procedure will effectively find the conditions deliberately created in the reference weldment.

11.4.5 API Sensitivity Reference Standard

The sensitivity reference standards for use in measuring the screen height of return echoes from known geometric conditions (the notches in the block) must be made of materials similar to those in production applications. Figures 21A, 21B, and 21C on pages 35 and 36 in API 1104 represent these sensitivity reference standards. The peak

on the instrument screen that return echoes from these notches produce must be at least 80% of the screen height. Adjusting the equipment to meet this requirement will ensure proper calibration.

11.4.6 Parent Material Ultrasonic Testing

Before ultrasonic testing of a completed pipe weld, the UT inspector must conduct a compression wave test on the parent metal adjacent to the weld to locate any reflectors in the parent material that may interfere with the weld metal inspection. Once the inspector finds the parent material to be sound or documents any reflectors in the parent metal, he may inspect the weld.

11.4.7 Scanning and Evaluation Level

Section 11.4.7 in API 1104 identifies the scanning techniques and screen height requirements for manual compression wave testing of the parent material, and for manual and automated testing of welds. Inspection of the parent material and inspection of the weld must be performed and documented independently.

11.4.8 Production Ultrasonic Testing

UT inspectors are required to report only rejectable indications (defects), unless the company specifically requests reporting of all indications, including indications not defined as rejectable (discontinuities). See API 1104 Section 9.6 for a detailed discussion of UT indications.

11.4.9 Identification of Reported Indications

Section 11.4.9 of API 1104 lists the information required to report a defect or other indication.

SECTION 12—MECHANIZED WELDING WITH FILLER METAL ADDITIONS

Welding procedures for a given welding process vary with the level of automation involved. Follow the correct section of API 1104 for the process and automation level you are using.

12.1 Acceptable Processes

API 1104 Section 5 discusses welding procedures for manual and semiautomatic processes.

API 1104 Section 12 discusses welding procedures for mechanized welding with filler metal additions, for the processes listed in Section 12.1: submerged arc welding, gas metal arc welding, gas tungsten arc welding, flux cored arc welding, and plasma arc welding.

API 1104 Section 13 discusses welding procedures for automatic welding without filler-metal additions. It applies only to the flash butt-welding process.

12.2 Procedure Qualification

Significant differences between API 1104 Section 5 and API 1004 Section 12 include:

- Section 12 applies to submerged arc welding, gas metal arc welding, gas tungsten arc welding, flux cored arc welding, and plasma arc welding only if you perform them in a mechanized mode. Section 5 applies if you perform these processes in a manual or semiautomatic mode.
- Section 12 gives the option to weld two pipes of any length for testing as long as they have fully welded joints. Section 5 says a butt-joint weld must join two pipe nipples (two short pieces of pipe).
- Section 12 refers you to Section 5 for destructive testing requirements and to Section 9 for nondestructive testing requirements. The major difference is that Section 12 does not require nick-break testing to qualify the procedure.

12.3 Record

Section 12.3 refers you to API 1104 Figures 1 and 2 on pages 5 and 6 for recommended WPS, PQR, and WQTR forms.

12.4 Procedure Specification

Section 12 lists the variables for a mechanized welding procedure. Many are the same as the variables for manual and semiautomatic welding in Section 5, but some differences exist:

- Section 12 does not provide suggested groupings for diameter and wall thickness to qualify a procedure, but it does provide such groupings to qualify the equipment and operators.

- Section 12 says to put the number and sequence of beads with the wall thickness group on the welding procedure form. However, Section 12 also advises the use of API 1104 Figure 1 in Section 5 as a model for the welding procedure form, and that model places the number and sequence of beads with the filler metal.
- In Section 12, flame characteristics are not a variable.
- Section 12 does not specify a minimum percentage of root bead welding before removing a lineup clamp.
- Section 12 says to describe the requirements for joint end and interpass cleaning, but does not refer to tools. Section 5 says to describe the tools to use for cleaning and/or grinding, but does not refer to cleaning requirements.
- In Section 12 but not in Section 5, the width to be heated for preheat and postheat is a requirement.
- Section 12 requires the AWS classification number or brand number for shielding flux. Section 5 requires only the type of flux.
- Section 12 requires the inspector to recognize and document other important factors necessary to produce a good weld, and gives examples. Section 5 does not explicitly state this requirement.

12.5 Essential Variables

API 1104 Section 12.5 lists the essential variables. Review each of these essential variables. You should build the WPS around the essential variables because they dictate the extent of change the code allows for each variable before you must requalify the procedure.

Nonessential variables can be adjusted without having to requalify the procedure, but of course you must use sound engineering judgment in any adjustment of nonessential variables.

12.6 Qualification of Welding Equipment and Operators

Section 12.6 provides for testing by destructive and/or nondestructive methods, and refers you to Section 6 for destructive testing requirements. The major difference is that Section 12 does not require nick-break testing to qualify the equipment and operators.

Read carefully the essential variables for the welding operator that appear in API 1104 Section 12.6.1. They are different from the essential variables of a PQR. Be sure you understand the differences. You should build the welding operator qualification test record around these essential variables because they dictate the extent of change the standard allows for each variable before you must requalify the operators. Nonessential variables not explicitly listed in Section 12.6.1 can be adjusted without having to requalify the operators.

12.7 Records of Qualified Operators

The contractor must maintain records of test results for each operator, and must keep a list of operators and the procedures for which they have qualified. See API 1104 Section 5.2 and Figure 2 on page 6. If for any reason the abilities of an operator come into question, he may be required to requalify.

12.8 Inspection and Testing of Production Welds

The content of Section 12.8 consists solely of references to other sections of API 1104.

12.9 Acceptance Standards for Nondestructive Testing

The content of Section 12.9 consists solely of references to other sections of API 1104.

12.10 Repair and Removal of Defects

The content of Section 12.10 consists solely of references to other sections of API 1104.

12.11 Radiographic Testing

The content of Section 12.11 consists solely of references to other sections of API 1104.

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SECTION 13—AUTOMATIC WELDING WITHOUT FILLER-METAL ADDITIONS

- 13.1 Acceptable Processes** As noted above, API 1104 Section 13 discusses welding procedures for automatic welding without filler-metal additions. It applies only to the flash butt-welding process.
- 13.2 Procedure Qualification** API 1104 Section 13.2 requires at least two test welds. It requires radiographic and other nondestructive testing first, followed by destructive testing—the tensile, nick-break, and side-bend tests.
- API 1104 Table 7 on page 40 lists the type and number of test specimens required for procedure qualification. This requirement depends on the outside diameter of the pipe, with larger pipe diameters requiring more specimens.
- API 1104 Section 13.2.3.3.1 contains preparation requirements for nick-break testing. Compared to Sections 5 and 6, these specimens are wider, and more specimens are required.
- 13.3 Record** API 1104 Section 13.3 contains record-keeping requirements similar to those in API 1104 Sections 5 and 12, although many of the categories in API 1104 Figures 1 and 2 don't apply to the flash butt-welding process.
- 13.4 Procedure Specification** API 1104 Section 13.4 lists all of the pertinent information for a flash butt-welding procedure specification.
- 13.5 Essential Variables** API 1104 Section 13.5 lists the essential variables, but does not give a range of acceptability for these variables. Therefore, *any* change in any of the variables requires requalification of the procedure.
- Nonessential variables (those elements of a procedure specification that aren't explicitly listed in Section 13) can be adjusted without having to requalify the procedure, but of course you must use sound engineering judgment and create a revision in any adjustment of nonessential variables.
- 13.6 Qualification of Equipment and Operators** Section 13.6 calls for qualification of each welding unit (machine) and each operator through testing by both radiographic and mechanical (i.e., destructive) methods, and refers you to Section 13.2 for specific testing requirements.
- 13.7 Records of Qualified Operators** The contractor must maintain records of test results for each operator, and must keep a list of operators and the procedures for which they have qualified. See API 1104 Section 5.2 and Figure 2 on page 6. If for any reason the abilities of an operator come into question, he may be required to requalify.

13.8 Quality Assurance of Production Welds

The company may dictate what kind of inspection will occur, when, and how often. Rejection may be based on a strip-chart recording, nondestructive testing, excessive reinforcement, and deviation from the acceptable postheat treatment ranges specified in the WPS.

13.9 Acceptance Standards for Nondestructive Testing

Isolated slag inclusions (ISIs) are defects if they exceed the dimensions stated in API 1104 Section 13.9.2. Other defects are unacceptable no matter how small they are.

13.10 Repair and Removal of Defects

The company must agree to the repair of a weld. You can't do so much grinding to remove surface defects that you reduce the wall thickness below its minimum limit. Otherwise, you're allowed to grind, chip, and/or gouge to remove defects, and then to repair the weld as described in API 1104 Section 10, except that porosity in a flash butt weld is not repairable.

If you are repairing defects other than porosity in a flash butt weld and porosity occurs in that repair, Section 13.10.2 directs you to follow the limits in API 1104 Section 9.3.8.2 or Section 9.3.8.3. However, those subsections refer to slag inclusions; Section 9.3.9.2 and 9.3.9.3 refer to porosity.

13.11 Radiographic Procedure

This section refers you to API 1104 Section 11.1.

APPENDIX A—ALTERNATIVE ACCEPTANCE STANDARDS FOR GIRTH WELDS

A.1 General

The normal method of determining a weld's acceptability is to identify the length of defects within the completed weld. Appendix A in API 1104 offers an alternative way to determine acceptance standards by means of fracture mechanics analysis and fitness for duty. These alternative acceptance methods have an increased tolerance for imperfections, but require additional testing to ensure that the welds are fit for duty. These alternative methods apply only to circumferential pipe girth welds for which NDT is required.

Unlike the previous sections of API 1104, Appendix A uses only values expressed in U.S. Customary (inch-pound) Units, but use of SI (metric) Units is permitted.

A.2 Stress Analysis

The use of Appendix A requires a determination of the various conditions that subject a pipeline to internal stress.

- Axial stresses can occur from welding and can cause internal stress to exceed the material's yield strength or tensile strength, resulting in distortion or cracking.
- Cyclic stress can occur over the life of the pipeline due to hydrostatic testing, installation stresses (preload), and thermal, seismic, and subsidence stresses.
- The growth rate and stress concentration of normally benign weld imperfections can increase due to excessive levels of contaminants such as CO₂ and H₂S in products carried by pipelines.
- Sustained loads on pipelines can cause a dormant imperfection to become critical, especially in the presence of contaminants such as H₂S, hydroxides, nitrates, or carbonates in products carried by pipelines.
- Dynamic loading occurs due to repetitive changes in stress loading in the pipeline and its components when automatic actuating valves repeatedly open and close.

A.3 Welding Procedure

API 1104 Section A.3.1 requires qualification of welding procedures according to Section 5 for manual and semiautomatic welding and Section 12 for mechanized welding. During tensile testing, the specimen must not fail in the weld. In addition, crack-tip-opening displacement (CTOD) testing—a form of impact testing to measure the material's toughness—is required.

The welding procedures applicable to this annex are significantly more rigorous than those in Section 5 and Section 12, and the WPS essential variables are different. API 1104 Section A.3.1 lists the essential variables for the WPS and any change in those variables requires requalification of the procedure.

Qualification of welding procedures to be used with this appendix shall be in accordance with Section 5 or 12 with additional mechanical testing properties in accordance with A.3.2 (Reduced section tensile, Charpy V notch, CTOD).

To test girth welds in pipe according to this appendix, the only acceptable fracture toughness test is CTOD, performed according to the British Standard BS 7448: Part 2 (the first worldwide standard that applies specifically to weldments). API 1104 Section A.3.2 provides acceptance criteria and additional procedural information.

To qualify the girth-welding WPS requires testing of the weld metal and the heat-affected zone (HAZ), with three specimens from each area. If one specimen fails to meet fracture toughness requirements, another three from the same area must be tested.

A.4 Qualification of Welders

Welders must be qualified according to API 1104 Section 6.

For mechanized welding, the welding unit and operator must be qualified according to API 1104 Section 12.6.

A.5 Inspection and Acceptable Limits

To locate imperfections, whether planar or rounded, use inspection methods capable of determining an imperfection's length, height, and depth. For rounded imperfections only, API 1104 Table A-1 on page 55 provides alternative criteria.

Evaluate arc burns from inadvertent arc strikes or improper grounding according to API 1104 Table A-4 on page 59. When multiple imperfections exist in close proximity, they may behave as one. Therefore, API 1104 Figure A-6 provides criteria for determining whether one imperfection will interact with another to create a more serious condition.

A.6 Record

The type, location, and dimensions of all accepted imperfections must be recorded. This information must be stored with radiographs or other pipeline inspection records.

A.7 Example

Section A.7 of API 1104 presents a case study of a fracture toughness test on a girth weld on a large-diameter pipe. This example contains nine steps followed by an evaluation of imperfections. For the nomenclature and definitions of applicable symbols, see API 1104 Section A.9.

A.8 Repairs

Defects (i.e., imperfections deemed unacceptable) according to API 1104 Appendix A must be repaired or removed according to API 1104 Sections 9 and 10.

A.9 Nomenclature

API 1104 Section A.8 defines the nomenclature and symbols used in the API 1104 Appendix A.

APPENDIX B—IN-SERVICE WELDING**B.1 General**

“In-service” means operating. This appendix applies to in-service pipelines in which crude petroleum, petroleum products, or fuel gases are pressurized and/or flowing. Work on such pipelines involves special safety considerations to prevent leaks and explosions. Therefore, only fillet welds are possible in an in-service setting. If any conflict arises between the main body of API 1104 and this appendix, the appendix should govern.

Welding or installing accessories or attachments on in-service pipelines entails two major concerns: burn-through for thin-walled piping, and hydrogen cracking. Although API 1104 Appendix B explains how to prevent both of these problems, its major focus is on hydrogen cracking. Study Guide Table B.1 shows the three major causes of hydrogen cracking.

Table B.1
Causes of Hydrogen Cracking

Condition	Cause of Condition	Preventive Measures
Hydrogen in the weld	Presence of moisture and other impurities	Proper cleaning, preheating, and use of low-hydrogen electrodes and processes
Development of a crack-susceptible microstructure	Martensite formation, due to heating followed by rapid cooling of the weldment	Preheating, control of heat input, and/or use of a temper-bead deposition sequence
Tensile stress	Poor fit-up, and internal stresses in normal operation	Proper fit-up to minimize stress concentration at the weld root

B.2 Qualification of In-Service Welding Procedures

This appendix applies the requirements for developing a welding procedure in API 1104 Section 5 to in-service welding, and provides additional procedure specifications and essential variables.

B.2.1 Procedure Specification

Refer to API 1104 Section 5 for the general requirements for developing a welding procedure specification.

B.2.1.1 Specification Information

Section B2.1.1 of this appendix presents the additional procedure specification requirements for in-service welding of fillet welds that are not in API 1104 Section 5.

B.2.1.1.1 Pipe and Fitting Materials

A prerequisite to in-service welding on pipelines is determining the material's carbon equivalent (CE) and yield strength¹. To obtain this information, refer to the base material specification or a material test report.

Carbon equivalent is a formula used to calculate preheat requirements based on percentages of significant constituents of a material. The formula for determining CE appears in API 1104 on page 62, footnote 8.

B.2.1.1.2 Pipeline Operating Conditions

For in-service welding on pipelines, the written procedure should document the contents of the pipe, pressure, and flow rate.

B.2.1.1.3 Heat Input Range

In-service welding on pipelines may require large amounts of amperage and voltage to overcome heat loss due to the flow of the pipe's contents, so the welding procedure must recommend the amount of heat input necessary for welding.

Heat input is a formula based on the combined effects of the welding amperage, voltage and travel speed. The formula for determining heat input appears in API 1104 on page 62, footnote 9.

B.2.1.1.4 Weld Deposition Sequence

The in-service procedure for a multipass weld must identify the temper bead deposition sequence—the order in which welding beads are positioned within the joint.

B.2.2 Essential Variables

The essential variables for procedure qualification in API 1104 Section 5 apply to in-service welding, except as explained in API 1104 Section B.2.2.

B.2.2.1 Changes Requiring Requalification

- Changing the specified minimum yield strength is not an essential variable.
- An increase in the operating conditions that result in a change in cooling rates is essential.

¹ Yield strength is the amount of load in pounds per square inch (psi) or megapascals (MPa) at which a material will begin to yield or permanently deform.

- Changing the pipe wall thickness is not an essential variable.
- Changing from the temper bead deposition sequence to any other sequence is an essential variable.

B.2.3 Welding of Test Joints

The same branch-on-pipe connection joint used for the welder multiple qualification test may be used for in-service welding of test joints. The test joint must simulate the operating conditions that cause heat loss due to the flowing contents of the pipe.

B.2.4 Testing of Welded Joints

B.2.4.1 Preparation

To test in-service welded joints, follow the requirements in API 1104 Section 5.8, but cut the specimens at the locations specified in API 1104 Figure B-3 on page 66. Table B-1 states the requirements for type and number of specimens.

For welding of smaller-diameter pipes (4.5 in [114.3 mm] or less), API 1104 Table B-1, footnote a, requires welding of two joints to obtain the required number of test specimens.

B.2.4.2 Longitudinal Seam Welds

Test longitudinal seam welds according to API 1104 Section 5.6. If backing was used, remove it. If the specimens are flattened, testing must occur at room temperature.

B.2.4.3 Branch and Sleeve Welds

Test in-service branch and sleeve welds as you would when qualifying a fillet weld procedure in API 1104 Section 5.8. Remove the specimens from the test weld according to API 1104 Figure B-3. Table B-1 states the requirements for type and number of specimens, and contains two footnotes relevant to testing of in-service welded joints.

B.2.4.4 Macro-Section Tests—Branch and Sleeve Welds

Macro testing involves cutting a welded test joint through its cross section, polishing the weld and heat-affected area, and examining the surface visually with little or no magnification (10X or less).

B.2.4.4.1 Preparation

API 1104 Figure B-4 on page 67 shows the details of the macroetch specimen. Machine the sides of the cut specimen and polish them to a 600 grit finish before

applying the etchant. To etch the surface, apply hydrochloric acid or ammonium persulfate with a cotton swab, then rub until the weld structure becomes clear.

B.2.4.4.2 Visual Examination

Visually examine the cross section of the macroetch specimen in enough light so magnification isn't necessary. A fillet weld macroetch should show depth of fusion beyond the fusion faces (base metal surface), especially in the root of the joint.

B.2.4.4.3 Hardness Testing

Hardness testing is based on the material's ability to resist indentation. In hardness testing, a prescribed load forces a small-diameter ball or a sharp cone into the material. Although several methods of hardness testing exist, API 1104 Appendix B requires the Vickers method. It entails creating five indentations in the heat-affected zone (HAZ) of the weld using a 10 kg load, and then hardness-testing two of the four macroetch specimens according to the requirements of ASTM E 92, *Standard Test Method for Vickers Hardness of Metallic Materials*.

B.2.4.4.4 Requirements

API 1104 Section B.2.4.4.4 provides the requirements for visual examination of a macroetch specimen:

- The weld should show complete fusion at the root of the joint.
- The weld must be free from cracks.
- The legs of the fillet welds must comply with procedural requirements.
- The fillet weld profile (convexity and concavity) must not deviate more than 1/16 in [1.6 mm].
- The undercut depth should not exceed the lesser of 1/32 in [0.8 mm] or 12.5% of the pipe wall thickness.
- Heat-affected zone (HAZ) hardness values over 350 HV require evaluation to determine the risk of hydrogen cracking

B.2.4.5 Face-Bend Test Branch and Sleeve Welds

API 1104 Figure B-5 on page 67 shows the details of the fillet weld face bend specimen. Notes 1 through 4 correspond to the provisions in B.2.4.5.1. The requirements for face bending in Appendix B are consistent with the requirements in API 1104 Sections 5 and 6, except for the recommendation that the specimen be cut oversize and machined to the proper size.

B.2.4.5.2 Method

Face-bend testing cannot occur for 24 hours after welding. The bending will take place in a guided bend test jig like the one illustrated in API 1104 Figure 9 on page 15.

B.2.4.5.3 Requirement

After bending, visually examine the convex surface of the bent specimen. Reject any imperfection on the bent surface exceeding 1/8 in [3 mm] or half of the nominal wall thickness, and reject corner cracks that originate from the outside edge of the specimen if their length exceeds 1/4 in [6 mm] unless obvious imperfections exist. Bend specimens commonly have slight tears at the edge. As long as no inclusions or incomplete fusion are present in the tear, this condition is acceptable if it less than 1/4 in long.

**B.3 In-Service
Welder
Qualification**

Welders performing in-service welding must qualify according to API 1104 Section 6.2 and the requirements of API 1104 Section B.3.

A welder qualifying on pipe less than 12.750 in [323.9 mm] is qualified up to and including the diameter for which he tests. A welder qualifying on pipe 12.750 in [323.9 mm] or larger is qualified to weld all pipe diameters. A welder who meets the multiple qualification requirements of API 1104 Section 6.3 and of API 1104 Section B.3 should qualify for in-service welding in all positions, on all thicknesses, and all diameters as long as no changes occur in the essential variables listed in API 1104 Section 6.3.

B.3.1 Welding of Test Joint

In welding the test joint, try to duplicate the characteristics of the in-service pipe. Filling the pipe with water and having water flow through the pipe during welding should produce conditions equal to or more severe than in-service conditions. The simulation also should involve techniques to prevent cracks and burn-through. The welding should follow the applicable WPS, with special adherence to heat input and temper bead procedures (see Study Guide Sections B.2.1.1.3 and B.2.1.1.4).

The finished weldment must meet the requirements of API 1104 Sections 6.4 and 6.5, and the operating conditions for which the welder qualifies must be recorded in the documentation of finished results.

**B.4 Suggested
In-Service
Welding
Practices**

Apply to in-service welds the requirements of API 1104 Section 7, Design and Preparation of a Joint for Production Welding, and the additional requirements of API 1104 Section B.4.

- For safety reasons, determine the operating pressure, wall thickness, and flow conditions in the area of welding.

- Verify that the area to be welded is free from imperfections.
- Verify that the wall thickness is acceptable.
- Inform welders of the precautions required for welding on petroleum piping. They should be familiar with the American Petroleum Institute's Recommended Practice API RP 2201, *Safe Hot Tapping Practices in the Petroleum & Petrochemical Industries*.
- Clamp sleeve and saddle welds during fit-up to insure proper alignment.
- Use backing steel or tape to prevent burn-through when butt welding longitudinal sleeves.
- Follow the suggested sleeve and branch welding sequences in API 1104 Figures B-6 through B-11.
- Properly sequence the weld beads to ensure completion of one weld bead before starting another, and to control distortion and residual stress.

B.5 Inspection and Testing of In-Service Welds

Apply to in-service welds the testing requirements in API 1104 Section 8, Inspection and Testing of Production Welds, and the additional requirements of API 1104 Section B.5.

The inspection method must be able to detect hydrogen, underbead, delayed, and toe cracking. A general note on page 64 recommends using a combination of magnetic particle and ultrasonic testing for inspecting sleeve-to-saddle and branch-to-carrier pipe welds. Establish a suitable delay time to ensure that post-inspection delayed cracking does not occur.

B.6 Standards of Acceptability: Nondestructive Testing (Including Visual)

Apply to inspection of in-service welds the acceptance standards in API 1104 Section 9, Acceptance Standards for Nondestructive Testing.

B.7 Repair and Removal of Defects

Apply to repair of in-service welds the requirements of API 1104 Section 10, Repair and Removal of Defects, plus the additional requirement that the wall thickness of the pipe should remain sufficient to maintain the pipe's operating pressure.

EXERCISE QUESTIONS—SECTION 1

- 1.1 What topics does API 1104 cover?
- A. Gas welding of butt welds
 - B. Arc welding of fillet and socket welds
 - C. Welding carbon and low-alloy steel piping
 - D. Welding petroleum pipelines
 - E. All of the above
- 1.2 Which nondestructive testing method(s) is specified in API 1104?
- A. Nick-break test
 - B. Bend test for butt welds only
 - C. Radiographic examination
 - D. Metallurgical evaluation
 - E. All of the above
- 1.3 Which welding process(es) is specifically mentioned for use with API 1104?
- A. Flash butt
 - B. Submerged arc
 - C. Oxyacetylene
 - D. Gas metal arc
 - E. All of the above
- 1.4 SI Units are acceptable to use with API 1104.
- A. True, as long as each system is used independent of one another
 - B. False
 - C. True, as long as the inspector places the inch pound value in parentheses
 - D. True, as long as the metric values are used in conjunction with the inch pound values
 - E. The inspector should use codes published in either SI or inch pound units
- 1.5 When is it permissible to join pipe using a process not covered under API 1104?
- A. When a procedure has been established for its use
 - B. Only those processes cited in Section 1 may be used
 - C. When approved by the company
 - D. When approved by the committee
 - E. Both A and D above
- 1.6 Welds in API 1104 may be produced by:
- A. Position welding
 - B. Position or roll welding
 - C. Position, roll, or a combination of both
 - D. Only position welding
 - E. Only roll welding

1.7 Approved welding processes may be used to weld:

- A. New construction
- B. In-service welding
- C. Structural nontubular applications
- D. Cyclical applications
- E. Both A and B above

EXERCISE QUESTIONS—SECTION 2

- 2.1 Which of the referenced codes is published by a foreign society?
- A. ASTM E 164
 - B. API Spec 5L
 - C. AWS A5.28
 - D. BSI BS 7448
 - E. None of the above
- 2.2 Which organization publishes most of the NDE specifications cited in API 1104?
- A. API
 - B. ASNT
 - C. ASTM
 - D. AWS
 - E. NACE
- 2.3 Which organization publishes most of the filler metal specifications for API 1104?
- A. AWS
 - B. ASNT
 - C. ASTM
 - D. BSI
 - E. NACE
- 2.4 Which organization publishes a document on personnel certification in NDE used by API 1104?
- A. API
 - B. ASNT
 - C. AWS
 - D. BSI
 - E. NACE
- 2.5 Which of the following specification numbers represents a filler wire for GTAW?
- A. A5.1
 - B. E 747
 - C. A5.18
 - D. ER70S-2
 - E. A5.29
- 2.6 Which of the following specification numbers represents procedures for UT inspection?
- A. A5.28
 - B. E 164
 - C. RP SNT-TC-1A
 - D. A5.1
 - E. BS 7448

2.7 Which of the following numbers represents a specification number for Sulfide Stress Cracking Resistant Metallic Materials for Oil Field Equipment?

- A. MR0175
- B. E71T-1
- C. E6010
- D. F7A0
- E. A5.18

EXERCISE QUESTIONS—SECTION 3

- 3.1 The term that best describes a detectable irregularity in a weld is:
- A. defect
 - B. imperfection
 - C. indication
 - D. concavity
 - E. ridge
- 3.2 API 1104 identifies which of the following organization's standards for definition of welding terms?
- A. API
 - B. ASNT
 - C. AWS
 - D. BSI
 - E. NACE
- 3.3 What process or application uses equipment that controls only the filler metal feed?
- A. Roll welding
 - B. Submerged arc welding
 - C. Gas tungsten arc welding
 - D. Semiautomatic welding
 - E. Root bead welding
- 3.4 The process where the pipe remains stationary during welding is called:
- A. automatic welding
 - B. position welding
 - C. roll welding
 - D. root bead welding
 - E. semiautomatic welding
- 3.5 What does the term 'roll' welding mean?
- A. Welding with an all position welding electrode only
 - B. Welding is carried out with pipe assembly rotated
 - C. Applies only when welding is done with a semiautomatic process
 - D. Welding is carried out with pipe assembly stationary
 - E. Welding done without a welding procedure
- 3.6 The term that best describes welding without manual manipulation of the arc other than guiding or tracking is:
- A. mechanized welding
 - B. semiautomatic welding
 - C. automatic welding
 - D. manual welding
 - E. orbital welding

3.7 Which of the following specification numbers represents the document API 1104 refers to for definitions?

- A. ASNT A 5.1
- B. ISO 1027
- C. AWS A3.0
- D. AWS A3.2
- E. Both C and D

EXERCISE QUESTIONS—SECTION 4

- 4.1 API 1104 applies to welding of pipe that conforms to which specifications?
- A. AWS A5.28
 - B. BSI BS 7448
 - C. API Specification 5L
 - D. Any applicable ASTM specifications
 - E. Both C and D
- 4.2 Once opened, filler metals and fluxes shall be:
- A. stored in any convenient container
 - B. protected from deterioration or damage
 - C. kept in the original manufacturers opened shipping container
 - D. stored in ambient air
 - E. secured in special plastic bags
- 4.3 What determines the tip size for gas welding equipment?
- A. Manufacturer's instructions
 - B. Trial and error
 - C. Welding procedure
 - D. Engineering drawing
 - E. Pressure of the gas
- 4.4 Shielding gases used to shield the arc should never be:
- A. an inert type gas
 - B. gas mixtures
 - C. field intermixed in their containers
 - D. kept in containers in which they are supplied
 - E. both A and B above
- 4.5 Filler metals that are coated shall be protected from:
- A. dust
 - B. strong magnetic fields
 - C. excessive ultraviolet rays
 - D. excessive changes in moisture
 - E. none of the above
- 4.6 When is it permissible to use a filler metal not conforming to the specifications listed in API 1104?
- A. When approved by the company
 - B. When approved by the committee
 - C. When the WPS involved with its use is qualified
 - D. Only filler metals with specification numbers listed in Table 1 may be used
 - E. Only filler metals approved by the engineer may be used

- 4.7 When is it permissible to use base materials that are not manufactured in accordance with the specifications listed in API 1104?
- A. When the material is approved by the engineer
 - B. When the material has chemical and mechanical properties that comply with an ASTM or API 5L specification
 - C. It is not permissible to use a base material that does not have an approved specification number in accordance with Section 4
 - D. When the material is qualified in a WPS
 - E. Both A and D above

EXERCISE QUESTIONS—SECTION 5

- 5.1 API 1104 groups base metals into three groups based on their minimum yield strength. Which of the following is defined as Group a?
- A. Less than 42 000 psi
 - B. Less than or equal to 42 000 psi
 - C. Greater than 65 000 psi
 - D. Greater than 42 000 psi and less than 65 000 psi
 - E. Greater than 85 000 psi
- 5.2 When qualifying a welding procedure on pipe with an outside diameter of less than 4.5 in and with a specified minimum yield strengths greater than 42 000 psi, what is the minimum number of tensile tests required?
- A. 0
 - B. 1
 - C. 2
 - D. 4
 - E. 8
- 5.3 When preparing a tensile specimen for testing:
- A. cut a 1/8 in notch into each side of the weld
 - B. machine or grind all reinforcements smooth
 - C. cut a transverse notch into the weld
 - D. weld reinforcement should not be removed on either side
 - E. bend the specimen in a guided bend jig
- 5.4 AWS Specification A5.20 is used for welding:
- A. pipe in both uphill and downhill positions
 - B. pipe in 2G position only
 - C. root pass welding only
 - D. electrodes in Group 3
 - E. both A and B above are correct
- 5.5 When performing a nick-break test, the exposed area of fracture shall be at least how wide?
- A. 1/2 in
 - B. 3/4 in
 - C. 5/8 in
 - D. 1-1/2 in
 - E. A dimension is not specified

- 5.6 API 1104 has grouped base material into three distinct groups. In Group 'b' the specified minimum yield strength is:
- A. less than or equal to 42 000 pounds per square inch (psi) (290 MPa)
 - B. greater than 42 000 psi (290 MPa) but less than 65 000 psi (448 MPa)
 - C. greater than 42 000 psi (290 MPa) but less than 68 000 psi (469 MPa)
 - D. greater than 289.58 MPa but less than 448.16 MPa
 - E. both B and D
- 5.7 When conducting a procedure qualification on materials with an outside diameter of 135 mm and a wall thickness of 10 mm, the number of tensile test(s) required is:
- A. two
 - B. one
 - C. none are required
 - D. four
 - E. none of the above
- 5.8 When preparing a tensile specimen for testing:
- A. weld reinforcement shall be removed on both sides
 - B. the specimen must be machined
 - C. the specimen may be oxygen cut
 - D. weld reinforcement should not be removed on either side
 - E. both A and C
- 5.9 AWS Specifications A5.1 and A5.5 are used for welding:
- A. using the SMAW process
 - B. pipe in 2G position only
 - C. root pass welding only
 - D. electrodes in Groups 1, 2, and 3
 - E. both A and D above
- 5.10 When performing a nick-break test, the exposed area of fracture shall show complete penetration and fusion. The greatest dimension of any gas pocket(s) shall not exceed:
- A. 1/16 in wide maximum
 - B. the combined area shall not exceed 2% of the exposed surface area
 - C. 5/8 in wide maximum
 - D. 1/2 in wide maximum
 - E. both A and B are correct
- 5.11 Carbon steel electrodes for Flux Cored Arc Welding can be found in what specification?
- A. AWS A3.0
 - B. AWS A5.20
 - C. API 5L
 - D. ASTM E 164
 - E. All of the above

EXERCISE QUESTIONS—SECTION 6

- 6.1 A welder shall be requalified whenever which of the following occurs?
- A. A change from vertical uphill to vertical downhill
 - B. A change of filler metal classification from Group 1 to Group 3
 - C. A change from one process to another
 - D. A change from a V to a U groove
 - E. All of the above
- 6.2 Which of the following is not specified as a requirement for visual weld inspection?
- A. Free from cracks
 - B. Free from penetration
 - C. Free of burn-through
 - D. Filler wire protrudes less than 1/8 in into inside of pipe
 - E. Neat appearance
- 6.3 For multiple qualification, a welder shall be required to:
- A. make a butt weld in the fixed position
 - B. layout, cut, fit, and weld a full-sized branch-on-pipe connection
 - C. join pipes greater than 4.5 in OD
 - D. weld in the 6G position only
 - E. both A and B
- 6.4 When mechanized or semiautomatic welding is used, filler wire protruding into the inside of the pipe:
- A. is not permitted
 - B. length of protrusion shall not exceed 1/16 in
 - C. length of protrusion shall not exceed 0.79 mm
 - D. shall be kept to a minimum
 - E. both B and C above
- 6.5 For a welder qualification on 0.500 in wall pipe greater than 4-1/2 in in diameter, but less than or equal to 12-3/4 in in diameter, the number of destructive test specimens required are:
- A. 4
 - B. 8
 - C. 6
 - D. 16
 - E. 24

- 6.6 In branch-on-pipe connection qualification, the finished weld:
- A. shall exhibit a neat, uniform appearance
 - B. shall exhibit no undercut
 - C. no nick-break test is required
 - D. shall not contain any burn-through exceeding 1/4 in
 - E. both A and D above
- 6.7 How many root-bend specimens are required to qualify a welder on pipe with an outside diameter of 203 mm and a wall thickness of 14.3 mm according to Table 3?
- A. None
 - B. 1
 - C. 2
 - D. 3
 - E. 4
- 6.8 What is the total number of test specimens required to qualify a welder on pipe with an outside diameter of 203 mm and a wall thickness of 14.3 mm according to Table 3?
- A. 2
 - B. 3
 - C. 4
 - D. 8
 - E. 6

EXERCISE QUESTIONS—SECTION 7

- 7.1 Who shall decide when weather conditions are suitable for welding?
- A. The project engineer
 - B. The company
 - C. The supervisor of welding
 - D. The contractor
 - E. The welder
- 7.2 For position welding, the maximum face reinforcement should not exceed:
- A. the thickness of the pipe
 - B. the amount of pipe offset
 - C. 1/16 in maximum
 - D. 1/16 in minimum
 - E. 1/8 in maximum
- 7.3 When pipe is welded above ground, the working clearance around the pipe should not be less than:
- A. 450 mm
 - B. 400 mm
 - C. 18 in
 - D. 16 in
 - E. B and D above
- 7.4 Which of the following are acceptable means for welders to identify their work?
- A. Stenciling their identification symbol adjacent to the weld
 - B. Recording their identification symbol on a weld “map”
 - C. Writing their identification symbol adjacent to the weld using a permanent marker
 - D. Recording their identification on a traveler
 - E. Any of the above methods as prescribed by the company
- 7.5 Pipe ends of the same thickness should not be offset by more than:
- A. 1/16 in
 - B. 1/32 in
 - C. 1/8 in
 - D. 1/4 in
 - E. no offset is permitted

7.6 When is it permissible to conduct roll welding?

- A. When the pipe is secured against movement and with adequate clearance around the pipe
- B. When line up clamps are used as prescribed by the WPS
- C. When the engineer and contractor agree on use
- D. When alignment is maintained with skids or a structural framework
- E. When qualified by an all position WPS

7.7 When is it a requirement to remove surface porosity clusters, bead starts, and high points before welding?

- A. When using semiautomatic or mechanized welding processes
- B. When using manual and semiautomatic processes
- C. With all new construction and in-service welding
- D. When requested by the company
- E. All of the above

EXERCISE QUESTIONS—SECTION 8

- 8.1 Who determines the frequency of inspection?
- A. The welder
 - B. The chief inspector
 - C. The quality assurance head
 - D. The company
 - E. The contractor
- 8.2 What should be included in the documentation of qualification for inspection personnel?
- A. education and experience
 - B. training
 - C. results of a qualification exam
 - D. all of the above
 - E. Only A and B
- 8.3 How often shall Levels I and II NDT personnel be recertified?
- A. Every 6 months
 - B. Every year
 - C. At least every 2 years
 - D. At least every 3 years
 - E. At least every 5 years
- 8.4 Who determines the type of inspection to be done?
- A. The welder
 - B. The inspector
 - C. The QC Manager
 - D. The company
 - E. None of the above
- 8.5 Which of the following destructive or nondestructive testing methods may not be used?
- A. Visual inspection
 - B. Radiographic inspection
 - C. Trepanning
 - D. Penetrant testing
 - E. Bend specimens
- 8.6 Nondestructive testing personnel, other than visual inspection personnel, shall be qualified in accordance with which of the following?
- A. ASNT RP SNT-TC-1A or ACCP
 - B. ASME Section V
 - C. ASTM 265E
 - D. Any recognized national certification program
 - E. A and D above

8.7 How often must Level III nondestructive testing personnel be recertified?

- A. At least every year
- B. At least every two years
- C. At least every three years
- D. At least every four years
- E. At least every five years

EXERCISE QUESTIONS—SECTION 9

- 9.1 Incomplete fusion shall be considered a defect when the length of an individual indication exceeds:
- A. 1/8 in
 - B. 25% of wall thickness
 - C. 1/4 in
 - D. 1.0 in
 - E. no incomplete fusion is permitted
- 9.2 Porosity is:
- A. evidence of gas trapped in the cooling metal
 - B. generally a spherical indication
 - C. is considered a defect if a single pore is larger than 1/8 in
 - D. of the types P, CP, HB
 - E. all of the above
- 9.3 Which of the following apply to an ESI?
- A. A nonmetallic solid trapped in the weld metal
 - B. Broken slag lines
 - C. An indication usually found at the fusion zone
 - D. A nonmetallic solid trapped between the weld metal and base metal
 - E. All of the above
- 9.4 What are the results when a portion of the root bead has been blown into the pipe?
- A. Porosity
 - B. Nonmetallic solids in the base metal
 - C. Undercut
 - D. Burn-through
 - E. Underfill
- 9.5 Which of the following apply to star cracks?
- A. Caused by vibrations during welding
 - B. Caused by metal contractions during solidification
 - C. Caused by inclusions
 - D. Generally weaken the weld excessively
 - E. Are usually ground out and repaired
- 9.6 The maximum width of an isolated slag inclusion in a weld on a pipe whose outside diameter is 6.625 in is:
- A. 1/16 in
 - B. 1/8 in
 - C. 1/2 in
 - D. 1.59 mm
 - E. both B and D above

- 9.7 The maximum length of a crater crack is:
- A. 1/8 in
 - B. 5/32 in
 - C. no cracks are allowed
 - D. 1/2 the width of the bead
 - E. craters in welds cannot crack
- 9.8 When using ultrasonic testing, linear indications buried within the weld are unacceptable if they:
- A. exceed 2 in in aggregate length in a continuous 12 in length of weld
 - B. exceed 5/32 in
 - C. have an aggregate length that exceeds 8% of the weld length
 - D. exceed 6% of the weld length
 - E. both A and C above
- 9.9 When visually inspecting a pipe weld you measure some undercut at the face of the weld. The undercut mechanically measures 1/64 in deep and approximately 6 in long. The undercut is:
- A. not acceptable
 - B. must first be checked against radiograph measurements
 - C. unacceptable because it exceeds 2 in
 - D. acceptable
 - E. undercut cannot be produced on face side of weld
- 9.10 Linear indications are those indications whose:
- A. length is more than three times its width
 - B. length is equal to its width
 - C. length is more than four times its width
 - D. width is equal to its length
 - E. length is less than its width

EXERCISE QUESTIONS—SECTION 10

- 10.1 Upon visual detection of a weld crack, what should the inspector do?
- A. Send it to production for repair
 - B. Have it removed from the line—unless permitted by 9.3.10
 - C. Submit it for additional nondestructive testing
 - D. A and C above
 - E. Send it to the company representative
- 10.2 Repaired welds shall:
- A. meet the standards of acceptability of Section 9
 - B. be examined by the company representative
 - C. be submitted for radiographic inspection
 - D. be ground smooth with a minimum of metal removal
 - E. be reinspected by a Level III inspector
- 10.3 Which of the following are required in a weld repair procedure?
- A. Method of defect removal
 - B. Preheat requirements
 - C. Specification information contained in 5.3.2
 - D. Welding process or processes
 - E. All of the above are required
- 10.4 Defects other than cracks may be repaired:
- A. with prior company authorization if the defect is in the root
 - B. with prior company authorization if the defect is in the filler beads
 - C. with prior company authorization if the defect is in the cover pass
 - D. without using a qualified welding repair procedure
 - E. A and B above
- 10.5 Cracked welds may be repaired provided which of the following criteria are met?
- A. The length of the crack is less than 8% of the weld length
 - B. The weld is made by a qualified welder
 - C. A complete repair procedure has been developed and documented
 - D. All of the above
 - E. B and C above

EXERCISE QUESTIONS—SECTION 11

11.1 Who should agree on the radiographic procedure to be used?

- A. The inspector and the welder
- B. The company and the radiographer
- C. The company and the welder
- D. The company and the CWI
- E. The company and the radiographic contractor

11.2 Ultrasonic testing personnel Level III:

- A. are permitted to calibrate equipment
- B. are permitted to interpret test results
- C. may be required to demonstrate skills for the company representative
- D. shall develop the application technique and approve testing procedure
- E. all of the above

11.3 Using the ISO IQI, the image quality indicator used to test a CJP weld in a pipe with a 0.432 in wall thickness is identified by what number?

- A. 10
- B. 11
- C. 12
- D. 15
- E. 17

11.4 Using the ASTM E 747 IQI, the essential wire diameter to use for a CJP weld in a pipe wall thickness of 0.55 in is:

- A. 0.008 in
- B. 0.010 in
- C. 0.013 in
- D. 0.016 in
- E. 0.020 in

11.5 What conditions must be considered when using ultrasonic testing on in-service welds?

- A. The scope of use for ultrasonic testing is at the option of the inspector
- B. Pipe seams are not required to be ground flush
- C. Results are nonuniform from unit to unit
- D. Surface imperfections can interfere with its use
- E. Surfaces must be coated prior to testing

- 11.6 A radiographic test method using gamma radiation is being used to test a weld. When wire type image quality indicators are used, the image of the essential diameter shall be:
- A. the thickness of the image quality indicator
 - B. clear with the image quality indicator visible next to the weld
 - C. clear across the entire area of interest
 - D. the image quality indicator does not have to be visible on the film.
 - E. wire type image quality indicators are not permitted in API 1104
- 11.7 Who shall interpret the radiographic film of production welds?
- A. Level I radiographer
 - B. Level I or Level II radiographer
 - C. The welding inspector
 - D. Level II or Level III radiographer
 - E. The company representative
- 11.8 What is the essential diameter required for radiographing 0.750 in steel with an ISO IQI?
- A. 0.013 in [0.33 mm]
 - B. 0.020 in [0.51 mm]
 - C. 0.016 in [0.41 mm]
 - D. 0.025 in [0.64 mm]
 - E. 0.010 in [0.25 mm]
- 11.9 A weld was made on a pipe that had a wall thickness measurement of 9.5 mm with 1.5 mm face reinforcement. What is the essential diameter of an ASTM E 747 image quality indicator used for this radiograph?
- A. 0.013 in [0.33 mm]
 - B. 0.020 in [0.51 mm]
 - C. 0.016 in [0.41 mm]
 - D. 0.025 in [0.64 mm]
 - E. 0.010 in [0.25 mm]
- 11.10 The abbreviation DWE/SWV stands for:
- A. Double-Wall Exposure for Single-Wall Viewing
 - B. Double-Wall Exposure for Double-Wall Viewing
 - C. Single-Wall Exposure for Single-Wall Viewing
 - D. Double-Wall Exposure on Shielded Weld V Grooves
 - E. Double-Weld Exposure for Single Welded Viewing

EXERCISE QUESTIONS—SECTION 12

- 12.1 For mechanized pipe welding, the use of a lineup clamp:
- A. is required
 - B. must be of the internal type
 - C. must be of the external type
 - D. is required and cannot be removed unless the entire weld is completed
 - E. must be specified in the procedure
- 12.2 Which of the following is not an essential variable for a WPS using mechanized welding processes?
- A. Pipe wall thickness
 - B. Direction of welding
 - C. Postweld cleaning
 - D. Welding process
 - E. Pipe diameter
- 12.3 Radiographic testing of welds made by mechanized processes shall be in accordance with:
- A. Section 6.4
 - B. Section 11.1
 - C. Section 13.9
 - D. Section 9.3.10
 - E. Section 8
- 12.4 In mechanized welding, the travel speed:
- A. is recorded in millimeters only
 - B. need not be addressed if current and volts are recorded
 - C. is recorded in in only
 - D. must be recorded for each pass
 - E. both A and C above
- 12.5 Of the following, which is not considered an essential variable in a mechanized welding procedure?
- A. A change from V groove to U groove
 - B. A change from a 1/8 in filler wire to a 1/16 in filler wire
 - C. An increase in time between the fill pass and the cap pass
 - D. An increase in the range of gas flow rates
 - E. A change in plasma gas orifice diameter

EXERCISE QUESTIONS—SECTION 13

- 13.1 How many test specimens are required for qualifying a flash butt weld procedure?
- A. 24 total for 19 in OD pipe
 - B. 32 total for 29 in OD pipe
 - C. 40 total for 32 in OD pipe
 - D. 4 tensile strength specimens required for all sizes
 - E. All of the above
- 13.2 Which of the following is not an essential variable for flash butt welds?
- A. Welding position
 - B. Axial speed tolerances
 - C. Pipe material
 - D. Filler metal
 - E. Pipe wall thickness
- 13.3 As a minimum all completed flash butt welds shall:
- A. be heated above the Ac3 temperature
 - B. use controlled cooling
 - C. use strip recorder to document heat treating
 - D. be heat treated again if out of specified temperature ranges
 - E. all of the above
- 13.4 Which of the following methods is not specified in a flash butt weld repair procedure?
- A. Grinding
 - B. Chipping
 - C. Gouging
 - D. Surface etching
 - E. All of the above
- 13.5 When should NDT be performed on a flash butt weld?
- A. Immediately after welding
 - B. After flash removal and heat treatment
 - C. Before final heat treatment
 - D. After mechanical testing
 - E. Not specified
- 13.6 When evaluating a nick break specimen that was performed on a flash butt weld, the maximum size slag inclusion allowed is:
- A. 1/2 in in length
 - B. 1/32 in in depth
 - C. 1/2 in in width
 - D. 1/8 in in length or width
 - E. both A and C above

- 13.7 Procedure qualification tests for a flash butt weld are being performed on a pipe that has an outside diameter of 20 in. What is the total number of specimens that will be tested?
- A. 16
 - B. 24
 - C. 40
 - D. 32
 - E. 28
- 13.8 In flash butt welding all of the following are essential variables except:
- A. a change from flat to vertical welding
 - B. a change in welding current tolerance
 - C. a change from steel pipe to stainless pipe
 - D. a change from a 6 mm wall pipe to a 10 mm wall pipe
 - E. a change in filler metal diameter
- 13.9 A single ISI in a flash butt weld shall not exceed:
- A. 3/8 in in length
 - B. 1/2 in
 - C. 1/8 in in length
 - D. 1/16 in in length
 - E. no ISI is allowed
- 13.10 What is the maximum permissible outside weld reinforcement for a flash butt weld?
- A. 1/16 in [2 mm]
 - B. Unlimited
 - C. 1/32 in [1 mm]
 - D. 1/8 in [3 mm]
 - E. To be determined by testing

EXERCISE QUESTIONS—APPENDIX A**Alternative Acceptance Standards for Girth Welds**

- A1. External exposure to carbonates and nitrates in the soil has been shown to produce:
- A. a small number of cases of axial cracking
 - B. a large number of cases of circumferential cracking
 - C. axial cracking due to circumferential stress
 - D. axial cracking due to axial stress
 - E. Both A and C
- A2. Acceptance limits for buried slag in a girth weld is:
- A. lesser of $t/4$ or 0.25 in in width and lesser of $t/4$ or 0.25 in in length
 - B. lesser of $t/4$ or 0.25 in in width and 0.25 in in length
 - C. lesser of $t/4$ or 0.25 in in width and $t/4$ in length
 - D. lesser of $t/4$ or 0.25 in in width and $4t$ in length
 - E. $t/4$ in width and $2t$ in length
- A3. The maximum depth for an unrepaired arc burn is:
- A. $1/64$ in
 - B. $1/32$ in
 - C. $1/16$ in
 - D. $3/32$ in
 - E. $1/8$ in
- A4. Which of the following is used to determine the maximum axial design stresses for a pipeline?
- A. A visual weld inspection
 - B. A stress analysis
 - C. A tensile test
 - D. A nick break test
 - E. A chemical analysis
- A5. What type of test is required to use the alternative girth weld acceptance criteria?
- A. The CTOD fracture toughness test
 - B. The CVN toughness test
 - C. The nick break test
 - D. The tensile test
 - E. The guided bend test

- A6. How many options are used in Appendix A use for the determination of acceptance limits of planar imperfections?
- A. 2
 - B. 3
 - C. 4
 - D. 5
 - E. 6
- A7. What is the primary purpose of Appendix A?
- A. To define the procedure for CTOD and Charpy V Notch impact testing
 - B. To delineate between circumferential and axial stresses in pipelines
 - C. To define the effect of various anomalies on the suitability of the whole weld for a specific service
 - D. To describe the use of fracture mechanics analysis and fitness for purpose criteria in establishing a more rigorous imperfection allowance
 - E. To provide pipe size and strength specifications for use in service
- A8. Arc burns on the internal or external surface of the pipe are the result of:
- A. inadvertent arc strikes
 - B. improper grounding
 - C. excessive amperage
 - D. all of the above
 - E. both A and B above
- A9. With company approval, validated fitness for purpose procedures may be used to develop:
- A. tensile and yield strength values
 - B. acceptance criteria for imperfections
 - C. CVN breaking energy values
 - D. acceptance criteria for girth weld procedure and welder qualification test specimens
 - E. all of the above
- A10. Qualification of alternative acceptance welding procedures shall be in accordance with:
- A. Sections 5 and 6
 - B. Section 6 or 12
 - C. Section 5 or 12
 - D. Appendix A with additional mechanical properties in accordance with Section 5
 - E. none of the above

EXERCISE QUESTIONS—APPENDIX B

- B1. The two main concerns with welding on in-service pipelines are:
- A. burn through and hydrogen cracking
 - B. weld cooling rates and weld sequence
 - C. yield strength of pipe material and fittings
 - D. tensile strength of pipe and weld sequence
 - E. fit up and weld sequence
- B2. For an encirclement tee:
- A. the circumferential welds should be completed before beginning the longitudinal seams
 - B. circumferential welds need not be made
 - C. the longitudinal seams should be completed before beginning the circumferential welds
 - D. weld sequencing is not necessary on tees
 - E. circumferential welds at the end of tee shall be welded at the same time
- B3. All welders performing repair work should be familiar with the safety precautions associated with cutting and welding on piping that contains or has contained crude petroleum, petroleum products, or fuel gases. Additional guidance can be found in:
- A. ANSI Z49.1
 - B. API RP 2201
 - C. API RP 1570
 - D. AWS A3.0
 - E. API 510
- B4. For branch and sleeve welds, each macro-section test specimen:
- A. should be ground on both sides to at least 600 grit finish and etched
 - B. should be ground on both sides to at least 300 grit finish and etched
 - C. should be smooth on least one face to at least 600 grit finish and etched
 - D. should be smooth on least one face to at least 300 grit finish and etched
 - E. shall be machine cut
- B5. For in-service welder qualification for longitudinal seam welds on pipe with a 0.375 in wall thickness, the type and number of test specimens are:
- A. one tensile, one nick-break, and two side bends
 - B. two tensile, two nick-break, and two side bends
 - C. two tensile, two nick-break, two root bends, and two face bends
 - D. one tensile, one nick-break, one root bend, and one face bend
 - E. two tensile, and four side bends

- B6. For in-service fillet welds, specified minimum yield strength is:
- A. an essential variable
 - B. not an essential variable
 - C. is an essential variable if pipe and fitting yield strength is less than or equal to 42 ksi
 - D. is an essential variable if pipe and fitting yield strength is greater than 42 ksi but less than 65 ksi
 - E. is considered an essential variable if pipe and fitting yield strength is greater than 65 ksi
- B7. When the maximum allowable heat input to avoid burning through is insufficient to provide adequate protection against hydrogen cracking an alternative precaution is:
- A. a temper bead deposition sequence may be used
 - B. an increase in travel speed is necessary
 - C. decrease the voltage to ensure a wetter puddle
 - D. decrease the amperage to ensure a wetter puddle
 - E. an increase in cooling rate is necessary
- B8. When qualifying a procedure for in-service welding, the face bend test for branch and sleeve welds should not be tested:
- A. less than 24 hours after welding
 - B. more than 24 hours after welding
 - C. less than 48 hours after welding
 - D. more than 24 hours after welding
 - E. when temperature of test specimen exceeds 125°F
- B9. For hydrogen cracking to occur how many conditions must be simultaneously satisfied?
- A. 2
 - B. 3
 - C. 5
 - D. 8
 - E. 10

**ANSWER KEY FOR STUDY GUIDE
API STANDARD 1104, TWENTIETH EDITION**

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